Journal of Horticultural Science & Biotechnology (2009) **84** (6) 595–598

Flower bud thinning in 'Rojo Liso' cactus pear

By J. A. ZEGBE* and J. MENA-COVARRUBIAS
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Zacatecas, Apartado Postal No. 18, Calera de Víctor Rosales, Zacatecas, Código Postal 98500, México
(e-mail: jzegbe@zacatecas.inifap.gob.mx) *(Accepted 11 August 2009)*

SUMMARY
The export of cactus pear fruit from Mexico has increased over the last decade, with growing consumer demand for larger and higher quality fruit. Growers are concerned that yields decrease when fruit thinning is used to increase fruit size. Our objective was to assess the effects of flower bud (FB) thinning on the pre-harvest and post-harvest attributes and yields of 'Rojo Liso' cactus pear (*Opuntia ficus-indica*) fruit. The experiments were conducted in 2005 and 2006. The treatments used were: 1) no thinning, considered as the control; 2) thinning every second bud (T1); or 3) thinning two out of every three buds (T2). Marketable fruit (having an equatorial diameter > 5 cm) in the thinned treatments increased compared to the unthinned controls in both seasons. Thinning did not reduce fruit yield. Fruit quality was similar among treatments, both at harvest and after storage, except for the soluble solids concentrations which were higher in both the T1 and T2 treatments in 2005. Fruit weight loss in storage was similar among treatments. Flower bud thinning can therefore be recommended for commercial use.

Cactus pear (*Opuntia* spp.) is a Mexican fruit crop that is cultivated extensively (*ca*. 51,000 ha) in the semi-arid highlands of Central and North-Central Mexico. It has gained in economic importance in Europe, America, Asia, and Africa (Basile, 2001). In Mexico, cactus pear production has a high social impact, but low competitiveness, compared to other commodities such as dry pepper, alfalfa, and peach (Rincón-Valdez *et al*., 2004). However, the high export volume during the last decade has made it a commercially viable crop. Therefore, fruit size, fruit quality, and shelf-life are becoming increasingly important for distant consumer markets.

As for other fruit crops such as peach (Crisosto *et al*., 1994) and apple (Mpelasoka *et al*., 2000), the final size and shelf-life of cactus pear fruit depend on orchard management practices during the growing season (Zegbe *et al*., 2006). Post-harvest handling (Ochoa *et al*., 2002) and cultivar choice (Fernández-Montes *et al*., 2000) also play important roles, especially for the shelf-life of the fruit. Irrigation (Zegbe *et al*., 2006), nutrition (Weiss *et al*., 1993; Ochoa *et al*., 2002), and flower bud (FB) thinning (Inglese *et al*., 1995) are crucial to enhance fruit size. Flower bud thinning (i.e., keeping six buds per mature cladode) is a common practice to increase fruit size and to advance ripening (Inglese *et al*., 1995). However, this thinning approach significantly reduces fruit yield (Inglese *et al*., 1995). Mexican growers therefore refuse to thin buds to this level. In a preliminary report, Zegbe and Mena-Covarrubias (2007) explored an alternative FB thinning protocol that involved thinning every second bud along the cladode in one treatment, and two out of every three buds in another treatment. This was done in only one season using a limited number of plants. Fruit yield was maintained, and fruit size increased in the two cultivars tested. Here, we report the results of a more comprehensive study with the objectives of assessing the effects of FB thinning on pre- and post-harvest fruit attributes and on the yield of 'Rojo Liso' cactus pear. Because inter-fruit competition for available carbohydrates will be reduced by this new thinning protocol, we expected no adverse effects on yield and/or expected the fruit size to increase. We used 'Rojo Liso' cactus pear because of its export market potential.

