Irrigation Enhances Postharvest Performance of 'Cristalina' Cactus Pear Fruit

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Abstract

Cactus pear fruit is grown mainly under rain-fed conditions in marginal semi-arid and arid highlands of central and north-central Mexico. Drip-irrigation can increase fruit yield ≈ 3.5-fold. However, the effects of irrigation, particularly on postharvest life of fruit, are unknown. This research examines the influence of irrigation on postharvest quality and shelf life of 'Cristalina' cactus pear fruit. Irrigation treatments were: non-irrigated (NI as control), supplemental irrigation (SI), and full irrigation (FI). Treatments were arranged in a randomized complete-block experimental design with three replicates. Twenty four fruits per treatment were harvested randomly from around the plants. Three sets of 72 fruits each were formed. One set was used to evaluate fruit quality at harvest. The other two were stored at room temperature (24 ± 1°C and 40 ± 8% RH) or in a cold room at 10°C and 85% RH. Fruit quality measures were: fruit weight, pulp weight, firmness, total soluble solids concentration (TSSC), dry matter concentration (DMC), and weight loss. At harvest, fruit weight was greater in FI than in SR and NI, but the edible portion of the fruit (pulp) was larger in FI and SR than in NI. Firmness and DMC were similar among treatments, while TSSC was the highest in NI fruit. After 49 days at room temperature, fruit quality was similar to that observed at harvest except for firmness, which was best conserved in FI fruit. The latter findings were consistent with those observed after 63 days in a cold room. FI and SI fruit had less weight loss than NI fruit under both storage conditions. Therefore, FI and SI (as a water-saving irrigation alternative) enhanced and maintained some quality attributes. Both irrigation treatments tended to increase the shelf life of cactus pear fruit, critical for longer storage periods required to reach distant markets.

INTRODUCTION

Cactus pear (*Opuntia* spp.) is a crassulacean acid metabolism plant grown in marginal arid and semi-arid regions of Mexico and in similar agro-ecosystems around the world. This plant is used for alleviating soil erosion, for animal feed and industrial purposes, and for human consumption as a vegetable (young cladodes) or fruit. To optimize production and fruit quality of this crop, standard agricultural practices for pest and weed control, pruning, thinning, mineral and organic nutrition, and irrigation are needed (Pimienta-Barrios, 1986; Inglese, 1995; Fernández-Montes and Mondragón-Jacobo, 1998; Sáenz-Quinetero, 1998; Potgieter, 2001; García-Herrera et al., 2008). Irrigation has increased yield and fruit quality, particularly fruit size (Gugliuzza et al., 2002). However, although some preharvest practices have been examined (Ochoa et al., 2002; Schirra et al., 1999a,b), to our knowledge, the postharvest effect of irrigation on cactus pear fruit quality and weight loss has been not studied. This research examines the influence of irrigation on postharvest quality and shelf life of 'Cristalina' cactus pear fruit. Because of water shortages, cactus pear irrigation is not a common practice, but is increasing to improve productivity and fruit size for export markets. Water availability will always limit agriculture in arid and semiarid lands suitable for growing cactus pear; therefore we have introduced and tested supplemental irrigation (Oweis et al., 1999) as a water-saving irrigation technique for cactus pear fruit production.

MATERIALS AND METHODS

The experiment was conducted at the Campo Experimental Zacatecas, Calera, Zacatecas, México (lat. 22°54'N, long. 102°39'W, elevation 2,197 m) from March to October, 2012. The experimental site has an annual mean temperature of 14.6°C and receives 416 mm rainfall with 75% occurring between July and October. Average annual pan evaporation is 1,609 mm. The orchard soil has a loam texture, 1.73% organic matter content at pH 7.75. Six-year old cactus pear plants (*Opuntia albicarpa* Scheinvar 'Cristalina') were used. 'Cristalina' bears late-maturing, white-pulped fruit. Plants were spaced at 4 × 3 m and trained to an open vase system.

