Deficit Irrigation Influences Yield and Lycopene Content of Diploid and Triploid Watermelon

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Abstract

Many vegetable production regions in the southwestern US are strictly regulated on water use. In addition, demand for high quality and nutritious vegetables has increased. This study was performed to explore the effects of deficit irrigation on yield, fruit quality and lycopene content of red-fleshed diploid and triploid watermelon (*Citrullus lanatus* (Thunb) Matsum & Nakai) cultivars. Irrigation treatments were 1.0, 0.75 and 0.5 evapotranspiration (ET) rates. Cultivars used were 'Summer Flavor 710', 'RWW 8036', 'Allsweet', 'Sugarlee', and 'SWD 7302' (diploids) and 'Summer Sweet 5244', 'SWT 8706', 'Sugar Time', and 'Tri-X-Sunrise' (triploids). Total water applied through a subsurface drip system was 395, 298 and 173 mm, for the 1.0, 0.75 and 0.50 ET, respectively. Total yields were highest at 1.0 ET (53.9 t ha^{-1}) compared with 0.5 ET (26.8 t ha^{-1}). Triploids had a 34% higher total yield and fewer culls (2%) compared with diploid cultivars (25%). Highest yields were obtained for 'Sunrise', 'SWT 8706', and 'SWD 7302'. Highest soluble solid content was measured for 'Sugar Time' (13.4%) and was significantly higher than other cultivars (range 9.7-11.0 %). Triploid cultivars had more firm flesh, compared with diploids (12.0 vs. 9.9 N). Lycopene content increased slightly with maturity (55.8 to 60.2 µg g^{-1} fw), and was significantly higher at 0.75 ET than 1.0 ET in melons at ripe and overripe maturity stages. Lycopene content averaged over all treatments was 60-66 µg g^{-1} fw for triploids and 45 to 80 µg g^{-1} fw for diploid fruit.

INTRODUCTION

Watermelons are grown on over 2.43 million hectares worldwide, with consumption in the leading producing countries at 8 to 62 kg per capita in the US and Turkey, respectively (Maynard, 2001). Watermelon is a natural source of lycopene, a carotenoid known for its antioxidant properties, with its action as a potent free radical scavenger (Di Mascio et al., 1989). The average content of lycopene in watermelon fruit sampled from the retail produce was reported to be 48.7 µg g^{-1} fw, higher than reported for fresh market tomatoes (USDA, Carotenoid Database for US Foods, 1998). More recently, Perkins-Veazie et al. (2001) reported that seedless watermelons have more lycopene (> 50 µg g^{-1} fw) than seeded ones. That study also showed significant variability in lycopene content among watermelon germplasm.

Watermelon constitutes one of the largest vegetable crop grown in southwest Texas. Depending on seasonal variation and location, they are generally produced using 305 to 559 mm of water. However, pumping restrictions from underground aquifers in the region are reducing the supply of high quality irrigation water. Consequently, more efficient irrigation systems, such as subsurface drip irrigation (SDI), are becoming critical for watermelon production. In a study where deficit irrigation was applied through SDI immediately after fruit set, first harvest yields were significantly reduced (Leskovar et al., 1999). The effect of irrigation strategies and the interaction with cultivars on fruit lycopene content is unknown. The present study was conducted to determine the effects of deficit irrigation through a SDI system on yield, fruit quality characteristics and lycopene content of red-fleshed diploid and triploid watermelon cultivars.