MATERIALS AND METHODS

Experimental site and plant material

This study was conducted during the 2005 and 2006 growing seasons in a commercial orchard ('Rancho La Tunera') located in Santa Fe, Jerez, Zacatecas, Mexico (22° 32'N; 103° 03'W; 1,976 m asl). The experimental site has an annual mean temperature of 25.7ºC and 482 mm of rainfall, with 62% occurring between July and October. The soil is a clay loam with a pH of 7.1 and 1.63% (w/w) organic matter. Five-year-old 'Rojo Liso' cactus pear (*Opuntia ficus-indica*) plants were used. 'Rojo Liso' is an early-maturing cultivar with a red pulp. Plant spacing was at 5 m × 3 m, with an open-vase training system. Except for FB thinning, all plants received the standard cultural practices used for local commercial production, including pruning, fertigation, and pest control.

Treatments

The treatments used were: 1) no thinning (considered to be the control; C); 2) thinning every second FB along the cladode (T1); or 3) thinning two out of every three FBs along the cladode (T2; Figure 1). Sometimes, FBs appear in pairs along the cladodes. In this case, we kept the stronger FB, while the weaker FB was removed. This

*Author for correspondence.

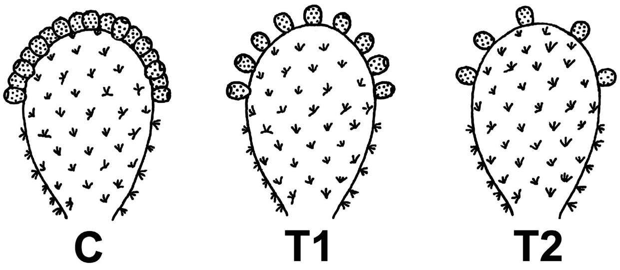

FIG. 1
Treatments applied to cactus pear: no thinning, control (C); thinning every second bud along the cladode (T1); or thinning two out of every three buds along the cladode (T2).

was done in both the TI and T2 treatments, but not in the controls. The thinning treatments were applied manually. A completely randomised design was used, with four replications per treatment. There were four plants per replication, with one guard plant at each end of each replication.

Yield and size distribution of fruit

The two central plants in each plot were used for data collection. Harvests started on 5 July 2005 and on 15 June 2006, 58 and 62 d after full bloom (DAFB), respectively. Export harvest maturity (i.e., when the fruit peel became reddish-green) was used as the criterion for the start of harvest. There were seven harvests in 2005 and six in 2006. Fruits from each plant were harvested, graded into four Categories by equatorial diameter (i.e., 3.5 – 4.0, 4.1 – 5.0, 5.1 – 5.9, and 6.0 – 7.0 cm), counted, and the total weight of all fruit per plant recorded as gross yield. The mean fruit weight was calculated by dividing the gross yield by the number of fruit per plant. Blemished fruit were excluded from both the weights and the counts.

Fruit quality attributes at harvest and after storage

To assess fruit quality, 72 fruit (24 per treatment) were picked at random from around the outer part of the plants. This was done on 27 July 2005 (80 DAFB) and on 30 June 2006 (71 DAFB). A further 72 fruit (24 per treatment) were also collected, as above, for fruit quality assessments after 4 weeks of storage. These assessments were done on 26 August 2005 (110 DAFB) and on 28 July 2006 (98 DAFB).

The fruit quality parameters evaluated at harvest, and after storage, were: flesh firmness, total soluble solids concentration (SSC), peel and pulp weights, pulp-to-peel ratio, and the dry matter (DM) content of the fruit, using the following protocols. After removing the fruit skin, two flesh firmness determinations were done on opposite sides of the equator of each fruit using a press-mounted Wagner penetrometer (Model FT 327; Wagner Instruments, Greenwich, CT, USA) with an 11.1-mm head. The SSC of the juice from each fruit was measured using a digital refractometer with automatic temperature compensation (Model PR-32α; Atago Co. Ltd., Tokyo, Japan). The peel and pulp were separated and weighed to assess the pulp:peel ratio. The DM content of the fruit was determined using 25 g of a composite sample of fresh cortical tissue taken from three fruit, then oven-dried at 65°C for 2 weeks. Fruit weight loss was evaluated at harvest, and at 1-week intervals for 4 weeks, by weighing fruit individually with a precision scale (Mettler PE11; Mettler Instruments, Greifensee-Zurich, Switzerland). Fruit weight loss was calculated as the percentage reduction from the original weight. Storage was at a temperature of 20° ± 2°C and a relative humidity of 40 ± 4% in 2005. The corresponding values for 2006 were 15° ± 2°C and 45 ± 4%. These were similar to the storage conditions used by commercial growers.

