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Effect of drip irrigation and fertilizer regimes on fruit quality of a pomegranate (*Punica granatum* (L.) cv. Rabab) orchard

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A B S T R A C T

We investigated the effect of different drip irrigation strategies including irrigating one side of trees with 50% and 75% of ET_C (DI50, DI75); irrigating alternate sides of trees with 50% and 75% of ET_C (PRD50, PRD75), and full irrigation (FI) that received 100% ET_C and three prevalent fertilizers type including manure (M), chemical (CF) and foliar (FF) fertilizers on quality of pomegranate fruit in a semi-arid area. Results showed that the values of measured attributes varied from 64.4 to 71.2% in aril, 28.8 to 35.6% in peel, 49.0 to 55.7% in juice percentage, 1.055–1.064 g cm^{-3} in juice density, 12.4 to 15.7 in maturity index (MI), 1.14 to 1.53% citric acid in titratable acidity (TA), 17.5 to 19.2°Brix in total soluble solids (TSS), 10.8 to 12.3 mg per 100 mL of juice in vitamin C and 3.12 to 3.26 in pH. On average, PRD strategies increased the juice percentage, MI and decreased the TA in comparison with FI while the results of DI strategies were in contrast to PRD. Furthermore, higher level of water stress (PRD50 and DI50) increased the TSS and decreased the vitamin C in comparison with other irrigation strategies. CF fertilizer showed the lower values in MI, TSS, peel percentage and juice density and the higher values in aril percentage, TA and vitamin C in comparison with other fertilizer types. Among the irrigation strategies, PRD50, PRD75 and DI75 strategies is recommend due to the positive impact on fruit quality attributes; however, it is important to consider the negative effect of PRD50 on fruit yields. For fertilizer types, the fertilizers including microelements (M and FF) are preferred in comparison with CF (including NPK). Based on the results, correct harvest maturity and ripening for pomegranate fruit can be determined when TA is reached lower than 1.32% citric acid, MI is increased to higher than 13.95 and TSS is greater than 18.25°Brix.

1. Introduction

Pomegranate is a popular fruit of tropical and subtropical regions that is gaining great interest as a result of the beneficial effects on health (Lansky and Newman, 2007). Iran is the origin of pomegranate and is ranked high in the world for pomegranate cultivars, quality, cultivated area, production and export. Fars province is the largest producer in Iran with a cultivated area of 19,224 ha and production of 199631 Mg year^{-1}. In Fars province, Neyriz with an area of 4000 ha and annual production of 55000 Mg year^{-1} is a center of pomegranate production (Ministry of Jahad of Agriculture, 2010).

In recent years, reduction in groundwater resources and severe droughts has destroyed some of the pomegranate orchards in Neyriz (Parvizi et al., 2014). Therefore, proper irrigation water management should be used to cope with the water resources reduction. Water scarcity in arid and semi-arid areas has led to development of new water saving techniques, such as partial root zone drying (PRD) and deficit (DI) irrigation. Pomegranate as a xeromorphic plant shows drought tolerance characteristics such as high leaf relative apoplastic water content and ability to confront the water stress by developing complementary stress avoidance and stress tolerance mechanisms (Rodriguez et al., 2012). Pomegranate is fairly drought resistant; however, it requires regular watering to produce high yield and large unit fruit weight (Holland et al., 2009). Some investigations showed that the water stress can have detrimental or beneficial effects on fruit quality of pomegranate (Khattab et al., 2011; Mellisho et al., 2012; Laribi et al., 2013; Mena et al., 2013). Laribi et al. (2013) showed that deficit irrigation, when applied late in the season, during ripening, resulted in an increase in total soluble solids (TSS). Considerable differences have been observed in the response of pomegranate fruits to deficit irrigation treatments by Mellisho et al. (2012) so that fruits from trees under moderate level of water stress showed a decrease in fruit growth,

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inducing a lower final fruit size and lower total yield, accompanied by changes in fruit chemical characteristics, which reflected earlier ripening. In contrast, a higher level of water stress during the second half of fruit growing period was more critical for fruit size than for their chemical characteristics.

In pomegranate with increasing irrigation level, fruit length, diameter and volume increased significantly and TSS, peel thickness, fruit peel and fruit firmness decreased by increasing the amount of applied irrigation water (Khattab et al., 2011). Furthermore, total sugars, vitamin C and total anthocyanin gradually decreased by increasing irrigation levels where the least irrigation treatment resulted in the highest values of these traits (Khattab et al., 2011).

