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Effects of deficit irrigation on some physiological traits, production and fruit quality of 'Mazafati' date palm and the fruit wilting and dropping disorder

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ABSTRACT

Date palm (*Phoenix dactylifera* L.) fruit wilting disorder, caused by the high increase in temperature and decrease in relative humidity of the environment, is more prevailing due to climate change over the last decades. This has affected negatively the economy of single-product palm growers. The physiological effects of deficit irrigation on 'Mazafati' date palm during four months, starting from two months before flowering (early January) up to two months after flowering which is concomitant with the middle of the Kimri stage (late April) was investigated. Two irrigation levels of 100% ETc and 70% ETc at three irrigation intervals of 50, 100 and 150 mm cumulative evaporation in two locations with different average daily and annual temperatures in Sistan and Baluchestan province of Iran were compared. Deficit irrigation at intervals of 100 mm evaporation resulted to the highest bunch weight and yield in two orchards and, the highest water use efficiency was obtained in the location 2 (warmer area). Wilting percentage of bunch was not affected by irrigation levels, but the irrigation interval at 100 mm evaporation showed the best control. The increase in mean weight of fruit was observed only in the location 1 with irrigation intervals of 50 and 100 mm evaporation. The highest amount of soluble solids and soluble sugars was obtained in the second location with irrigation interval at 150 mm evaporation. Total phenolic compounds and fruit starch showed the lowest and highest with full irrigation, respectively. Deficit irrigation at all three irrigation intervals increased the activity of peroxidase and polyphenol oxidase in fruits and leaves. Reduction of calcium and iron of leaf during the disorder was observed with deficit irrigation at different irrigation intervals. However, reduction in leaf zinc was observed only at 150 mm irrigation interval. According to the results, irrigation level of 70% with 100% did not show a significant difference in fruit qualitative properties, and irrigation at 100 mm evaporation intervals before the disorder risk period is recommended to control the disorder. It seems to be a more increasing in percentage or duration of deficit irrigation on date palm in future researches to be promising.

1. Introduction

Date palm (*Phoenix dactylifera* L.) fruit wilting disorder has become the main problem to date growers in the last two decades. The reasons for this phenomenon is falling the relative humidity to less than 20% and the increase in temperature to over 45 °C accompanied with hot winds, occurring during the Khalal into the Rotab fruit growth stages. This will cause the whole fruits of bunch to drop within ten days. The bunches and stalks that are not in this phase of fruit growth due to later fertilization, are not affected (Mireei and Sadeghi, 2013).

Deficit irrigation (DI) is referred to as water restriction in certain growth periods of the plants, and was first used in the 1980s as a way to limit vegetative growth of peaches and save water. DI reduces mainly the vegetative growth of trees and as a result reduces the competition of vegetative and reproductive growth and significantly reduces the cost of orchard operations. This reduction in costs can, in some cases, offset a reduction in profits due to the reduction in the size of the fruit (Chalmers, 1981). The use of DI in controlling diseases and improving the quality of the fruit is less considered. For example, one of its positive results is the reduction of cadmium in fruits (Benavides et al., 2005). It also controls the physiological disorders of blossom end rot in tomato and bitter pit in apple which are due to calcium deficiency in fruit, and also botrytis bunch rot disease in grapes (Austin and Wilcox, 2011; Mpelasoka et al., 2001; Zegbe-Domınguez et al., 2003). Date bunch wilting disorder have been damaging soft dates for many years.

If DI properly programmed, no or less negative effects will occur. The sensitivity of flower buds to water deficiency is different during the flowering period and thereafter. In peaches due to flower induction and

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fruit growth, early September in the northern hemisphere represents the time of transition from sensitivity, and then the sensitivity decreases. In the late ripening cultivars of stone fruits, the lag phase of fruit growth of (pith hardening) is a suitable period for reduced irrigation. During this period, the growth of fruits is slow and with applying DI, the growth of the shoots will decrease and the fruit content will improve (Naor, 2005). The best results in pistachio achieved when a DI equivalent of ETc 50% applied in the second stage of fruit growth (full shell expansion to the onset of rapid kernel growth) and ETc 25% after harvest. The most stressful period in pistachio begins with the onset of the third stage or rapid kernel growth (Goldhamer and Beede, 2004). The induction of persimmon flowers is in the summer of previous year and the differentiation of flower organs will occur the current season until flowering, so the effect of DI during flowering, fruit set, and the first half of May (beginning of flower induction for next season), will affect the yield and the size of the fruit in the current and next season (Kanety et al., 2014). For 'Conference' pear complete irrigation until harvest and up to two weeks after harvesting and then DI until the stage of leaf fall is recommended, because, in contrast to the control, it maintained yield and fruit quality of the next year by storing. (Marsal et al., 2012).

