Environmental Influences on Cactus Pear Fruit Yield, Quality and Cold Hardiness and Development of Hybrids with Improved Cold Hardiness

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INTRODUCTION

Development of freeze-hardy clones of cactus pears is the principal limitation to establishing commercial cactus-pear plantations in Texas, Arizona, and New Mexico (Uphof, 1916; Griffiths, 1915; Nobel,1990; Russell and Felker 1987; Gregory et al., 1993). While most winters in south Texas are sufficiently mild that little or no damage to cactus pears occurs, about every 10 to 15 years, severe cold fronts originating in Canada reach the southern portions of the United States. These severe weather patterns offer little opportunity for plants to become hardened off because these fronts may bring the first below freezing temperatures of the winter, as well as below- freezing temperature for 24 to 48 consecutive hours, with minimum temperatures of S12°C (Gregory et al., 1993).

For example, on December 21, 1989, mid-afternoon temperatures were 25°C. At 1:00 a.m. on December 22, the temperature went below 0°C and were about S7°C all day on December 22. A minimum temperature of S12°C was reached before sunrise on December 23 and temperatures remained below freezing all of December 23. On the morning of December 24, a minimum temperature of S12°C was reached again, but by mid-afternoon on December 24 temperatures had risen above 0°C. This freeze caused 100% mortality to more than 40 cactus pear clones that were 5 years old and more than 3 m tall, including the supposedly cold hardy Opuntia robusta types from South Africa. As discussed later, this freeze may not have been directly responsible for 100% mortality of these cactus clones as secondary infections appeared to have become established on main trunk portions and to have contributed to the mortality.

While all of the common cactus-pear fruit clones were killed to ground level, the native *Opuntia lindheimerii* and the spineless *Opuntia ellisiana* suffered no damage. In fact, *O. ellisiana* experienced no damage from this freeze about 500 km north of Kingsville where temperatures of S20°C were reached. A putative spineless hybrid between *O. lindheimerii* and some unknown parent we have designated as clone 1233 that has undulating cladode margins and small fruits, experienced only slight damage from this freeze.

Since our cactus pear improvement program was established in January 1984, the field has experienced three similar minor freezes in 1984/1985, 1990/1991, 1996/1997 in addition to the severe freeze of 1989. As the age and the damage of the plants was very different in the three similar freezes, we report a comparison of the damage and freezing temperatures.

Since this freeze, we have collected specimens at high-elevation sites in northern Mexico, seeking fruit-producing clones (accessions 1392 to 1412, 1442 to 1460) that should possess greater tolerance to freezing weather. We have also obtained clones (accessions 1376 to 1391) from Ing. Fernando Borrego Escalente from Universidad Autonoma Agraria Antonio Narro (Barrientos-Perez et al., 1992) and we have obtained 29 (accessions 1413 to 1441) clones obtained by Dr. Lorenzo Martinez Medina that were the only seedlings out of 300,000 seedlings that survived a freeze of S16°C in Saltillo (Medina, 1969).

In addition to the collection of cold hardy materials from northern Mexico, we have initiated a hybridization program with the objective of combining the cold hardy genes of the native *Opuntia lindheimerii* with the excellent fruit characteristics of the common Mexican cactus-pear varieties (Wang et al., 1996).

Taking advantage of a drought year (92 mm rainfall during the cactus-pear growing season) in 1996, followed by an above normal rainfall year (377 mm rainfall) during the 1997 cactus growing season, we report profound differences in fruit yield and fruit quality for these years.

Last, we will review our progress in obtaining progeny that may have improved cold hardiness and fruit quality.

MATERIALS AND METHODS

In 1998, the Texas A&M University-Kingsville (TAMUK) Opuntia collection contained more than 125 accessions from Mexico, Chile, Brazil, South Africa, and Algeria. Thirty one accessions for which we have frost data back to 1984 are described in this paper (Table 1). Vegetative materials were planted without irrigation at the TAMUK field station.