Nine experimental units, each comprising nine cactus pear plants, were selected and randomly allocated to three irrigation treatments (three experimental units per treatment). The two middle trees of every experimental unit were used for data collection. The irrigation treatments were: 1) non-irrigated (NI, rain-fed control), 2) supplemental irrigation (SI), and 3) full irrigation (FI). SI and FI treatment were drip-irrigated through 2 emitters (each one at 50 cm away from plant trunk) per plant that together emitted 8 L h^{-1}. Irrigation supply in SI and FI was controlled by on/off valves as needed. Throughout the experiment, volumetric soil water content was monitored in all treatments before and 24 h after each irrigation with time domain reflectometry (TDR, Mini-Trase System, Soil Moisture Equipment Corp., Santa Barbara, CA, USA). Irrigation treatments were applied according to soil water balance (Zegbe and Serna, 2012).

Plants received standard cultural practices used for local commercial production, including drip irrigation, cladode pruning, fruit thinning, row fertigation, and pest-weed control as needed.

Twenty-four fruits per treatment (8 fruits per replicate) were harvested randomly at the green-mature stage from around the plants. Three sets of 72 fruits each were formed. One set was used to evaluate fruit quality at harvest. The other two were stored at room temperature (24 ± 1°C and 40 ± 8% RH) or cold room (10°C and 85% RH). Fruits were treated with a solution of 1% chlorine and 2.5 ml/L copper sulphate before storage. Fruit quality measures were: fruit and pulp weights (g) were individually weighed with a precision scale (VE-303, Velab, USA). After removing the fruit skin, two flesh firmness determinations (kg) were done on opposite sides of the equator of each fruit using a press-mounted Effegi penetrometer with an 11.1-mm tip (model FT 327, Wagner Instruments, Greenwich, CT, USA). From each fruit, total soluble solids concentration (°Brix) was determined by mixing several drops from each side of the fruit with a digital refractometer with automatic temperature compensation (model PR-32α, Atago, Co. Ltd., Tokyo, Japan). Dry matter concentration of fruit (mg/g fresh weight) was determined using 25 g of a composite sample of fresh cortical tissue from three fruits, which was oven-dried at 60°C for two weeks to constant weight. During storage, each fruit was individually weighed every week until an irrigation treatment reached 8% of fruit weight loss (FWL). FWL was calculated as the percentage reduction from initial weight.

Data were analysed using a randomized complete-block model with the GLM procedure of SAS software (SAS Institute ver. 9.1, 2002-2003, Cary, NC, USA). Treatment means were compared and separated by Tukey's test at 5%.

RESULTS AND DISCUSSION

Previously published results (Gugliuzza et al., 2002; Zegbe et al., 2006) partially agree with those given here because at harvest, fruit weight was greater in full irrigation (FI) plants than in supplemental irrigation (SI) or non-irrigated (NI) plants, but the edible portion of the fruit (pulp) was larger in FI and SI than in NI. Firmness (F), fruit skin colour (FSC), and dry matter concentration were similar among treatments, while total soluble solids concentration was highest in NI fruit. This could be due to dilution, because NI produced the smallest fruit size with the lowest fruit and pulp weights (Table 1). After six weeks at room temperature, fruit quality was similar to that observed at harvest except for F, which was best maintained in FI fruit. The latter findings are consistent with those observed after eight weeks in the cold room (Table 1). Although not significant among treatments, FSC tended to change from greenish to yellowish in 2 and 13% of fruits after six (room temperature) or eight (cold room) weeks storage, respectively (Table 1).