Data analysis

Data were analysed as a completely randomised model using the ANOVA procedure in the SAS software package (Version 9.1; SAS Institute, Cary, NC, USA). To stabilise the variance, those variables expressed in percentages, or in discrete units, were arcsine- or square-root-transformed, respectively. Means are reported after back transforming. Treatment means were separated by Tukey's HSD ($P = 0.05$).

RESULTS AND DISCUSSION

Pre-harvest effects

Yield and fruit size distribution: Flower and fruit thinning regulate the final fruit size and yield in cactus pear (Inglese *et al*., 1995). The optimum number of six fruit per cladode, as suggested by Inglese *et al*. (1995), increased fruit size, but reduced yields by *ca*. 50% (Zegbe and Mena-Covarrubias, 2007). We measured much lower, non-significant, and more acceptable reductions in yield by FB thinning. Compared to treatment C, treatments T1 and T2 tended to reduce yields by 10.2% and 19.2%, respectively, in 2005 (Table I). However, fruit size, in terms of mean fruit

TABLE I
Effects of flower bud thinning on fruit yield, mean fruit weight, fruit size distribution, and the incidence of blemished fruit in 'Rojo Liso' cactus pear

Year/Thinning treatment[‡]	Fruit yield (kg/plant)	Mean fruit weight (g)	Fruit size distribution (% in each diameter Category) 1 (7.0 – 6.0 cm)	2 (5.9 – 5.0 cm)	3 (4.9 – 4.1cm)	4 (4.0 – 3.5 cm)	Blemished fruit (kg/plant)
2005							
C	33.3a[†]	96a	1.1b	51.9b	45.7a	1.3a	0.1a
T1	29.9a	98a	2.4ab	68.4a	28.5b	0.7a	0.1a
T2	26.9a	103a	3.7a	66.3ab	29.4b	0.6a	0.0a
2006							
C	42.3a	100b	6.2a	59.1a	33.1a	1.6a	0.4a
T1	35.9a	107ab	9.5a	61.7a	27.9a	0.9a	0.2ab
T2	41.7a	111a	11.4a	64.3a	23.7a	0.7a	0.1b

[†]Mean separations within a column and a year was by Tukey's HSD ($P = 0.05$). Mean values followed by the same lower-case letters were not significantly different.
[‡]The treatments used were: no thinning, control (C); thinning every second bud along the cladode (T1); or thinning two out of every three buds along the cladode (T2).

TABLE II
Effects of flower bud thinning on flesh firmness, peel and pulp fresh weights (FW), pulp:peel ratio, and total soluble solids and dry matter contents of 'Rojo Liso' cactus pear fruit at harvest

Year/Thinning treatment‡	Flesh firmness (N)	Peel FW (g)	Pulp FW (g)	Pulp:peel ratio	Soluble solids content (%)	Dry matter content (mg g^{-1} FW)
2005						
C	28.7a†	50.8a	66.9a	1.35a	13.6b	193.1a
T1	30.1a	53.2a	70.1a	1.34a	14.6a	201.4a
T2	37.2a	54.2a	64.2a	1.20a	14.8a	201.1a
2006						
C	34.6a	63.4a	60.3a	0.96a	12.2a	150.3a
T1	34.9a	62.9a	60.1a	0.96a	12.3a	156.0a
T2	33.7a	63.9a	60.1a	0.96a	12.1a	165.4a

†Mean separations within a column and a year was by Tukey's HSD (P = 0.05). Mean values followed by the same lower-case letter were not significantly different.
‡The treatments used were: no thinning, control (C); thinning every second bud along the cladode (T1); or thinning two out of every three buds along the cladode (T2).