Reduced irrigation of dates, increased water productivity, as well as the beneficial effects on early ripening and reducing the contamination by the fungus *Fusarium proliferratum* and reduced fruit dropping (Gribaa et al., 2013; Hillel, 2013). For this, DI has been used in the range of 65–75% of full irrigation based on evapotranspiration measurements. Different cultivars and different stages of date fruit growth have shown different sensitivity to DI (Liebenberg and Zaid, 1999). During the development of the bunch and its rachis, the date fruitlets grow slowly and probably do not require a large volume of water. In contrast, after the end of the rachis growth (2nd half of April), there is a rapid increase in the fruit size, so it is expected that DI during this phenological stage will lead to small fruits and a decrease in yield, hence, palm growers should be warned for not limiting water supply during this period (Gribaa et al., 2013). Considering the mentioned report, in present research, DI during a four-month period was applied for the control of the 'Mazafati' date bunch wilting, while, the physicochemical parameters of fruit and the antioxidants and stress marker changes were considered.

2. Materials and methods

2.1. Plant materials and experimental design

During the growing season in 2017, two orchards of 10–12 year-old 'Mazafati' date (8 × 8 m) with a history of bunch wilting were selected in two regions of Sistan and Baluchestan province of Iran.

The geographic and climatic characteristics of the two studied locations are shown in Table 1. Selected palm trees were pollinated with pollen of M003 genotype in both locations and tried to be under uniform orchard operations throughout the season. After the fruit set (about 4 weeks after pollination), the number of bunches was adjusted to 8 per palm tree. Determination of the amount of water delivered to the plants was estimated according to the Penman-Monteith equation and was distributed to the trees by volume meter. The amount of plant evapotranspiration (ET_C) in this method is: ETc = ETo.Kc, where ETo is reference evapotranspiration and Kc is crop coefficient and its value was determined according to the values provided for the dates by the FAO (Allen et al., 1998). Irrigation water was delivered through a Babbler system with an average of 4.5 liters per minute around the palms. Irrigations were applied for intervals of 50, 100 and 150 mm cumulative evaporation (P50, P100, and P150) at two irrigation levels of 70% (V70) and 100% (V100) ETc for four months from 2 months before bunching up to two months after it (mid stage of Kimri). Before and after this period, irrigation was carried out with the usual amount and interval of the area (7–10 days in warm months and up to 24–27 days in cool months). The amount of water delivered to the plants, the applied crop coefficient and the irrigation dates during the mentioned period are given in Table 2. At the harvest stage (Rutab), all bunches were harvested from each tree and the total weight of the fruits were recorded. Water-use efficiency (WUE) was calculated as fresh date palm yield in each tree divided by total year irrigation water applied. Five strands of each brunch from four bunches were randomly assigned in each tree at four directions, and the number of fruits after fruit set were recorded in these strands. The number of dried and dropping fruits were recorded at each stage of fruit growth till harvest time and expressed as percentage. Sampling of leaflets from the middle of the leaves around each tree in the stage of disorder (50% drying and dropping during the Khalal up to Rutab stage) was carried out to measure the mineral elements. Fruit samples (20 fruits of each bunch) were collected at the Rutab stage to determine the physicochemical parameters. Fruit samples and leaf samples adjacent to the bunch were collected for measuring enzyme activity. Collected fruit and leaf samples were frozen immediately and kept at -80 °C for the biochemical measurements.

2.2. Determination of physical and biochemical traits

Fruit firmness was measured (kg/cm^2) at one or two points on the equatorial zone of date fruits by applying a plunger of 3 mm in diameter, using a penetrometer TA-XT2 (Stable Microsystems Texture Technologies Inc., UK). Add distilled water to fruit flesh and then centrifuge it and finally total soluble solids (TSS) of fruit juice were obtained as brix degree (Brixº) with a digital refractometer (DR 6000, A. Kruss Optronic GmbH, Hamburg, Germany). Total acids were indicated by titration with 0.1 N sodium hydroxide in the presence of phenolphetalein as indicator, and the percentage of total acids was obtained as equivalent to malic acid content (Horwitz, 2000). For measurement of total phenolics, Folin–Ciocalteu reagent was used. Total phenolics were calculated from a calibration curve obtained by the absorbance of known concentrations of gallic acid at 750 nm after reacting with the reagent. Phenolics content was expressed in milligrams per gram dry weight (mg g^{-1} DW) (Velioglu et al., 1998). Soluble sugar contents were determined according to the phenol–sulphuric acid method (Dubois et al., 1956). Starch contents were determined according to McCready et al. (1950).

Table 1
Geographical and climatic characteristics of the two studied locations.

Locations (L)	Latitude (N)	Longitude (E)	Altitude (m)	Annual Precipitation (mm)	Absolut Max Temperature (°C)	Absolut Min Temperature (°C)	Average Annual Temperature (°C)	Average Wind Speed (km/h)	Mean Annual Relative Humidity (%)	EC of irrigation water (dS/m)
L_1 (Bampour)	27° 09′	60° 40′	491	110.2	50	−6.2	26.9	7.59	30	1.9
L_2 (Nikshahr)	26° 12′	60° 12′	456	169.5	49.6	2.8	28	10.37	44	2.2