The latter effect should be evaluated with sensory techniques, because consumer acceptance and repeated purchases depend on fresh fruit appearance. Fruit continue transpiring after harvest, causing fruit weight loss (FWL). Excessive FWL produces shrivelled fruit with altered flavour (Maguire et al., 2001). In cactus pear fruit, unlike other fruits, 8% FWL is sufficient to develop a shrivelled appearance (Cantwell, 1995). In this experiment, storage was completed when one out of three irrigation treatments reached 8% FWL. Fruits from NI plants reached 8% FWL after six weeks at room temperature (Fig. 1A). This FWL was consistent under cold room storage (Fig. 1B) and supported by the pulp to peel ratio (Pu/Pe), because FI produced the lowest Pu/Pe (Table 1). Clearly, FI and SI (as a water-saving irrigation alternative) can increase the shelf life of cactus pear fruit, which is imperative for both longer storage periods and reaching distant markets. Data suggests that FI and SI could have induced favourable changes on the epidermis (Maguire et al., 1999), resulting in less FWL, as demonstrated in other postharvest research on cactus pear fruit (Schirra et al., 1999a; Lopez-Castañeda et al., 2010) and in peaches undergoing different irrigation regimens (Crisosto et al., 1994).

CONCLUSIONS

Full and supplemental irrigation enhanced and maintained fruit and pulp weights and firmness under both storage conditions, but significantly reduced total soluble solids concentration. Both irrigation treatments increased the shelf life of cactus pear fruit, critical for the longer storage periods required to reach distant domestic and international markets.

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Tables

Table 1. Mean fruit weight (FW), pulp weight (PW), pulp to peel ratio (Pu/Pe), flesh firmness (FF), dry matter concentration (DMC), total soluble solids concentration (TSSC), and fruit skin colour (FSC) of 'Cristalina' cactus pear fruit from plants undergoing different irrigation treatments at harvest and after six or eight weeks storage at room temperature or cold room.

Irrigation treatments	Fruit quality attributes						
	FW (g)	PW (g)	Pu/Pe	FF (N)	DM (mg/g FW)	TSSC (%)	FSC (hue°)
				At harvest			
Non-irrigated	124.3 b[x]	78.0 b	1.7 a	26.3 a	167.5 a	13.1 a	96.5 a
Supplemental irrigation	148.3 b	93.5 ab	1.7 a	24.3 a	161.2 a	12.6 ab	97.2 a
Full irrigation	179.0 a	108.6 a	1.6 a	27.2 a	158.8 a	11.9 b	98.3 a
MSD[y]	26.0	18.3	0.2	5.9	16.8	0.7	2.4
CV[z] (%)	13.0	15.0	10.2	16.7	10.2	5.3	2.4
			Room temperature (24 ± 1°C and 40 ± 8% RH)				
Non-irrigated	128.2 b	91.3 b	2.6 a	18.6 b	144.1 a	12.8 a	94.1 a
Supplemental irrigation	153.3 b	110.4 ab	2.5 a	19.3 b	137.6 a	12.4 ab	95.1 a
Full irrigation	193.2 a	129.1 a	2.0 b	25.3 a	128.3 a	11.2 b	97.5 a
MSD	35.4	29.7	0.4	3.2	17.2	1.5	4.8
CV (%)	12.3	13.5	14.3	12.5	13.7	3.9	3.4
			Cold room (10°C and 85% RH)				
Non-irrigated	121.4 c	87.2 b	2.6 a	18.8 b	167.6 a	13.0 a	81.1 a
Supplemental irrigation	149.8 b	106.0 ab	2.4 a	17.9 b	160.1 a	12.6 a	85.1 a
Full irrigation	186.0 a	120.5 a	1.8 b	24.6 a	154.0 a	11.5 a	87.3 a
MSD	26.2	18.9	0.4	6.3	31.9	1.4	6.2
CV (%)	11.9	14.2	12.1	18.9	11.8	4.6	3.3

[x] Mean separations within a column at harvest or storage condition were by Tukey's test at 5%. Mean values followed by the same lower-case letter are not significantly different.

[y] Minimum significant difference.

[z] Coefficient of variation.