weight, tended to increase with thinning in 2005, and was significant in treatment T2 in 2006 (Table I). The first two fruit-size Categories (the most marketable fruit) were increased by FB thinning, while the poorest marketable fruit (Categories 3 and 4) were reduced compared to treatment C (Table I). Of the total fruit produced, ≥ 70% from the T1 and T2 treatments was marketable in both years, compared to 53% and 65% for treatment C in 2005 and 2006, respectively. This result suggests better partitioning of photo-assimilates into fruit in both FB-thinned treatments. The incidence of blemished fruit was not affected by the FB-thinning treatment in 2005, but was significantly reduced for the FB-thinned treatments in 2006 (Table I). The effects of FB-thinning on the measured parameters presented in Table I were similar between seasons. One exception was yield, which decreased by 11.3% in T2 compared to treatment C, in 2006 (Table I). When severe pre-bloom FB-thinning was applied, the cactus pear plants reacted by inducing a second flower bud reflux (re-flowering), as previously pointed out by Inglese (1995). This was reflected in the numbers of fruit harvested in T2. Mean fruit numbers per plant were 426, 357, and 378 for treatment C, T1, and T2, respectively.

Fruit quality at harvest: Flower bud-thinning in cactus pear is not known to enhance fruit quality (Inglese *et al*., 1995; Gugliuzza *et al*., 2002). Previous observations were confirmed in our experiments, in both years (Table II). The external appearance of the fruit was the criterion used for harvest. Judging by the SSC values presented in Table II, fruit might have been harvested at a more advanced stage of development in 2005 than in 2006. Yet, for each year, there were no significant differences in any parameter measured among the various treatments (Table II). In both years, there was a non-significant trend for fruit DM contents to be higher in T1 and T2 than in C, indicating a more favourable partitioning of photo-assimilates into the fruit in the FB-thinned treatments.

Post-harvest effects

Fruit quality after storage: The final size and shelf-life of cactus pear fruit depend on orchard management practices during the growing season (Zegbe *et al*., 2006), as well as on post-harvest handling (Cantwell, 1995). The quality of fruit at harvest, for the different treatments, was maintained after 4 weeks of storage in both years (Table III). This was consistent with previous results from our laboratory for out-of-season production of cactus pear (Zegbe and Mena-Covarrubias, 2008). The non-significant trend for higher DM contents in T1 and T2 than in C, observed at harvest (Table II), was maintained after storage, in both years (Table III).

Fruit water loss: Water loss from fruit after harvest is a major cause of fruit deterioration during storage (Wills *et al*., 1998). After harvest, cactus pear fruit continue to transpire (Corrales-García and Hernández-Silva, 2005) resulting in shrivelling and a loss of marketability. Weight loss in fruit from treatments T1 and T2 tended to be lower (or the same) compared to C in both years (data not shown). This implies that treatments T1 and T2 induced either minimal or no alterations in the fruit peel. The removal of glochids (spines) from cactus pear fruit increases weight loss during storage (Cantwell, 1995). We did not remove glochids, and this might have contributed to the similar and low levels of weight loss among the

TABLE III
Effects of flower bud thinning on flesh firmness, peel and pulp fresh weights (FW), pulp:peel ratio, and total soluble solids and dry matter contents of 'Rojo Liso' cactus pear fruit after 4 weeks of storage

Year/Thinning treatment‡	Flesh firmness (N)	Peel FW (g)	Pulp FW (g)	Pulp:peel ratio	Soluble solids content (%)	Dry matter content (mg g^{-1} FW)
2005						
C	25.2a†	37.1a	77.8a	2.15a	13.1a	149.3a
T1	26.7a	38.3a	79.7a	2.10a	13.0a	178.9a
T2	24.8a	39.4a	74.9a	1.91a	13.3a	179.2a
2006						
C	25.6a	51.9a	69.2a	1.4a	11.3a	155.2a
T1	26.5a	50.8a	68.1a	1.4a	11.1a	157.9a
T2	26.3a	52.2a	71.4a	1.4a	11.0a	156.2a

