



Cladode Pruning Affects Yield and Fruit Quality of 'Roja Lisa' Cactus Pear [*Opuntia ficus-indica* (L.) Mill.]: A Preliminary Study

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Authors' contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: This study assessed the initial effect of experimental pruning (EP) or grower's pruning (GP) of cactus pear fruiting cladodes on fruit yield (FY), fruit size distribution (FSD), and fruit quality (FQ) at harvest and after storage.

Study Design: Treatments were arranged in a completely randomized design with eight or ten replicates, with a single plant as replicate, for EP or GP, respectively.

Place and Duration of Study: The experiment was set up in a drip-irrigated commercial orchard of 'Roja Lisa' cactus pear [*O. ficus-indica* (L.) Mill.] plants located at Santa Fe, Jerez, Zacatecas, México, from February to August 2006.

Methodology: The EP considered two agronomic practices: 1) exposing the center of each plant while eliminating unproductive cladodes and those shading other cladodes and 2) concentrating fruiting cladodes in the outer part of the plants. The GP randomly eliminated some cladodes from the central part and around the plants only. Treatments were arranged in a completely randomized design with eight or ten replicates, with a single plant as replicate, for EP or GP, respectively. The response variables were: FY, FSD, and FQ at harvest and after storage. The FQ attributes were: mean fruit mass (MFM), flesh firmness (FF), total soluble solids concentration, pulp and peel mass, dry matter concentration, and fruit water loss (FWL) during storage.

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Results: EP increased MFM by 42% over GP and produced 15% more marketable fruit (fruit equatorial diameter from 5.0 to 7.0 cm), but FY was reduced by 39%. The FF was higher in EP fruit than GP fruit after storage. The other FQ attributes were similar in both pruning treatments, both at harvest and after three weeks at room temperature. The FWL was also similar under both pruning systems. More targeted pruning has the potential to increase the productivity of cactus pear orchards.

Conclusion: Experimental pruning increased fruit size and the percentage of commercial fruit, but reduced both overall and commercial fruit yields. After three-week storage at room temperature, flesh firmness remained greater in EP fruit. Fruit water loss was not influenced by pruning treatments during the storage.

Keywords: *O. ficus-indica* (L.) Mill.; fruit size and distribution; storability.

1. INTRODUCTION

In modern cactus pear [*O. ficus-indica* (L.) Mill.] orchards, annual pruning of cladodes (APC) is essential for high fruit yield and fruit quality [1], in addition to irrigation and fruit thinning [1,2,3]. The APC is necessary to regulate the size and shape of plants and to remove cladodes that are unproductive or misplaced inside the plant (e.g., cladodes that are shading others, ground-oriented or located in the central part of the plants). The APC promotes fruiting cladodes, facilitates plant sanitary control and harvesting, and maintains an adequate balance between vegetative and reproductive growth for the next growing season [1]. However, the APC receives little or no attention from Mexican growers due to lack of knowledge of this practice, pruning costs, or both. Although there is a consensus that APC maintains cactus pear productivity and enhances fruit quality [1,4], there is only one published scientific paper supporting these assertions, this is a study of four pruning intensities in less than one-year-old cladodes [5]. Nowadays, there is an agreement among growers to look for new and more professional ways of cladode pruning in order to enhance plant shape [6], orchard management, and fruit size and quality [1]. Therefore, the objective of this research was to compare the initial effect of an experimental pruning and grower's pruning of cactus pear fruiting cladodes on fruit yield, fruit size distribution, and fruit quality, both at harvest and after storage at room temperature.

2. MATERIALS AND METHODS

2.1 Experimental Site, Plant Material and Orchard Management

The experiment was set up in the commercial orchard Rancho La Tunera, located in Santa Fe, Jerez, Zacatecas, México (lat. 22° 32' N, long.

103° 03' W, elevation 1,976 m) from February to July 2006. The experimental site has an annual mean temperature of 16.5°C (with a minimum and maximum average temperature of 7.4°C and 26.0°C, respectively) and receives 482 mm annual rainfall, with 62% occurring between July and October. The average annual pan evaporation is 1,609 mm. The orchard soil has a clay loam texture with 1.63% organic matter content at pH 7.1. Six-year-old cactus pear [*O. ficus-indica* (L.) Mill. cultivar 'Roja Lisa'] plants were used. 'Roja Lisa' is an early-maturing and red-pulped cultivar. Plants were spaced at 5 x 3 m without a trained system defined. Except for cladode pruning, plants received standard cultural practices used for local commercial production, including drip irrigation, row fertigation, and pest or weed control as needed [7].