The annual rainfalls were obtained from data at the King Ranch less than 3 km from the field plots. The 1996 rainfall from January through the end of the fruit-production season (July 31) was 92 mm, while the rainfall for the same period in 1997 was 377 mm. Thus, 1996 was a drought year while 1997 was a high-rainfall year. Additionally, on March 30, 1997 a severe hail storm damaged the cladodes. As this hail storm was about three weeks before flowers normally occur and, as the Italian practice of removing all the flowers to stimulate late flowering does not eliminate fruit production throughout the year, we believe this storm was not the cause of the low fruit production in 1997.

The hours of freezing weather was measured by a recording thermograph on site in 1984/1985 and 1989, and by the Department of Environmental Engineering at Texas A&M University-Kingsville in 1996/1997. The other data on duration and minimum temperature was obtained from the Southern Regional Climate Center at Louisiana State University. It is difficult to precisely compare the intensities of these freezes as slightly different measurement techniques were used. It is also important to note that the number of hours below freezing in 1984/1985, 1990/1991, and 1996/1997 is cumulative for many freezes during those winters. In contrast, the 1989 data is for a single intensive freeze that did not permit the plant tissue to warm up before the next freeze.

Cladode survival was estimated about one month after the freezes by estimating the percentage of tissue necrosis on the cladodes. This percentage necrosis was ranked as 100%, 75%, 50%, 25% or 0 % damage where 100% was no visible damage to the cladode and 0% was 100% of the cladode surface area exhibited visual symptoms of frost damage. The experimental unit was the individual plant, thus there were 10 replicates. For the 1984/1985 and 1990/1991 data there was only one recently planted cladode to evaluate. In contrast, in 1996/1997 the plants were six years old and many plants were in excess of 2.5 m in height. The freeze damage in 1996/1997 was evaluated based only on the terminal cladodes. These terminal cladodes were analyzed separately for fully mature cladodes (resulting from growth of the previous spring) and for immature cladodes (resulting from late autumn growth). Frost damage scores of 1984/1985 were taken from Russell and Felker (1987), frost scores of 1989/1990 and 1990/1991 were taken from Gregory et al., (1993); while the frost scores of 1996/1997 are new measurements.

Many *Opuntia* in our collection exhibit black sooty lesions about 10-15 cm long and 5-8 cm wide. These lesions are more prevalent in cool wet rainy winter weather and are most prevalent on older growth. R. Barnes of the Texas Plant Disease Diagnostic Laboratory has identified the causal agent of these lesions as *Dioplodia* spp, a weak, opportunistic fungal pathogen that can normally be controlled by sanitation. We visually estimated the severity of these lesions on our collection in 5 ranks. A ranking of 1 indicated absence of lesions, 2 indicated a low incidence of the lesions on the lower trunk, 3 indicated a low incidence on the lower trunk and some damage on the upper branches, 4 indicated massive presence on the trunk and a some presence on the upper branches, and 5 indicated massive presence on both the trunk and the upper branches.

Fruits were harvested according to color for best fruit quality. Purple (1279, etc.) and red fruits (1281, etc.) were harvested when fruits reached ½ to 2/3 color. Orange fruits (1287, etc.) were harvested from the first color change to 1/3 color. Pale-yellow fruits (1383, etc.) were harvested at full color with extended perianth scar. The Chilean green fruit clone (1319) was harvested at the first color change and associated with the extended perianth scar. Fruit yield and contents were measured as previously described (Parish and Felker, 1997; Gregory et al., 1993).

Hybridization and seed germination were conducted according to Wang et al. (1996). Six to 10 flowers were hybridized for each cross.

RESULTS

While the number of hours of below-freezing weather and the absolute minimum temperatures were approximately similar in 1984/1985, 1990/1991, and 1996/1997 (Table 2), the frost damage was radically different (Table 3). This appears to be related to the age of the plant because the maximum age of the cladodes was 9 months in 1984/1985, 5 years in 1989, 1 year in 1990/1991 and 6 years in 1996/1997. A striking example of the difference in cold hardiness of the varieties for these years occurred with clone 1287 that had only 19% and 26% of its cladodes free of visual symptoms of damage in 1984/1985 and 1990/1991 when the cladode was planted for less than one year. However, when clone 1287 was 6 years old in 1996/1997, the mature outer cladodes of the plant exhibited no visual damage from the same approximate freezing conditions and the immature cladodes only had frost damage around the margins of the cladodes for a 90% frost survival. Less striking changes occurred with the other fruit clones 1277, 1281, and 1300 but it is clear that despite the same physical outward appearance of a cladode, frost damage to that cladode will be much more severe if the cladode has been planted for less than a year versus still being attached to a mature plant.

