RELATIVE COLD HARDINESS OF FRUIT AND VEGETABLE OPUNTIA CLONES IN THE TEXAS A&I UNIVERSITY COLLECTION.

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In 1984, with National Science Foundation funding, a germplasm collection of Opuntias was established at Texas A&I University that have been used in other parts of the world for either fruit, vegetable, or forage production. Drs. Charles Russell and Henri LeHouerou were most helpful in collecting that material.

While undomesticated Opuntia species without edible fruit occur in northern Alberta Canada, nearly all of the fruit and vegetable varieties are nearly subtropical. Evidently Texas is the northern edge of the limit of the spineless and spiny fruit cultivars since the collection experienced major damage from freezes of - 9 C in 1984/1985(Russell and Felker, 1987), -12 C in 1989/1990 and - 7 C in 1990/1991.

Fortunately after the freeze of Christmas 1989, a spineless Opuntia clone that suffered no damage from the freeze was discovered by County Agent Buddy Johnson in La Pryor, Texas(near Crystal City). This clone has slightly smaller pads than the native O. lindheimerii but it does not have thorns. This could be useful material in breeding studies to enhance cold hardiness of fruit, vegetable, and fodder cactus varieties.

Since about 3 years are required to produce fruit from time of planting, the interspersion of freezes has made evaluation of fruit quality difficult. Nevertheless we have been able to obtain fruit quality measurements over a 3 year period for many of these clones. It is the intent of this communication to report fruit quality data for the clones which produced fruit and companion data on frost hardiness and spine characteristics. Together these measurements will allow for an overall suitability index for regions that experience similar patterns of freezing weather.

MATERIALS AND METHODS

Field plot design The initial planting occured in the summer of 1984. The field was laid out with 49 clones being assigned to random positions in each of 3 locations in the field(randomized complete block design with 3 blocks of 49 Opuntia clones). In each block, each accession was represented by a row of 5 plants with a 3.3 ft spacing of plants in-the-row. The between-row-spacing was 13 ft.

Since planting, the field was disked several times a year and the herbicide tebuthiuron used at 2 kg/ha. Roundup (glyphosate) was used to control johnsongrass (Sorghum halepense). Freezing weather (- 9 C) caused considerable mortality to many of these clones in 1984/1985 as previously reported. Where planting stock was available, the clones were replanted. In the spring of 1989 a 55 ft by 310 ft greenhouse heated by 2 portable kerosene salamanders was erected over all five rows of block 2. On December

25 and 26 1989 temperatures of -12 C occured that killed all clones described in Russell and Felker(1987) to ground level(The native O. lindheimeri suffered no permanent damage nor did a spineless Opuntia spp from New Mexico). Not even the most frost sensitive clones inside the greenhouse exhibited any apparent damage.

The clones in block 1 and 3 were replanted in the spring and summer of 1990. A frost of -7 C occured on December 1990 that caused considerable damage to the recently replanted clones outside the greenhouse. The clones were visually ranked for damage assessment. The damage assessment from the 1990 freeze is used in Table 2 that also compares agronomic and fruit characters.

The first fruit production occured in the summer of 1987 and by 1989 (5 years from planting) extensive fruit production occurred on many of the plants. The plants inside the unheated greenhouse have produced insignificant fruit compared to those outside the greenhouse.

Fruit scoring was recorded every seven to ten days beginning in April 1987, as cultivars initiated fruit for the first time. Field measurements were taken for length, thickness and fresh weight of fruits. Harvesting was initiated when a visible color change occurred in the skin layer indicating maturity. Some fruits were collected early due to problems with birds and insects. The fruit was placed in paper bags for 1 to 3 weeks and stored at room temperature in order to allow for full maturation. Mature fruit was then stored in a freezer until the time of lab analysis. Physical characteristics such as color, amount of glochids, disease problems, and pulp and peel ratios were scored and measured.

Matured fruits were measured for chemical composition (A.O.A.C., 1970). Fruits were analyzed for pH, titratable acidity, and percent sugars (soluble solids). The fruits were blended to form a puree that was filtered using ordinary coffee filters. The pH of the filtrate was determined using a calibrated pH electrode. Titratable acidity was determined by pipetting ten ml of filtrate into a beaker, diluting to 125 ml, and titrating with 0.10 N NaOH to pH 8.1. Sugars were measured by applying a filtrate smear on a Bausch & Lomb Abbe Refractometer with an automatic temperature compensator.