2.2 Treatments and Experimental Design

Plants of cactus pear were subjected to two treatments. The first treatment consisted of eliminating some cladodes randomly from the central part and around the plants, as is standard practice for local grower's pruning (GP, as control). The second treatment, experimental pruning (EP), consisted of a) eliminating cladodes that were unproductive or shading others around the plant and exposing the center of each plant, and b) concentrating fruiting cladodes in the outer part of the plants. Unlike the previously described cladode pruning system [5], in this experiment, entire cladodes were removed. On average (\pm standard deviation), 25 \pm 6 or 75 \pm 5 cladodes were removed for GP or EP plants, respectively. The corresponding cladode fresh masses were 33 \pm 7.4 kg and 87 \pm 5 kg and the time required to prune each plant was ~ 10 or 30 min for GP or EP, respectively. The treatments were applied on February 28, 2006, almost two months before blooming, which

occurred on April 20. The experiment was conducted in a completely randomized design with eight and ten replicates (with a single plant as replication due to plants availability) for EP and GP treatments, respectively.

2.3 Response Variables

The harvest was done in four events, starting on June 4 and ending on July 20, 2006. The harvested fruits from each plant were sorted by equatorial diameter (cm) into Grade 1 to Grade 4 (1 = 7.0 to 6.0 cm, 2 = 5.9 to 5.0 cm, 3 = 4.9 to 4.1 cm, and 4 = 4.0 to 3.5 cm) and the number and mass of fruit per grade were determined [7,8]. Fruit from each plant was counted and the total mass measured as fruit yield. Commercial yield per plant was calculated by adding the fruit in Grades 1 and 2.

Fruit quality (FQ) was evaluated at harvest and after three weeks in storage at room temperature (mimicking growers' storage conditions) at 16 ± 3 °C and 42 ± 13 % relative humidity, where storage conditions were recorded every two hours with a data logger (model 42276, ExTech, Instruments, MA, USA). Two lots each of 24 and 30 Grade 1 fruits (three per replicate) from EP and GP plants, respectively, were randomly selected from the third harvest. The first and a second lot of fruits were used to assess FQ at harvest and after storage, respectively. FQ was determined as follows: the mass of each fruit was recorded with a precision balance (Mettler PE11, Mettler Instrumente, Greifensee-Zurich, Switzerland). After removing the fruit skin, two flesh firmness determinations were done on two opposite sides, in the equatorial part of each fruit, using a press-mounted Wagner penetrometer (model FT 327, Wagner Instruments, Greenwich, CT, USA) with an 11.1 mm head. By mixing some drops from each side of the fruit, the total soluble solids concentration was measured using a digital refractometer with automatic temperature compensation (model PR-32 α , Atago, CO., Ltd., Tokyo, Japan). For each fruit, peel and pulp were separated and weighed with a precision balance, and the pulp-to-peel ratio (P:P ratio) was estimated. Dry matter concentration of fruit was determined from 25 g composite samples of fresh pulp tissue from three fruits. Samples were oven-dried at 60 °C for one week to constant mass. The FQ from a second lot of fruit stored at room temperature was evaluated three weeks later using the same procedures. Fruit water loss

was evaluated by weighing the fruit individually at harvest and weekly during storage.

2.4 Data Analysis

Data were analyzed using an unbalanced completely randomized model with the GLM procedure of SAS software (SAS Institute ver. 9.3, 2002-2010, Cary, NC, USA). Fruit grades, expressed as a percentage, were arcsine-transformed and means are reported after back-transforming [9]. Treatment means were compared and separated by the least significant difference from Fisher's test at $P = 0.05$.

3. RESULTS AND DISCUSSION

3.1 Pre-harvest Results

Cactus pear plants subjected to experimental cladode pruning (EP) significantly increased mean fruit mass (MFM) above those receiving growers' pruning (GP) (Table 1). The latter was reflected in a trend of increased percentages of fruit in Grades 1 and 2 and decreased fruit in Grades 3 and 4 in EP plants. However, EP plants had reduced fruit yield (FY) and commercial yield (CY). We were expecting such negative effects due to the large amount of both vegetative and reproductive material that was removed from EP plants initially for shaping, training, and adjusting harvesting height.