Furthermore, foliar application of some micronutrients particularly Mn, Zn and B has received greater attention in the studies of the use of inorganic fertilizer application (Mir et al., 2012). Many investigators studied the effect of broadcast application and spraying macro and micronutrients such as N, P, K, B, Zn, Ca and Mn on fruit quality in trees (Khayyat et al., 2007; Wojcik et al., 2008; Marzouk and Kassem, 2011; Asgharzade et al., 2012; Mordoğan et al., 2013; Meng et al., 2014; Fernandez-Hernández et al., 2014). In pomegranate, foliar application of B, Zn, Mn and Ca were effective in improving nutritional status, yield and fruit quality (El-Khawaga, 2007; Hasani et al., 2012; Khalil and Aly, 2013; Obaid and Al-Hadethi, 2013). Furthermore, foliar application of potassium nitrate significantly influenced fruit quality of pomegranate (Malas Yazdi) when fruits were in the beginning stages of growth and development (Khayyat et al., 2012). Mirzapour and Khoshgoftarmanesh (2013) showed that soil application of FeEDDHA + zinc sulfate, particularly as localized placement, is an effective approach to improve the yield and fruit quality of pomegranate in the calcareous soils. Single and combining application of N, P, and K fertilizers could enhance fruit yield and juice content in aril and increase TSS, total sugar and vitamin C content but decrease total acid content in aril juice of pomegranate (Zhang et al., 2012). Increase in juice percent, percent aril in the fruit, sugars (total, reducing and nonreducing) and juice acidity due to increasing the levels of nitrogen application was reported by Prasad and Mali (2000). The effect of PRD irrigation strategy on fruit yield and quality of grape (dos Santos et al., 2003; Du et al., 2008), mango (Spreer et al., 2007), apple (Leib et al., 2006) and orange (Shahabian et al., 2012) has been reported. However, there is no study on the effect of PRD irrigation strategy and different fertilizer types and their combination on fruit quality of pomegranate. Therefore, the main aims of this experiment were to study the effects of PRD irrigation strategy and three types of prevalent used fertilizers by orchard owners on qualitative parameters of the pomegranate fruits.

Table 2
The amount of applied irrigation water in different irrigation strategies (mm).

Irrigation regimes	FI 100% ET_C		PRD and DI 75% ET_C		PRD and DI 50% ET_C	
Year	2011	2012	2011	2012	2011	2012
March	125.0	125.0	125.0	125.0	125.0	125.0
April	79.1	80.4	59.3	60.3	39.6	40.2
May	142.8	143.5	107.1	107.6	71.4	71.8
June	190.4	195.8	142.8	146.8	95.2	97.9
July	210.9	211.8	158.2	158.9	105.5	105.9
August	193.7	198.6	145.3	149.0	96.9	99.3
September	150.9	152.1	113.2	114.1	75.4	76.1
October	105.3	106.9	79.0	80.2	52.7	53.5
Growing season	1198.0	1214.1	929.8	941.9	661.6	669.6

2. Materials and methods

2.1. Experimental site

The experiment was carried out during 2 years (2011 and 2012) in a pomegranate orchard located at Rudkhor village, 100 km far from the east of the Neyriz city (Fars province, Iran) (28.9680°N, 54.9587°E, 1580 m.s.l.). The soil texture is loam and the electrical conductivity of soil saturation extract was 1.2 dS m^{-1}. The electrical conductivity of the irrigation water was 1.8 dS m^{-1} (Table 1) and no rainfall was recorded during the experimental growing season. In the study area, the mean annual maximum and minimum air temperatures are 26.3 and 12.3 °C, respectively. Furthermore, the mean annual precipitation and air humidity are 190 mm and 37%, respectively. The used orchard in the experiment has 9-year old pomegranate trees (*Punica granatum* (L.) cv. Rabab) with 5 m × 4 m spacing pattern and irrigated with drip irrigation system.

2.2. Irrigation and fertilizer treatments

In the study area, the pomegranate growing season usually begins in March and ends in late October. Irrigation interval was considered 4 days in this study and each irrigation interval was scheduled using the summations of daily water requirement in four next days. The 4 days interval was chosen based on the crop, soil properties and climate conditions in order to avoidance from water stress under full irrigation and minimized the water loss throughout the evaporation in high frequent irrigation. The procedure of water requirement calculations are presented in our previous study (Parvizi et al., 2014) and the water applied for different irrigation regimes are shown in Table 2.

Table 1
Some properties of soil and water used in the study area.

Soil properties

Sand (%)	Silt (%)	Clay (%)	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	OC[a] (%)	pH	EC_e[b] (dS m^{-1})
42	40	18	400	15	156	1.2	0.7	0.3	0.3	0.57	8.29	1.12

Irrigation water properties

Alkalinity (mg L^{-1})	Hardness (mg L^{-1})	SAR[d]	pH	TDS[c] (mg L^{-1})	EC_w (dS m^{-1})
200	750	1.46	7.33	1168	1.80

Na^{1+} (mg L^{-1})	Mg^{2+} (mg L^{-1})	K^{1+} (mg L^{-1})	Ca^{2+} (mg L^{-1})	SO_4^{2-} (mg L^{-1})	Cl (mg L^{-1})	CO_3H^- (mg L^{-1})	CO_3^{2-} (mg L^{-1})
92	72	3.12	180	461	160	244	0

[a] Organic carbon.
[b] Electrical conductivity.
[c] Total dissolved solid.
[d] Sodium adsorption ratio.