As the fruit in this collection were of many different colors, and as we did not know the color of the mature fruit, it was difficult to estimate maturity. As the fruit matures, the cavity formed by the flower scar fills in. In some clones the fruit is mature when this cavity no longer exists and a flat circular surface occurs between the flower scar at the end of the fruit. Since Opuntia is reported to be non-climacteric(Laksminarayana and Estrella, 1978), our 1987 procedure of allowing fruits to ripen in paper bags probably did not result in obtaining fruits with maximal fruit sugar.

RESULTS

The pH, total acidity and sugar content of the clones over a 3 year period is presented in Table 1. Generally clones with low pH values i.e. less than 5 also had the lowest sugar values i.e. less than 10. Suprisingly clone 1292 had one of the lowest and highest pH values. For example in 1988 when it had a pH of 4.3, the sugar content was only 8.4 %, while in 1989 when the pH was 6.0 the sugar content was 11.7 %. Presumably the 1989 fruits were harvested somewhat immature.

Some of the clones with low sugar content were in actuality forage type clones due to large thick pads. These forage type clones included O. robusta 1241, the Algerian clones 1253, 1258 and 1267. Two Brazilian clones 1270 and 1271 were intended for forage use in Brazil and are known as palma redonda and palma giganta respectively. These two clones produced large numbers of fairly-high sugar content fruit, all 3 years. In addition they are quite high biomass producers. Clone 1270 was also found to have an exceptionally high protein content of nearly 12 %(Gregory and Felker, 1991). Unfortunately as noted later, these 2 clones have poor resistance to freezing weather.

Most of the clones represented were of Mexican origin. Of the Mexican clones, 1280, 1287 and 1288 appear especially promising for consistent high fruit production and high sugar content.

The Chilean clones have produced very few fruit in Texas. However the fruits that were produced had high sugar contents. Clone 1118 and 1321 had particularly high sugar contents of 12% and 13.7 % respectively.

While the analytical data indicate that clones 1270, 1271, 1280, 1287 and 1288 all had similarly high sugar contents, it is Felker's opinion that clones 1287 and 1288 have a noticeably sweeter taste than the other clones. In addition the yellow fruited 1287 possesses a "fruity" flavor.

The fruit characters averaged over 3 years are compared to a productivity index, to presence or absence or thorns, and to their frost resistance in Table 2. Clones with low early production typically produced less than a dozen fruit in 1989, while fruits with high productivity produced hundreds of fruit that summer.

The fruit color is of importance since consumers of European descent in New York, Chicago and eastern United States have historically preferred red fruit, even if the sugar content were the same. Unfortunately, not all of the fruit colors were noted at the time the chemical analyses were made. The Chilean fruits typically are a lime green color and the Brazilian clones had yellow to yellow/orange fruits. The Mexican varieties exhibited a great deal of variation with some being red, orange, and lime green color.

TABLE 1 Mean pH percent acidity and sugars of fruit for Opuntia clones from 1987 through 1989.

Species	Origin	Acc. No.	1987 N	1987 pH	1987 Acidity	1987 Sugar	1988 pH	1988 Acidity	1988 Sugars*	1989 pH	1989 Acidity	1989 Sugars
O. ficus-indica	CH	1118					5.4	0.140	12.9	5.2	0.170	11.8
O. robusta	SA	1241								4.9	0.172	10.0
O. hyptiacantha	AG	1253	1	4.7	0.209	8.5				5.1	0.187	9.4
O. ficus-indica	AG	1258					5.7	0.060	8.5			
O. undulata	AG	1267	1	4.6	0.169	7.5	4.7	0.105	9.5			
O. stricta var stricta	BZ	1270	2	5.7	0.083	10.8	6.0	0.080	11.7	4.7	0.198	11.1
O. ficus-indica	BZ	1271	2	5.7	0.088	10.6	5.1	0.180	13.8	5.3	0.152	12.4
O. streptacantha	MX	1273					4.1	0.302	10.6			
O. streptacantha	MX	1274					5.6	0.040	10.4			
O. ficus-indica	MX	1277								4.6	0.244	9.4
O. ficus-indica	MX	1280	2	5.6	0.085	12.1	5.3	0.140	13.4	5.4	0.143	12.7
O. streptacantha	MX	1281	1	5.2	0.123	8.5	5.5	0.010	11.5			
O. streptacantha	MX	1283					5.3	0.080	11.3			
O. hyptiacantha	MX	1287	1	5.6	0.080	10.3	5.5	0.110	12.9	5.4	0.149	13.0
O. megacantha	MX	1288	3	5.6	0.058	12.6	5.2	0.106	12.6	4.6	0.230	11.3
O. megacantha	MX	1292	1	5.6	0.074	10.0	6.0	0.044	11.7	4.3	0.274	8.4
O. ficus-indica	MX	1294	2	5.5	0.075	12.5	5.5	0.083	8.2	4.9	0.190	8.3
O. ficus-indica	MX	1296					6.1	0.025	10.1	5.3	0.167	10.2
O. megacantha	MX	1299								5.0	0.181	9.9
O. ficus-indica	MX	1300					5.7	0.045	9.4	5.0	0.183	10.3
O. ficus-indica	MX	1301	2	5.2	0.083	9.9	5.1	0.095	11.6	5.4	0.156	10.9
O. ficus-indica	CH	1319					5.7	0.090	10.1			
O. ficus-indica	CH	1320	1	5.6	0.105	11.5						
O. ficus-indica	CH	1321					5.2	0.0150	13.7			