Although all the fruit clones died after the 1989/1990 freeze, this may be partially attributable to secondary rotting pathogens. About 1 month after the freeze, when the immediate extent of the necrosis was visible, the main stems were cut back to where green tissue was visible (often more than 1 m above ground level for 20-30 cm diameter stems). However, this green tissue was associated with rotten portions of the main stem. Despite this pruning, none of these fruit cacti survived. Perhaps if the cactus had been cut to the main stem portion the day after the freeze, secondary infections that also contributed to the mortality of the plants might not have become established.

We have observed great variability in this collection from rotten, black sooty discolored pads that have been initially identified as being caused by the weak fungal pathogen *Diplodia*. These symptoms are much worse during cool, wet winter rains than in the summer. In our covered greenhouse, these symptoms are much less evident. In the winter of 1996/1997 the cacti have been sprayed with a commercial copper sulfate solution (Kocide 101) about every 60 days that has resulted in many fewer symptoms. As can be seen in Table 3, clones 1273, 1387, and 1388 from Mexico had very low resistance to these pathogens with all of the plant being damaged. In contrast, clones 1281, 1380, and 1403 from Mexico had excellent resistance to this pathogen, with only minor presence of lesions on the trunk. The long-term solution must be to use resistant varieties.

Striking differences in fruit yield and sugar content occurred between the drought year of 1996 and the high-rainfall year of 1997 (Table 4). In most of the clones, fruit yield, fruit sugar content, and pulp/peel ratio were higher in 1996 than in 1997. In contrast, the fruit weight was lower in 1996 than in 1997, possibly due to the greater yield. For example clones 1320, 1380, 1279, and 1319 had yields of 55.2/26.9, 35.1/29.5, 35.3/13.9, and 19.8/2.0 in 1996/1997 respectively. The major exception to this was clone 1300 that had much greater yield in 1997 (37.8 t/ha) than in 1996 (9.9 t/ha). As an overall mean, production was 16.0 t/ha in 1996 versus 10.7 in 1997.

The mean sugar content of all varieties exhibited a pattern similar to the fruit yields with the mean sugar content being 14.0 in 1996 versus 11.8 in 1997. The Chilean clones 1319 and 1321 had the greatest sugar content in 1996 but not in 1997. Clone 1278 appeared to have high stable sugar contents over both years in having the fourth highest sugar content in 1996 and the greatest sugar content in 1997. Clone 1297 also had good sugar concentrations in both years. It is interesting that clone 1458, recently collected in the cold Chihuahuan Desert, had the second greatest sugar content in 1997. Two other clones from this recent germplasm collection in northern Mexico, 1403 and 1404, also produced large orange and purple fruits with moderate acceptable sugar concentrations and thus appear promising.

There was virtually no difference in fruit pH in 1996 (5.8 overall mean) versus 1997 (5.9 overall mean) (unpublished data).

The pulp/peel ratio was slightly but consistently greater in 1996 (1.01) than 1997 (0.89) (Table 5). In contrast, the fruit weight was considerably smaller in the drought year (109 g/fruit) than in the high-rainfall year (136 g/fruit). We attribute the lower fruit weight in the drought rainfall year to the greater yield of unthinned fruit, which, due to more unthinned fruit/pad, resulted in a lower fruit weight. Based on our own casual observations, clones 1287 and 1383 are more firm at later maturity stages than the other fruits, which we believe will lead to greater consumer preference for these fruits.

While the clones native (1255) or naturalized (1233) to Texas were cold hardy in Kingsville, they did not produce commercially acceptable fruit. For example, fruit of the native *O. lindheimerii* (1255) was about 40 g with a sugar content of 8%.