†Mean separations within a column and a year was by Tukey's HSD (P = 0.05). Mean values followed by the same lower-case letter were not significantly different.
‡The treatments used were: no thinning, control (C); thinning every second bud along the cladode (T1); or thinning two out of every three buds along the cladode (T2).

treatments. A weight loss of *ca*. 8% has been established as the threshold for causing shrivelling in cactus pear fruit (Cantwell, 1995). This value was reached before week-4 of storage (at 20º ± 2ºC and a relative humidity of 40 ± 4%) in treatment C and T1 in 2005. But fruit weight loss was ≤ 5% for fruit stored for 4 weeks at 15ºC in 2006. The differences in weight loss patterns between the two growing seasons may be related to the different storage conditions (temperature and relative humidity) used (Schirra *et al*., 1999; Wills *et al*., 1998).

In conclusion, FB-thinning, as applied in our experiments, did not significantly reduce fruit yield, but enhanced fruit size and the percentage of marketable cactus pear fruit. Fruit quality, in terms of the pulp-to-peel ratio, flesh firmness, total SSC, and DM content, was the same among treatments at harvest and after 4 weeks of storage. Fruit water loss tended to be lower in T2 in 2005. But, in 2006, fruit water loss was the same among all treatments and remained ≤ 5% during the 4-week storage period. We recommend either of these flower bud thinning treatments (T1 or T2) to commercial growers of cactus pear who are interested in export markets.

We thank Miguel and Valentín Nava Félix, the owners of the orchard 'Rancho La Tunera' where this study was conducted. We also thank Mr. Manuel González-Solís. We are grateful to Drs. M. Hossein Behboudian (Massey University, Palmerston North, New Zealand), Peter Felker (D'Arrigo Bros. Co., Salinas, CA, USA), and Mario D. Amador-Ramírez (INIFAP, Zacatecas, México) for their critical comments on the manuscript. This research was funded, in part, by The Fundación Produce Zacatecas A.C. (No. Ref.: 02/FPZ/2001) and by The CONACYT (No. Ref.: 0007-2005-1_12448).

REFERENCES

BASILE, F. (2001). Economic aspects of Italian cactus pear production and market. *Journal of the Professional Association for Cactus Development*, **4,** 31–46.

CANTWELL, M. (1995). Post-harvest management of fruits and vegetable stems. In: *Agro-Ecology, Cultivation, and Uses of Cactus Pear*. (Barbera, G., Inglese, P. and Pimienta-Barrios, E., Eds.). Plant Production and Protection Paper of the Food and Agriculture Organization of the United Nations, Rome, Italy. No. **132.** 120–136.

CORRALES-GARCÍA, J. and HERNÁNDEZ-SILVA, J. L. (2005). Cambios en la calidad postcosecha de variedades de tuna con y sin semillas. *Revista Fitotecnia Mexicana*, **28,** 9–16.

CRISOSTO, C. H., JOHNSON, R. S., LUZA, J. G. and CRISOSTO, G. M. (1994). Irrigation regimes affect fruit soluble solids concentration and rate of water loss of 'O'Henry' peaches. *HortScience*, **29,** 1169–1171.

FERNÁNDEZ-MONTES, M. F., MONDRAGÓN-JACOBO, C., LUNA-VÁZQUEZ, J., GUTIÉRREZ-ACOSTA, F., SÁENZ-QUINTERO, L. A., ZEGBE-DOMÍNGUEZ, J. A., MÉNDEZ-GALLEGOS, S. J. and MARTÍNEZ-GONZÁLEZ, J. C. (2000). *Principales cultivares mexicanos de nopal tunero*. SAGAR-INIFAP-Campo Experimental Norte de Guanajuato. Publicación Técnica, San Luis de la Paz, Guanajuato, Mexico. **No. 1.** 34 pp.