Figures

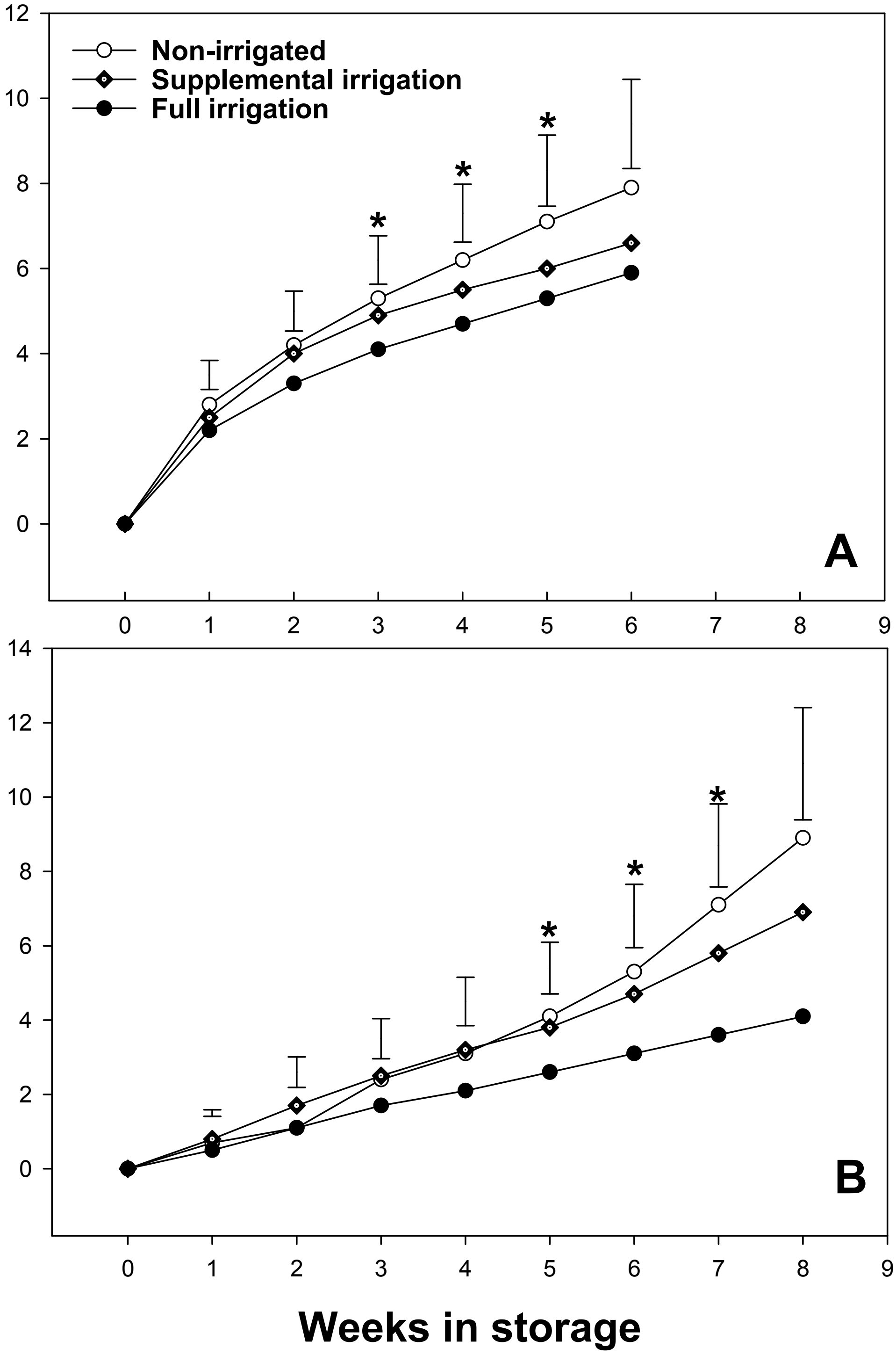

Fig. 1. Cumulative weight loss of 'Cristalina' cactus pear fruit from plants undergoing different irrigation treatments during storage at room temperature (24 ± 1°C and 40 ± 8% RH) (A) or cold room (10°C and 85% RH) for six or eight weeks, respectively. For each sampling date, vertical bars represent the minimum significant difference and asterisks indicate statistical differences by Tukey's test at 5%.