In 1996, after collecting and evaluating *Opuntia* species for more than 13 years, it was decided that the germplasm base adequately represented the gene pool of freeze-hardy genetic materials and that it was time for a hybridization program with the following objectives:

- Increase freeze hardiness of commercial fruit Mexican and Chilean fruit clones
- Decrease the seediness of cactus pears using low-seed-count Chilean varieties
- Increase the low yields of high-sugar-content, low-seed-count Chilean clones
- Increase the sugar content of high yielding, but low-sugar-content clones, such as 1320 and 1281.

With the objective of combining high yields with cold hardiness, the Mexican fruit accessions 1279, 1281, 1287, and 1383 were hybridized with Texas native *O. lindheimerii* (1255). To combine fruit yield and high-fruit-sugar content, the high-sugar-content parents, 1319 and 1321, were used. The list of crosses made, the fruit set, with the number of seeds germinated is shown in Table 6. Of particular interest are crosses between the Texas native *O. lindheimerii* (1255) that has great cold hardiness with a spineless highly productive orange/reddish fruit (1281) and a spineless large fruited purple fruit type (1279). This first report of viable seed between *O. lindheimerii* and *O. ficus-indica* and *O. hyptiacantha* types suggests a close genetic affinity among these parents. Extensive efforts to use the spineless cold hardy clones *O. ellisiana* 1464 and *O.* spp 1233 as either the male or the female in crosses with commercial fruit types were unsuccessful (Wang et al., 1996). Thus, it appears as if the only suitable parent for back crossing to increase cold hardiness will be the native *O. lindheimerii*.

The cross between two Chilean clones, one with high productivity and low sugar (1320) and the other with low productivity and high sugar (1321), should yield interesting progeny. A comparison of the two Chilean male parents with low productivity and high sugar (1321 and 1319) reveals that 1321 gave much higher seed set than 1319 for the same female parents (i.e., 1319 X 1277 yielded 0 mature seed while 1321 X 1277 yielded 200 mature seed). Thus 1321 should be used as the male parent in future crosses to decrease seed size while increasing sugar content.

The one exception to the effectiveness of Chilean clone 1321 as the male parent occurred in the cross with the large purple-fruited variety 1300. When 1321 was used as the male parent, no mature seeds were obtained, but when 1319 was used as the male parent, more than 200 seeds were obtained. Thus, despite very similar external appearances and similar fruit characteristics, these clones are genetically quite distinct.

Perhaps a difference in ploidy or chromosome number was responsible for these differences because Opuntia was found to be polyploid with the chromosome number of fruit varieties ranging from $2n = 6x = 66$ or $2n = 8x = 88$ (Pimienta-Barrios and Munoz-Urias, 1994). We are also aware that some of the seedlings are undoubtedly nucellar since polyembryony in *Opuntia* species was reported (Velez-Gutierrez and Rodriguez-Garay, 1996). We have made progress in characterization of *Opuntia* clones with RAPDs (Wang et al., in preparation) that will be helpful in identifying nucellar progeny.

The progeny listed in Table 6 were being grown in the greenhouse in the winter of 1997/1998 for a spring 1998 field progeny trial with 30 progeny per cross. The exception was 150 progeny of what we hypothesized to be the most genetically different parents, i.e., spiny Texas native *O. lindheimerii* (1255) with thornless, high-yielding clone 1281 that was designed to be a DNA mapping population.

DISCUSSION

The severe limitations on cactus-pear production imposed by freezing weather may not be as serious as previously surmised because 5-year-old mature plants suffered no damage to terminal cladodes from similar freezes (5 hours at £6.6°C, and S7.6°C minimum temperature) that caused more than 50% damage to recently planted (5-month-old) cladodes. While these *Opuntia* probably will not survive severe freezing weather for 3 days with S12°C minimum temperatures, these *Opuntia* are apparently considerably more freeze tolerant than citrus, which experiences considerable damage from S7°C freezes, even for mature plants. For the Texas Rio Grande Valley, where water rationing is becoming a more frequent occurrence and where freezing temperatures destroyed all the citrus trees in 1989, we suggest that fruit cactus should be considered a more cold hardy, less water requiring alternative fruit crop.