MATERIALS AND METHODS

Four-week old watermelon transplants were mechanically established in the field at the Texas A&M Agr. Exp. Station, Uvalde, on 9 April 2001. Irrigation treatments were based on evapotranspiration (ET) rates of 1.0, 0.75 and 0.5 ET. Diploid (2x) cultivars used were 'Summer Flavor 710', 'RWM 8036', 'Allsweet', 'Sugarlee', and 'SWD 7302'. Triploid (3x) cultivars used were 'Summer Sweet 5244', 'SWT 8706', 'Sugar Time', and 'Tri-X-Sunrise'. Plants for each experimental plot were grown on three single raised beds on 2.03 m centers with one row/bed and 0.9 m within row spacing, giving a theoretical plant population of 5,388 pl ha^{-1}. Plots were separated by a blank 2-m row, giving a 0.75 ratio of planted area (4,041 pl ha^{-1}). A subsurface drip system (20 cm depth) and plastic mulch were used. Drip type used was T-Tape TSX 508 (0.2 mm wall thickness) with emitters spaced every 30 cm and a flow rate of 332 $L \cdot h^{-1}$ per 100 m of bed at 55 kPa (T-systems International, Inc., San Diego, Calif.). Total irrigation applied was 395, 298 and 173 mm for the 1.0ET, 0.75ET and 0.50ET, respectively. Rainfall amounted to 165 mm. Harvests were made on 25 June, 16 July and 1 August 2001. In each harvest fruits were individually counted and weights measured according to the following class sizes: < 5 kg, 5-8 kg, 8-11 kg, and >11 kg (comparable to commercial watermelon grades #6, #5, #4, and #3 fruits per box). Culls fruits (small, bottleneck, or blossom end rot, BER) were counted and weighed. Total fruit weight and numbers for the three harvests combined were calculated. After each fruit was split in halves, fruit firmness was measured in Newtons (N) on three mesocarp spots around the center of the heart using a digital force meter (DFM 10, Chatillon, Greensboro, N.C.) with a 11 mm diameter round-head probe. Soluble solids content (SSC) was measured with a digital refractometer. Fruit lycopene content was extracted with hexane and measured spectrophotometrically at 503 nm as described by Sadler et al. (1990). Lycopene content was measured at ripe (25 June) and overripe (2 July) stages. The experiment was conducted using a split-plot experimental design with three replications. Irrigation rates were the main plots, and cultivars the subplots. Marketable yield, fruit quality and lycopene data were subjected to analysis of variance (ANOVA) by PROC GLM (SAS Institute, Inc., Cary, N.C.).

RESULTS AND DISCUSSION

Yield

Total yields were highest at 1.0 ET (53.9 t ha^{-1}), with almost a 2-fold higher yield than melons grown at 0.5ET (Table 1). At the 1.0 ET rate, there was a significant increase in the weight of larger (> 8 kg) fruit sizes (data not shown). Triploids (3x) have a 34% higher average total marketable yield (45 t ha^{-1}) and fewer culls than the diploid (2x) cultivars. Overall, highest yields were obtained for the triploids 'Sunrise' and 'SWT 8706' and the diploids 'SWD 7302' and 'Summer Flavor 710'; lowest yield was for 'Allsweet' (2x). Irrigation rates did not affect the weight of cull fruit. However, cull fruit weight was significantly higher for the diploids (except for 'Sugarlee') than the triploid cultivars.

Fruit Quality and Lycopene

Deficit irrigation had an effect on fruit quality characteristics (Table 2). Fruit flesh was slightly firmer at 0.5 ET compared with 0.75 ET, while minimum numerical differences were found in soluble solids content. In a previous study with muskmelon (*Cucumis melo* L. Group cantalupensis) irrigation systems - furrow, surface drip and SDI

- did not affect SSC (Leskovar et al., 2001). In this experiment, reducing the irrigation rate to 0.75 ET decreased the individual fruit length, diameter, and rind thickness compared with melons grown at 1.0 ET rate. When irrigation rates and timing of stress application were evaluated in a triploid and diploid cultivar, water deficit applied prior to or after fruit set decreased fruit number and size, while heart color of the flesh was not affected by irrigation (Leskovar et al., 1999). In that study, SSC of ripe melons increased in triploids irrigated with constant 0.5ET, or with irrigation reduced to 0.5ET after fruit set.

Across all cultivars, generally triploids had firmer fruit flesh than the diploids, except for 'Sugarlee' (Table 3). 'Sugar Time' (3x) had the highest level of soluble solids content (13.4%), compared with other cultivars that ranged from 9.7 to 11.0%. Lycopene content increased slightly with maturity (55.8 to 60.2 $\mu g\ g^{-1}$ fw) in all watermelons, and was significantly higher in both ripe and overripe melons grown at 0.75 ET than at 1.0 ET. Overall, lycopene content in overripe fruits ranged from 61-66 $\mu g\ g^{-1}$ fw for triploids and 45 to 80 $\mu g\ g^{-1}$ fw for diploid melons.