* % soluble solids
AG - Algeria, BZ - Brazil, CH - Chile, MX - Mexico.

TABLE 2. Fruit quality, presence of thorns and frost hardiness of Opuntia in Texas A&I germplasm collection.

Species	Origin	Acc. No.	No. Yr[1]	pH	Acidity	Sugar	Thorn	Fruit Color	Early[2] Product.	Frost[3] Resist.
O. ficus-indica	CH	1118	2	5.3	0.155	12.4	-	green	low	18 ± 25
O. robusta	SA	1241	1	4.9	0.172	10.0	-	purple	low	99 ± 1
O. hyptiacantha	AG	1253	2	4.9	0.198	9.0	+	purple	low	100 ± 0
O. ficus-indica	AG	1258	1	5.7	0.060	8.5	+	green	low	25
O. undulata	AG	1267	2	4.6	0.137	8.5	-	red	medium	0 ± 0
O. stricta var stricta	BZ	1270	3	5.5	0.120	11.2	-	yellow	heavy	38 ± 18
O. ficus-indica	BZ	1271	3	5.4	0.140	12.2	-	yel/red	heavy	44 ± 16
O. streptacantha	MX	1273	1	4.1	0.302	10.6	+		low	25
O. streptacantha	MX	1274	1	5.6	0.040	10.4	+		low	98 ± 4
O. ficus-indica	MX	1277	1	4.6	0.244	9.4	-		low	80 ± 13
O. ficus-indica	MX	1280	3	5.4	0.123	12.7	-	yellow	heavy	28 ± 32
O. streptacantha	MX	1281	2	5.4	0.067	10.0	-	red	low	47
O. streptacantha	MX	1283	1	5.3	0.080	11.3	+		low	59 ± 2
O. hyptiacantha	MX	1287	3	5.5	0.113	12.1	+	orange	medium	26 ± 6
O. megacantha	MX	1288	3	5.1	0.131	12.2	+	white	heavy	19 ± 13
O. megacantha	MX	1292	3	5.3	0.130	10.0	+	yellow	medium	25
O. ficus-indica	MX	1294	3	5.3	0.116	9.7	-	red/yel	heavy	64 ± 16
O. ficus-indica	MX	1296	2	5.7	0.096	10.1	-		low	36 ± 40
O. streptacantha	MX	1298	0				+			92 ± 12
O. megacantha	MX	1299	1	5.0	0.181	9.9	+		low	57 ± 6
O. ficus-indica	MX	1300	2	5.4	0.114	9.9	-	purple	low	52 ± 16
O. ficus-indica	MX	1301	3	5.2	0.111	10.8	-	red	medium	56 ± 19
O. ficus-indica	CH	1319	1	5.7	0.090	10.1	-	green	medium	28 ± 14
O. ficus-indica	CH	1320	1	5.6	0.105	11.5	-	orange	low	57 ± 23
O. ficus-indica	CH	1321	1	5.2	0.015	13.7	-		low	88 ± 11

AG - Algeria, BZ - Brazil, CH - Chile, MX - Mexico

[1]Mean for number of years for which fruit data is based.

[2]Fruit production based on 1987 data.

[3]Frost resistance based on survival of 4 month old single pads during a -7 C freeze of Christmas 1990.