This work also found striking differences in fruit yield and sugar content between a drought year and an above-average rainfall year. The drought stress was associated with greater quantities of fruit, but smaller fruit that had greater sugar content.

Texas A&M University-Kingsville, being less than 50 km from the Gulf Coast where inland winds create high air humidities in summer and winter, possibly results in an extreme humidity limit for *Opuntia* that, in turn, is responsible for the extensive sooty lesions on some of the *Opuntias*. Fortunately, there appears to be genetic sources of resistance in clones such as 1281, 1294, 1320, etc. The most susceptible clones (1387 and 1388) were O. amyclea species from Saltillo, Mexico.

The ideal cactus pear variety should have high yield, high fruit sugar content, good cold hardiness and disease resistance and, perhaps most important, attractiveness to the consumer. In the U.S. domestic market, the greatest demand is for red- and purple-fruited varieties; therefore, clones 1300 and 1279 seem to be ideal in many respects. However, other clones with orange, yellow, and lime-green fruit with good combinations of fruit sugar and yield include 1278, 1287, 1319, 1383, and 1390. Recent collections from northern Mexico are beginning to show signs of good yield, color, and fruit quality in orange (1403), purple (1404), and yellow (1458)

fruit colors, but additional seasons of evaluation will be needed for these materials. Progenies from the many wide hybrids performed here should also yield interesting crosses both from the perspective of new cactus-pear varieties and an understanding of the genetic affinities and heritabilities of important characteristics.

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Table 1. Opuntia Species in Texas A&M University - Kingsville Collection

Accession	Species	Collected location	Spine	Fruit Color
1233	O. lindheimeri X O. spp	Hargil, Texas	-	Purple
1255	O. streptacantha	Texas	+	Purple
1273	O. ficus-indica	Mexico	+	
1277	O. lindhermeri	Milpa Alta Mex	-	Orange
1278	O. ficus-indica Mexico	Mexico	-	Orange
1279	O. ficus-indica	Chapingo, Mexico	+	Purple
1281	O. streptacantha	Chapingo, Mexico	-	Red
1282	O. ficus-indica	Chapingo, Mexico	-	Pale-yellow
1286	O. streptacantha	Mexquite, SLP, Mexico	+	Red
1287	O. streptacantha	Mexquite SLP	+	Orange
1294	O. ficus-indica	Milpa Alta Mex	-	Orange
1297	O. megacantha	Chapingo, Mexico	+	Pale-yellow
1300	O. ficus-indica	Chapingo, Mexico	-	Purple
1301	O. ficus-indica	Expt stat. SPL	-	Purple
1319	O. ficus-indica	Nipao, Chile	-	Green
1320	O. ficus-indica	Nipao, Chile	-	
1321	O. ficus-indica	Til Til, Chile	-	Pale-yellow
1376	O. ficus-indica	AN- V1, Saltillo Mex.	-	Pale-yellow
1379	O. crassa	AN- V4, Saltillo Mex.	-	Red
1380	O. megacantha	AN- V5, Saltillo Mex.	-	Orange
1383	O. megacantha	AN-T2, Saltillo Mex.	+	Pale-yellow
1387	O. amyclea	AN-TV2, Saltillo Mex.	+	Pale-yellow
1388	O. amyclea	AN-TV3, Saltillo Mex.	+	Pale-yellow
1390	O. megacantha	AN-TV5, Saltillo Mex.	-	Pale-yellow
1392	O. spp	AN-F1, Saltillo Mex.	-	Red
1393	O. spp	Saltillo Mex.	-	Pale-yellow
1398	O. spp	Los Llanos Mex.	+	Red
1403	O. spp	Escobedo, Mexico	+	Orange
1404	O. spp	Escobedo, Mexico	-	Purple
1458	O. spp	Constitucion, Mexico	-	Pale-yellow
1464	O. ellisiana	Sonora Exp. Sta. TX	-	

Table 2. Temperature and Plant Age in Freezing Winter

Winter	1984-1985	1989-1990*	1990-1991	1996-1997
Hours < 0°C	129	62	40	62
Hours ≤3.9°C	n/a	25	n/a	11
Hours ≤6.7°C	n/a	16	n/a	5
Minimum temperature (°C)	-9	-12	-7	-7.6
Plant age (years)	1	5	1	6
* a single freeze year. n/a = not available.				

