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The effects of irrigation and fertilizer applications on yield, pomological characteristics and fruit cracking in Nova mandarin

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ABSTRACT

We studied the effects of different levels of fertilizer and irrigation applications on the yield, fruit cracking and pomological characteristics of Nova mandarin (*Citrus reticulate*). Two fertilizers, F_1 (NPK) and F_2 (NPK + $Ca(NO_3)_2$), and five levels of irrigation of 25% (I_1), 50% (I_2), 75% (I_3), 100% (I_4) and 125% (I_5) of measured Class A pan evaporation were examined in our studies. In addition, a non-irrigated treatment receiving only rain was used as control (I_0). The experiment was conducted under Mediterranean conditions for two seasons during 2007–2008. Plants were watered using drip irrigation. The amount of NPK used in fertilizer treatment was 260 kg ha^{-1} N, 103 kg ha^{-1} P_2O_5, 173 kg ha^{-1} K_2O and 13.2 g Fe chelate per tree. Results showed that mandarin's seasonal irrigation water requirement varied between 315 and 1015 mm. Both fertilizer and irrigation levels affected the number of cracks on the fruits. The number of fruit cracked in the F_2 application was on average 58% lower than those in the F_1. The number of fruit cracked in I_1, I_2, I_3, I_4, and I_5 irrigation treatments of F_2 application was 74%, 52%, 65%, 51%, and 50% less than those of F_1, respectively. The highest yields were 32 and 30 t ha^{-1} for I_3 in both years regardless of fertilizers. Statistically significant differences were obtained among the irrigation levels for fruit weight, height, size, juice content, brix, total soluble solids/acidity ratio, and seed. When other pomological characteristics in F_1 and F_2 treatments were considered the F_2 had higher mean values than those of F_1 in terms of fruit weight (15.0%), total soluble solids (2.8%), total soluble solids/acidity (7.1%), and seed number (21.7%). However, the F_1 application compared to F_2, increased shell-thickness by 8% and juice content by 9%. It is concluded that Nova mandarins can be irrigated as much as 75% of measured Class A pan evaporation to obtain high fruit yield as well as fewer fruits not cracked under Mediterranean conditions.

1. Introduction

Citrus fruits grown in South and West coastal regions of Turkey is a crop that has potential to increase agricultural production. In 2007, ~10^6 ha were cultivated for citrus fruits in Turkey. The increase in citrus fruits production was 3.2 times higher than the world average and reached 3.6×10^6 t, a 58% increase. In Turkey, 17% of the citrus fruits is grown in the city of Hatay, located in the Eastern-Mediterranean region, and the most common citrus is mandarin. While mandarin constitutes about 25% of the world citrus fruits production of 30 million tons, the annual production in Turkey is 8.5×10^5 t (FAO, 2009).

In arid and semi-arid climates, and especially during summer months, the irrigation water requirement of citrus increases due to higher air temperature and higher water evaporation rate. Given insufficient water resources and lack of an irrigation network in the Eastern-Mediterranean region makes it compulsory to consider irrigation strategies to use the available water resources more efficiently. Limited irrigation strategies provide water saving, and high production in yield and improvements in quality (Fereres et al., 2003) in citrus fruits trees consuming 900–1200 mm water per year (Doorenbos and Kassam, 1979).

Water stress in citrus causes deflowering, decay and decrease in the number of fruits and cracks on the fruit. Cracking is associated on thick-shelled orange (Valencia, Hamlin) and some thin-shelled mandarin kinds (Encore, Murcott, Nova). High air temperature, sudden decrease in ambient relative humidity, over irrigation and rainfall just before harvest and excess fruit load periods increase the ratio of cracking over citrus fruits. Some physiological and biochemical changes of fruits in ripening period was reported to have a relation with cracking in thin-shelled fruits and increase in ratio of cracking (Gao-Feifei et al., 1994). Not only water stress but also lack of nutrients causes cracking. Fruit thinning, application of K^+ or $CaNO_3$ in early period are effective methods to reduce

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cracking (Dalkılıç, 2005). It was determined that the number of cracking fruits vary between 0.8 and 24 per tree in Washington Navel Orange. The shell of cracked fruits contains more P, N and Ca than normal fruits (Erickson, 1957).

Fruit cracking occurs worldwide as a pre-harvest problem in mandarin and mandarin hybrids, and Nova mandarin is one of the citrus cultivars prone to fruit cracking. This has been reported by Bono et al. (1988), Garcia-Luis et al. (1994), Almela et al. (1994), and Barry and Bower (1997). Most of the studies on the control of fruit cracking focussed on increasing the shell thickness and strength of split-prone species by applying pre-harvest mineral nutrient sprays to the canopy or plant growth regulator (PGR) foliar sprays. Barry and Bower (1997) reported that application of 2% $Ca(NO_3)_2$ or 4% KNO_3 at the stages of 60% full bloom, 100% petal drop and 80% fruitlet drop reduced fruit cracking. Stander (2013) suggested that the application of 10 mg L^{-1} 2,4-D (dichlorophenoxy acetic acid) directly after physiological fruit drop on 'Marisol' Clementine and 'Mor' mandarin to reduce fruit cracking. Some successful application of 2,4-D and Ca have also been reported by Garcia-Luis et al. (1994) and Almela et al. (1994).