Those fruits with the greatest early production included the Brazilian clones 1271 and 1270, the yellow Mexican fruit 1280, and the white Mexican fruited 1288. The especially sweet tasting orange fruited variety 1287 had moderately heavy production. Of these early producers, the Brazilian clones and the Mexican 1280 clones were thornless while the Mexican clones 1288 and 1287 were thorny.

We had measured the fruit length, width and fresh weight of these clones. However as we have observed great variation in size of the fruits from the same clone, and as the number of fruits measured per clone was limited, it would not be appropriate to report fruit sizes. Most of the fruit were in the 80 to 120 g/fruit range.

The resistance to the freezing weather of 1990 is also presented in Table 2. The spineless O. robusta clone 1241, and the spiny Algerian clone of robusta type 1253 had essentially no damage from the freeze. Other promising cold hardy clones included the spiny Mexican clones 1274 and 1298 and the spineless Chilean clone 1321. Unfortunately neither the spiny clones 1274 or 1298 have yet set fruit, so it is not possible to ascertain the fruit potential. While the Chilean spineless clone 1321 produced only a few fruit, they had the highest sugar content (13.7%).

Some of the fruit clones with the highest sugar content had low resistance to freezing weather. For example the spiny Mexican clones, 1288 and 1287 that produced high sugar content fruits 3 years in a row had only 19 % and 26 % freeze resistance. Surprisingly while large plants (3 m tall) of 1288 did not resprout from the base after the 1989 freeze, growth originating from single pads planted only 4 months prior to the freeze did resprout. Evidently the direction of the wind, presence of secondary infections etc have great influence on the survival of fruit cactus after the freeze.

Due the their promising fruit quality, cladodes of 1288 and 1287 were removed from the mother plant, after the first night of the disastrous Christmas 1989 freeze when temperatures reached -7 C. These cladodes were placed in a heated greenhouse to use for explants for tissue culture propagation and suprisingly the cladodes had no damage. However the next 2 nights temperatures reached -12 C and both mother plants froze to ground level. As temperatures seldom are much colder than -7 C in the Rio Grande Valley we believe these 2 clones should be evaluated in several acre test plots in the Rio Grande Valley.

With funding from the Driscoll Foundation these 2 clones have been multiplied by plant tissue culture techniques. Limited quantities of these clones are now available for testing for serious growers in the Rio Grande Valley.

We have provided almost no fertilizer to these plants and given the fact that the Mexican literature indicates 6,000 kg/ha of cow manure to be a low dose(Pimienta this volume), we may be able to stimulate fruit production with applications of manure. A heavy manure application is scheduled for the fall of 1991.

While we now have absolutely cold hardy types for cattle feed i.e. the La Pryor spineless types, we do not yet have cactus fruit varities with acceptable quality for areas of Kingsville and farther north.

Fortunately our colleagues at the University Autonoma Agrarra Antonio Narro in Saltillo, headed by Ing. Fernando Borrego have made considerable strides in development of cold hardy fruit varieties(Borrego-Escalante et al., 1990). In March 1991, with funding from Mr. John Armstrong we were able to conduct a germplasm exchange with Ing Borrego in which we provided all of our good fruit clones in exchange for their 15 cold hardy clones being used for fruit, vegetables and fodder.

In addition, in October 1991 a Texas Prickly Pear Council collection trip obtained 10 cold hardy fruits clones from about 1700 m elevation from the mountains behind Saltillo, Mexico where temperatures of -12C are fairly routine. These 10 clones contained spiny and spineless variants with yellow, red, purple, white and pink fruit. We hope that a cold-hardy clone with high sugar content fruits will be identified in this material that will be a useful clone in south Texas.

SUMMARY

(1) In spite of their low cold tolerance, due to high sugar content, large fruit size, early and large production, the white fruited clone 1288 and the orange fruited clone 1287 deserve pilot scale evaluation in Rio Grande Valley.

(2) Promising fruit clones that have produced little or no fruits but with good cold tolerance i.e. thorny clones 1274, 1275, 1298 and thornless clone 1321 will be monitored for fruit sugar and acidity.

(3) Recently obtained cold hardy fruit, vegetable and forage clones from Ing. Borrego at Saltillo will be examined for fruit quality.

(4) Absolutely cold hardy spineless cacti of the "La Pryor" type need to be hybridized with fruit clones.

(5) Funds need to be obtained to multiply promising clones by tissue culture.

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