Table 3: Frost survival (%) and disease score of Opuntia species in Kingsville

Accession	1984-1985	1989-1990	1990-1991	1996-1997		Disease Score
				Young Cladode	Mature Cladode	
1233	100	100	100	100	100	1±1
1255	100	100	100	100	100	1±1
1273	8	0	25±0	60±42	80±0	5±1
1277	0	0	80±14	80±14	100±0	3±1
1281	0	0	47±0	85±7	100±0	2±0
1283	50	0	59±2	70±28	100±0	3±1
1287	19	0	26±6	90±0	100±0	3±1
1294	1	0	64±16	85±7	100±0	2±0
1300	1	0	52±16	52.5±39	100±0	3±1
1301	60	0	56±19	85±7	100±0	3±0
1464	100	100	100	100	100	1
1278*				65±21	100±0	2±0
1279*				75±21	100±0	3±1
1282*				90±0	100±0	3±1
1286*				100±0	100±0	3±0
1297*				80±0	100±0	3±0
1319*				50±28	100±0	3±1
1320*				80±0	100±0	2±0
1321*				70±0	100±0	2±0
1376*				85±7	100±0	3±0
1379*				70±0	100±0	4±1
1380*				85±7	100±0	2±0
1383*				80±0	100±0	4±1
1387*				95±7	100±0	5±1
1388*				95±7	100±0	5±1
1390*				70±0	100±0	3±1
1392*				60±42	100±0	3±0
1393*				65±21	100±0	3±0
1398*				75±7	100±0	3±1
1403*				70	100	2
1404*				100	100	2
1458*				10	90	3
100% frost survival were without damage. A disease score of 5 was most severe.						

Table 4. Fruit Yield and Sugar Content in 1996 and 1997

Accession	**Yield (t/ha)**		**Sugar content (TSS)**	
	1996	1997	1996	1997
1277	20.2	19.7±3.5	11.6±2.0	12.6±1.5
1278	11.7	21.3	14.8	14.1
1279	35.3	13.9	13.2	12.6
1281	26.5	22.7	13.7	11.8
1282	5.8	4.7	14.4	11.7
1287	11.1	5.1	14.2	11.4
1294	17.5	4.3	13.0	11.4
1297	4.6	7.2	14.9	13.2
1300	9.9	37.8	14.1	11.6
1301	1.6	1.6	13.2	11.5
1319	19.8	2.0	16.8	12.2
1320	55.2	26.9	13.9	10.3
1321	3.2	0.2	16.2	12.7
1376	12.1	4.2	13.3	11.1
1379	12.3	1.4	13.8	10.6
1380	35.1	29.5	12.8	11.1
1383	12.4	1.8	14.4	12.9
1390	20.6	11.7	14.5	12.9
1392	11.7	2.0	13.7	10.9
1393	7.7	4.8	13.6	10.3
1398	2.2	0.8	14.2	11.6
1403*			12.2±0.9	11.96±0.8
1404*			13.1±3.4	11.9±0.5
1458*			12.7±1.1	13.3±0.6
Average	16.0	10.7	14.0	11.8
Values are the means (n=6) ±sd.				
*From a more recent planting just beginning to bear fruit.				