CONCLUSIONS

The present study indicates that acclimation, fruit yield, and fruit quality responses to deficit irrigation differ between triploid and diploid watermelons. If water pumping restrictions from underground aquifers are further imposed, deficit irrigation will become a reality for vegetable producers. Deficit irrigation (e.g. 0.75 or 0.5 ET constant rate) will directly reduce yield, but it is most likely that fruit set and subsequent fruit growth may be less affected in triploid than diploid watermelons. Even though lycopene content varied widely among red-fleshed 2x and 3x cultivars, deficit irrigation was not detrimental to lycopene content on a per fruit basis.

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Tables

Table 1. Effect of irrigation rate and cultivar on diploid (2x) and triploid (3x) watermelon on total marketable yield, culls, and lycopene content at ripe and overripe stage.

Treatment		Yield ($t\ ha^{-1}$)	Culls ($t\ ha^{-1}$)	Lycopene ($\mu g\ g^{-1}$ fw) Ripe	Overripe
Irrigation rate					
1.0 ET		53.9 [a]	7.7	54.3 [b]	58.8 [b]
0.75 ET		34.2 [b]	6.2	57.9 [a]	62.4 [a]
0.5 ET		26.8 [c]	5.8	55.3 [ab]	59.6 [b]
LSD (0.05)		6.2	ns	2.5	2.1
Cultivar	Ploidy				
Summer Flavor 710	2x	41.1 [ab]	7.5 [bc]	77.3 [a]	80.6 [a]
RWM 8036	2x	28.9 [cd]	8.0 [bc]	50.1 [cd]	62.3 [b]
Allsweet	2x	20.7 [d]	26.5 [a]	43.5 [e]	45.7 [c]
Sugarlee	2x	36.1 [c]	2.9 [cd]	48.2 [cd]	49.0 [c]
SWD 7302	2x	40.1 [ab]	10.8 [b]	47.2 [de]	46.8 [c]
Summer Sweet 5244	3x	45.2 [ab]	0.4 [d]	62.2 [b]	65.9 [b]
SWT 8706	3x	47.4 [a]	1.3 [d]	58.8 [b]	63.8 [b]
Sugar Time	3x	40.0 [ab]	0.8 [d]	62.5 [b]	66.3 [b]
Tri X Sunrise	3x	46.0 [ab]	0.8 [d]	51.8 [cd]	61.6 [b]
LSD (0.05)		10.7	5.3	4.6	6.2

Two treatments (irrigation rate or cultivar) are significantly different if the difference between the means are larger than the LSD value (0.05).

Table 2. Effects of irrigation rates on watermelon fruit quality characteristics.

Irrigation rate	Firmness (N)	SSC (%)	Length (cm)	Diameter (cm)	Rind thickness (cm)
1.00 ET	10.7 [ab]	10.7	32.1 [a]	24.6 [a]	1.12 [a]
0.75 ET	10.1 [b]	11.1	26.9 [b]	20.5 [b]	0.96 [b]
0.50 ET	11.6 [a]	11.1	29.1 [ab]	21.2 [b]	0.94 [b]
LSD (0.05)	1.3	ns	3.5	3.3	0.11

Each value is a mean of nine cultivars, three replications and four fruit/replication.
N=newton; SSC=soluble solid content

Table 3. Effect of diploid (2x) and triploid (3x) cultivars on watermelon flesh firmness and soluble solid content (SSC).

Cultivar	Ploidy	Firmness (N)	SSC (%)
Summer Flavor 710	2x	7.7 [c]	11.0 [ab]
RWM 8036	2x	8.8 [bc]	9.7 [ab]
Allsweet	2x	10.8 [ab]	9.6 [b]
Sugarlee	2x	12.7 [a]	11.1 [ab]
SWD 7302	2x	9.0 [bc]	11.1 [ab]
Summer Sweet 5244	3x	11.8 [a]	10.8 [ab]
SWT 8706	3x	12.5 [a]	11.0 [ab]
Sugar Time	3x	11.3 [a]	13.4 [a]
Tri X Sunrise	3x	12.4 [a]	10.8 [ab]
LSD (0.05)		2.2	3.2