GUGLIUZZA, G., INGLESE, P. and FARINA, V. (2002). Relationship between fruit thinning and irrigation on determining fruit quality of cactus pear (*Opuntia ficus-indica*) fruits. *Acta Horticulturae*, **581,** 201–204.

INGLESE, P. (1995). Orchard planting and management. In: *Agro-Ecology, Cultivation, and Uses of Cactus Pear*. (Barbera, G., Inglese, P. and Pimienta-Barrios, E., Eds.). Plant Production and Protection Paper of the Food and Agriculture Organization of the United Nations, Rome, Italy. No. **132.** 78–91.

INGLESE, P., BARBERA, G., LA MANTIA, T. and PORTOLANO, S. (1995). Crop production, growth, and ultimate size of cactus pear fruit following fruit thinning. *HortScience*, **30,** 227–230.

MPELASOKA, B. S., BEHBOUDIAN, M. H., DIXON, J., NEAL, S. M. and CASPARI, H. W. (2000). Improvement of fruit quality and storage potential of 'Braeburn' apple through deficit irrigation. *Journal of Horticultural Science & Biotechnology*, **75,** 615–621.

OCHOA, M. J., LEGUIZAMÓN, G. and UHART, S. A. (2002). Effect of nitrogen availability on cactus pear (*Opuntia ficus-indica* L. Mill) postharvest quality. *Acta Horticulturae*, **581,** 225–230.

RINCÓN-VALDEZ, F., ECHAVARRÍA-CHÁIREZ, F. G., RUMAYOR-RODRÍGUEZ, A. F., MENA-COVARRUBIAS, J., BRAVO-LOZANO, A. G., ACOSTA-DÍAZ, E., GALLO-DÁVILA, J. L. and SALINAS-GONZÁLEZ, H. (2004). Cadenas de sistemas agroalimentarios de chile seco, Durazno y frijol en el estado de Zacatecas: una aplicación de la metodología ISNAR. *INIFAP-CIRNOC-Campo Experimental Zacatecas. Publicación Especial*. **No. 14,** 157 pp.

SCHIRRA, M., D'HALLEWIN, G., INGLESE, P. and LA MANTIA, T. (1999). Epicuticular changes and storage potential of cactus pear [*Opuntia ficus-indica* Miller (L.)] fruit following gibberellic acid preharvest sprays and postharvest heat treatment. *Postharvest Biology and Technology*, **17,** 79–88.

WEISS, J., NERD, A. and MIZRAHI, Y. (1993). Vegetative parthenocarpy in the cactus pear *Opuntia-ficus-india* (L.) Mill. *Annals of Botany*, **72,** 521–526.

WILLS, R., MCGLASSON, B., GRAHAM, D. and JOYCE, D. (1998). *Postharvest. An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals*. 4th Edition. Hyde Park Press, Adelaide, South Australia. 262 pp.

ZEGBE, J. A. and MENA-COVARRUBIAS, J. (2007). Técnica de raleo en frutos de nopal tunero (*Opuntia* spp.) cv. Cristalina. In: *XII Congreso Nacional de la Sociedad Mexicana de Ciencias Hortícolas A.C.* (Amador-Ramírez, M.D., Zegbe-Domínguez, J.A., Reveles-Torres, L.R., Mena-Covarrubias, J. and Serna-Pérez, A., Eds.). Zacatecas, México. 27. (Abstract).

ZEGBE, J. A. and MENA-COVARRUBIAS, J. (2008). Retraso de la cosecha en nopal tunero cv. 'Cristalina'. *Revista Chapingo Serie Horticultura*, **14,** 85–90.

ZEGBE, J. A., SERNA, A., MENA, J., BRAVO, A. G. and ECHAVARRÍA, F. G. (2006). Cactus pear (*Opuntia* spp.) responses to reduced irrigation. In: *International Symposium on Water and Land Management for Sustainable Irrigated Agriculture*. (Yazar, A., Gencel, B. and Tekin, S., Eds.). Adana, Turkey. 1–10.