Avoiding fluctuations in soil water content, as well as avoiding depletion of water from deeper soil layers is of critical importance in avoiding fruit cracking. Sandhu and Bal (2013) pointed out that management practices such as irrigation at 20% available soil moisture depletion, mulching with black polythene, application of farmyard manure (75 kg/tree), inorganic fertilizer (Nitrogen 350 g/tree), azotobacter (18 g/tree) and foliar spray of 1-Naphthaleneacetic acid at 40 ppm in lemon cv. Baramasi substantially reduced the cracking losses by 94.5% and resulted in better fruit quality. De Cicco et al. (1988) reported a significantly higher severity in fruit cracking of 'Navelina' orange when the total available water in the 40–80 cm soil layer was low. Although some studies have dealt with this complex phenomenon, the basic mechanism involved in fruit cracking remains unclear (Sandhu and Bal, 2013).

To reduce the negative impact of water stress, it is necessary to quantify the level of irrigation water that affects cracking and quality characteristics of fruits. Irrigation strategies defining relation of water-yield-fruit quality in different climatic conditions became more important for each fruit as well as mandarin. Therefore, the objective of this research was to determine the effects of different level of irrigation and fertilizers on irrigation-yield-fruit quality and cracking of mandarin under Mediterranean climatic conditions.

2. Materials and methods

The study was carried out in 2007 and 2008 in a 1-ha of citrus orchard at the University of Mustafa Kemal, Dörtyol experimental station (36°45′ N and 36°10′ E) in Hatay, Turkey. The soil of the research area is sandy loam in texture, unsalted, rich in calcium carbonate and alkali (Table 1). The weather of the region is typically Mediterranean, i.e., mild and rainy in winter and dry and hot in summer. Long term monthly average climatic data and measured climatic data during experimental period is given in Table 2. Ten-year-old Nova mandarin citrus trees (*Citrus reticulata*) grafted on local sour orange rootstock were used as a material. Irrigation water that had C_2S_1 quality-class (Ayers and Westcot, 1985) was applied using the drip irrigation. Two drip lines were used in each tree row, with self-compensating drippers (2 L h^{-1}) per tree, 0.50 m apart. The infiltration rate of the experimental soil was 7.4 mm h^{-1}. The experimental design was a split plot design with 3 replications. Each plot contained three trees spaced 5 and 7 m apart.

We used two fertilizers treatments and five levels of irrigation. In the F_1 fertilization, only N, P and K were applied to plots. Nitrogen was applied 1 kg per tree because trees were 10 years old and 1/2 was applied in February, 1/4 in May and 1/4 in July. In the F_2 fertilization treatment, the same fertilizer application as in F_1 was made to plots with an additional 2% Ca in the form of $Ca(NO_3)_2$ applied in the middle of July. The mean annual amount of fertilizers applied through the irrigation system during the experimental period (between 26 June 2007–29 October 2007 in the first year and 04 June 2008–07 October 2008 in the second year) was 260 kg ha^{-1} N, 103 kg ha^{-1} P_2O_5, 173 kg ha^{-1} K_2O and 13.2 g Fe chelate per tree

Table 1
Soil physical and chemical properties of the research field.

Depth (cm)	Saturation (%)	Sand (%)	Clay (%)	Silt (%)	Texture	$CaCO_3$ (%)	FC (%)	PWP (%)	Bulk density (g cm^{-3})	pH	ECe (μmhos cm^{-1})
0–30	37	60	12	28	SL	15	17	12	1.3	8.3	363
30–60	27	62	10	28	SL	22	13	9	1.4	8.4	296
60–90	30	66	11	23	SL	19	10	7	1.6	8.5	307
90–120	29	72	7	21	SL	35	8	6	1.6	8.5	273

SL: sandy loam; FC: field capacity; PWP: permanent wilting point; ECe: electrical conductivity of soil paste extract. Saturation, FC and PWP are weight based.

Table 2
Monthly for 2007–2008 and long term (1945–2008) climatic parameters at the experimental site.

Years	Parameter	May	June	July	August	September	October	November	December
1945–2008	Average temperature (°C)	21.3	24.8	27.3	27.9	25.8	21.5	16.3	11.8
	Relative humidity (%)	68	69	71	68	62	61	62	68
	Precipitation (mm)	75.7	44.5	21.5	35.9	58.1	102.4	89.4	122.1
	Wind speed (m s^{-1})	1.5	1.6	1.6	1.6	1.6	1.5	1.4	1.4
	Evaporation (mm)	137.6	161.9	187.2	185.4	150.3	96.1	51.2	34.3
2007	Temperature (°C)	22.8	25.7	28.1	28.8	26.5	22.9	16	10.5
	Relative humidity (%)	61.8	52.2	54.1	59.2	45.8	42.4	47.3	50.1
	Precipitation (mm)	83.5	28.1	28.5	18	29.6	8.3	82	84
	Wind speed (m s^{-1})	0.7	0.8	0.9	0.8	0.8	0.8	1	1
	Evaporation (mm)	137.7	173.4	206.3	174	156.2	108.8	56.5	38.4
2008	Temperature (°C)	21.4	26.8	28.1	29.7	27.4	21.7	15.3	10.0
	Relative humidity (%)	68.6	53.2	52.1	57.4	44.5	43.4	46.1	49.2
	Precipitation (mm)	63.2	23.9	17.5	17	22.4	9.1	83	82
	Wind speed (m s^{-1})	1.0	0.6	1.3	1.2	1.4	1.00	1.2	1.4
	Evaporation (mm)	133.8	145.6	198.3	162	154	122.3	47.5	32.1