The response of 'Roja Lisa' cactus pear plants to EP was comparable to that observed in temperate fruit trees [10]: reduced total yield, but enhanced fruit size. This indicates that assimilates were more available to sinks (fruits) in EP plants than in GP plants. The improvement in EP plants of both MFM and percentage of fruit in Grades 1 and 2, which the most marketable fruit for this cactus pear variety, is also consistent with the response of temperate fruit trees to pruning [10].

3.2 Post-harvest Results

The final size, quality, and shelf life of many fruits depend on pre-harvest orchard management [11]. However, previous studies in cactus pear fruit suggested that pre-harvest management does not affect either the quality or shelf life of cactus pear fruit [1,2,7]. The latter was confirmed in this study, with similar fruit quality attributes in the two pruning treatments except for flesh firmness, which was greater in EP fruit after three-week storage (Table 2).

Table 1. Fruit yield (FY), commercial yield (CY), mean fruit mass (MFM), and fruit size distribution of 'Roja Lisa' cactus pear in response to cladode pruning

Cladode pruning	FY (t/ha)	CY (t/ha)	MFM (g)	Fruit size distribution (%)			
				Grades (equatorial diameter, cm)			
				1 (7.0-6.0)	2 (5.9-5.0)	3 (4.9-4.1)	4 (4.0-3.5)
Growers	28.2a ^{*¶}	18.1a	116.5b	06.2a	59.1a	33.1a	1.6a
Experimental	17.3b	13.0b	165.3a	12.3a	62.8a	24.1a	0.8a
LSD _{0.05}	6.1	3.6	9.7	6.7	10.4	10.5	1.0
CV (%)	27.2	23.9	6.7	11.8	8.5	18.1	3.0

* Within columns means followed by the same letter do not differ from each other by the least significant differences (LSD) Fisher's test at $P = 0.05$. The CV is the coefficient of variation

Table 2. Fruit quality of 'Roja Lisa' cactus pear in response to cladode pruning at harvest and after three-week storage at room temperature ($16\pm 3^{\circ}\text{C}$ and $42\pm 13\%$ relative humidity). Mean fruit mass (MFM), flesh firmness (FF), total soluble solids concentration (TSSC), pulp-to-peel ratio (P:P), dry matter concentration of fruit (DMCF) on a fresh weight (FW) basis, and fruit water loss (FWL)

Cladode pruning	MFM (g)	FF (N)	TSSC (%)	P:P	DMCF (mg/g FW)	FWL (%)
At harvest						
Growers	124.8a ^{*¶}	34.6a	12.2a	0.96a	153.8a	---
Experimental	119.2a	37.4a	11.8a	0.86a	144.0a	---
LSD _{0.05}	8.2	3.7	0.4	0.11	20.2	
CV (%)	11.5	10.3	6.8	13.6	13.5	
After storage						
Grower	124.1a	25.6b	11.3a	1.4a	155.2a	4.0a
Experimental	114.0a	28.1a	10.7a	1.4a	153.0a	3.9a
LSD _{0.05}	11.1	2.4	0.6	0.2	13.0	0.5
CV (%)	7.9	10.0	5.8	22.5	8.4	18.0

Within columns means followed by the same letter do not differ from each other by the least significant differences (LSD) Fisher's test at $P = 0.05$. The CV is the coefficient of variation

Perhaps the harvest criterion used in this experiment (color break from green to red) did not allow observation of other changes in fruit quality attributes. In cactus pear fruit, unlike other fruits [12,13], 8% fruit water loss (FWL) is sufficient to develop a shriveled appearance [14], which did not occur here because FWL in both pruning treatment fruits was $\approx 4\%$ after three-week storage at room temperature (Table 2). This suggests that pruning treatments did not promote changes to the epidermis as irrigation did in various cactus pear cultivars [15,16].

4. CONCLUSION

The following conclusions can be drawn from this preliminary study. 1) Experimental pruning increased fruit size and the percentage of fruit in Grades 1 and 2, but reduced both overall and commercial fruit yields; 2) Fruit quality at harvest or after three-week storage at room temperature was unaffected by pruning treatments, except for

flesh firmness, which remained greater in experimental pruning fruit, and 3) After three-week storage at room temperature, fruit water loss was not influenced by pruning treatments. Therefore, this topic deserves further study to learn and understand the unique responses of this plant species to cladode pruning.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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