Table 5. Fruit Weight and Pulp/Peel in 1996 and 1997

Accession	**Fruit weight (g)**		**Pulp/peel**	
	1996	1997	1996	1997
1277	121.8±27.3	165.6±29.2	0.90±0.21	0.87±0.06
1278	120.2±22.7	132.8±35.9	1.91±0.23	1.71±0.40
1279	120.4±17.4	158.5±30.8	0.57±0.08	0.93±0.15
1281	104.6±18.3	154.6±30.7	1.02±0.20	0.74±0.21
1282	135.6±25.1	133.7±26.9	0.85±0.06	0.83±0.19
1287	137.9±14.9	152.9±38.7	0.79±0.07	0.70±0.13
1294	120.7±16.1	143.9±45.3	0.90±0.10	0.75±0.31
1297	99.6±13.2	138.7±11.0	1.30±0.21	1.27±0.10
1300	115.7±21.3	152.9±27.5	0.92±0.06	0.73±0.11
1301	88.6±19.8	110.6±9.7	0.77±0.26	0.90±0.17
1319	131.3±20.4	131.1±20.9	0.55±0.18	0.53±0.11
1320	108.7±15.5	162.0±17.5	1.07±0.33	0.95±0.17
1321	103.3±21.4	110.4±21.8	0.73±0.21	0.47±0.15
1376	76.3±10.6	129.3±23.1	1.03±0.32	0.89±0.10
1379	105.4±11.6	132.9±15.5	1.07±0.32	0.53±0.24
1380	126.3±22.0	138.1±15.6	0.99±0.07	0.95±0.21
1383	95.1±15.2	110.7±20.3	1.46±0.25	1.21±0.20
1390	101.6±9.9	121.7±16.9	1.50±0.34	1.36±0.15
1392	102.7±25.8	112.0±9.2	0.86±0.32	0.92±0.13
1393	72.3±7.6	118.0±9.7	0.81±0.19	0.76±0.12
1398	106.9±17.6	147.2±32.5	1.30±0.48	0.59±0.42
1403*	123.7±33.0	151.1±20.0	0.70±0.12	0.72±0.10
1404*	117.9±39.0	135.7±17.6	0.60±0.18	0.50±0.10
1458*	78.3±23.0	96.1±15.4	0.82±0.17	0.61±0.13
Average	109.3	136.1	1.01	0.89
Values are de means (n=6) ±sd. *From a more recent planting just beginning to bear fruit				

Table 6. Hybridization, Fruit Set, and Germination of Opuntia Species

Male/Female	Fruit Set (%)	Number of Mature Seeds	Number of Seeds Germinated
1255 X 1279 (purple)	67 %	6	66 %
1255 X 1281 (red)	83 %	About 200	40 %
1255 X 1287 (orange)	67 %	100	28 %
1255 x 1383 (pale-yellow)	90 %	About 100	24 %
1319 (green) X 1277 (orange)	83 %	0	/
1319 (green) X 1279 (purple)	95 %	20	50 %
1319 (green) X 1281 (red)	17 %	30	0 %
1319 (green) X 1287 (orange)	0 %	0	/
1319 (green) X 1300 (purple)	67 %	About 200	17 %
1319 (green) X 1320 (orange)	17 %	0	/
1319 (green) X 1380 (orange)	50 %	0	/
1319 (green) X 1383 (pale-yellow)	50 %	39	5 %
1319 (green) X 1390 (pale-yellow)	50 %	0	/
1321 (pale-yellow) X 1277 (orange)	83 %	About 200	60 %
1321 (pale-yellow) X 1279 (purple)	88 %	About 100	45 %
1321 (pale-yellow) X 1281 (red)	83 %	About 200	5 %
1321 (pale-yellow) X 1287 (orange)	100 %	About 200	35 %
1321 (pale-yellow) X 1300 (purple)	67 %	0	/
1321 (pale-yellow) X 1320 (orange)	83 %	About 200	20 %
1321 (pale-yellow) X 1380 (orange)	77 %	About 200	15 %
1321 (pale-yellow) X 1383 (pale-yellow)	100 %	About 100	23 %
1321 (pale-yellow) X 1390 (pale-yellow)	50 %	About 10	6 %
1279 (purple) X 1282 (purple)	100 %	10	10 %
1279 (purple) X 1287 (orange)	83 %	About 200	28 %
1281 (red) X 1282 (purple)	83 %	0	/
1287 (orange) X 1279 (purple)	17 %	0	/
1287 (orange) X 1282 (purple)	50 %	0	/
1383 (pale-yellow) X 1279 (purple)	88 %	About 200	12 %
1383 (pale-yellow) X 1282 (purple)	90 %	>200	32 %
1383 (pale-yellow) X 1300 (purple)	100 %	About 200	39 %