NUEVOS HIBRIDOS DE OPUNTIA LINDHEIMERII X O. FICUS INDICA FORRAJEROS SIN ESPINAS RESISTENTE AL FRIO

NUEVOS HIBRIDOS DE *OPUNTIA LINDHEIMERII* X O. *FICUS INDICA* FORRAJEROS SIN ESPINAS RESISTENTE AL FRIO

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Abstract

Progeny (127) of an interspecific cross between a spineless, red-fruited commercial type *O. ficus indica* TAMUK 1281 as the female parent and a spiny *O. lindheimerii* as the male parent were evaluated as 3-5 m tall, 4 year old plants in a rain-fed progeny trial in Argentina for forage potential. While many of the seedlings were apomictic and thus identical to the female parent, at least 45 % of the seedlings were true crosses with 68% of those being spiny. Ten segregants had many of the characteristics of the cold-hardy, spiny male parent (small fruit and bluish cladodes) but no spines and were therefore selected for further evaluation of productivity, cold hardiness and forage quality in replicated trials in the Province of Mendoza, Argentina. Five progeny i.e. 42, 46, 80, 83 and 150 had much greater biomass productivity than the most cold hardy spineless clone to date. i.e. O. *ellisiana* and all of these progeny had less frost damage than O. *ficus-indica*. One clone (46) had zero damage that was equal to O. *ellisiana* and various clones had minimal damage i.e. 83 and 94. It is suggested that these progeny be evaluated for forage production in mountainous and/or northern states in Mexico that have too much freezing weather for *O. ficus indica.*

Key Words: Cold hardy, forage, cactus, interspecific hybrid,

Introduction

Both wild spiny cacti and planted spineless cacti have been an important forage resource in Mexico. Flores and Aranda (1997) reported that 18 *Opuntia* species were used as forage on the more than 3 million ha of rangeland in northern Mexico and that 150,000 ha of cactus were planted by ranchers and small producers with government support. Lopez et al., (1996) reported the use of 25 species and 12 varieties of *Opuntia* for forage in the Coahuila state of Mexico. Due to the extended drought from 1993 to 1996, Flores and Aranda (1997) reported that more than 650,000 cattle died. However ranchers with cactus did not suffer such great losses as those whose cactus ran out. Furthermore, reproduction rates and production levels were greater for animals that received cactus supplements.

While a substantial portion of the cacti used for forage are non cultivated, spiny types, there are some spineless forage plantations. If fencing can be provided, spineless forage types such as *O. robusta* and O. *ficus indica* provide advantages over the spiny types, both in ease of handling and in generally greater growth rates. Spineless *Opuntia*s have been extensively used for forage in Brazil, South Africa, and Tunisia (Mondragon-Jacobo, and Perez-Gonzalez, 2001). All of the latter regions are in USDA cold hardiness zone 9 and 10 where most of the fruit-producing O. *ficus-indica* types can grow; however, none of O. *ficus-indica* types are adapted to regions with more freezing weather. In Mexico there are substantial areas in northern Mexico (States of Nuevo Leon, Coahuila, Chihuahua, Durango and Sonora) that are too cold for routine production of *Opuntia ficus indica* and related species that could be used for forage. A recent report suggests that spineless *Opuntia* spp clone 1233 for is adapted to USDA cold hardiness zone 8 and O. *ellisiana* clone 1364 is adapted to USDA zone 7 (Felker et al., 2006). Clone 1233 has high productivity even in the first year being able to produce more than 100 cladodes. In Mendoza, Argentina, *O. ellisiana* suffered no frost damage when temperatures dropped to -15^{o} C during two brief occasions (2-3 hours) in the winter of 2000 (Guevara *et al*., 2003). While O. *ellisiana* has high productivity 3 years after establishment when it reaches a leaf area index of 2 (Han and Felker, 1997), it would be desirable to have a spineless *Opuntia* with the same cold hardiness of O. *ellisiana* (USDA cold hardy zone 7) but with much faster growth rate. We report here data on cold hardiness and productivity of progeny from the cross of O. *ficus indica* TAMUK accession 1281 (low cold hardy, spineless, fast growing, red fruit, greenish pads) with the Texas native O. *lindheimerii*. (spiny, cold hardy, red fruited, bluish pads).

Methods

Wang *et al*. (1996) reported emasculation and bagging techniques for *Opuntia* and examined the sterility barriers between commercial O. *ficus-indica* fruit types, *O. lindheimerii*, O. *ellisiana* and a few apparent hybrid species. O. *ficus-indica* was found to produce fertile offspring when crossed with the spiny Texas native O. *lindheimerii* but not with O. *ellisiana* or a putative hybrid forage clone 1233. In July 1998,127 progeny (about 10 cm tall and 0.5 cm in diameter) of the interspecific cross between two wild, spiny Texas native *Opuntia lindheimerii* Texas A&M University Kingsville (TAMUK) accession 1250 male parents and a spineless commercial *Opuntia ficus indica* fruit type TAMUK accession 1281 were transferred from Texas A& M University Kingsville to Argentina. The plants were established in January 1999 under drip irrigation on the Universidad Nacional de Santiago del Estero experimental station near Santiago del Estero, Argentina on a 1.7 by 3.0 m spacing. The cultural operations included complete weed control in and between the rows. After combinations of glyphosate and hand tools achieved virtually bare ground, diuron was applied in a pressure regulated backpack sprayer with a boom of 4 nozzles (8001) spaced 50 cm apart at a concentration of 35 g l^{-1} of 85 % active compound. Diuron was typically applied once in the spring at the onset of the rains, once in mid-summer in the middle of the rainy season and once in late summer/fall to provide residual for the coming year. The plants were fertilized yearly with 110 g per plant of 15-15-15 as suggested by Potgieter (1996 pers comm.). Control of the burrowing insect cactoblastis (*Cactoblastis cactorum*) was achieved with 4 yearly sprays of the insecticide carbaryl (Sevin) at a dose of 1 g l^{-1} active ingredient along with a coadjuvant that we believe helps penetrate the cuticle to kill some of the larvae within the cladode. The nematicide carbofuran (Furadan) was applied to the base of the stems to control bacteriophagous nematodes that occurred above the soil line (Doucet et al., 2002).

At four years of age (when they were 3 to 5 m tall) the progeny were evaluated for fruit characters, spine characters, disease resistance, and form. As many of the progeny strongly resembled the female parent and as apomixis (asexual reproduction of seeds without fertilization) occurs frequently in *Opuntia*, we used Random amplified polymorphic DNA (RAPD) techniques on four of the female looking progeny and found they were apomicts. In addition, RAPD fingerprints of 9 of the non-female looking progeny showed that they were in fact true crosses. Therefore, it became easy to identify the true crosses phenotypically as progeny with any trait of the wild male parent that was not in the female parent, i.e. spines, heavy glochids, bluish cladode color, more round cladode shape, smaller and more narrow fruit were true crosses. Using these criteria at least 45 % of the seedlings in the Argentine field trial were true crosses with 68 % of those being spiny (Felker *et al*., in press). The fact that the male was spiny, the female spineless and that 68 % of the true crosses had some spines, would suggest that the presence of spines is probably a relatively simply inherited trait. Some of the segregants had characteristics of the cold-hardy, spiny male parent (small fruit and bluish cladodes) but without spines. Thus 10 spineless progeny of the O. *ficus-indica* 1281 x O. *lindheimerii* 1250 cross with small bluish looking pads were selected for further productivity, cold hardiness, and forage quality evaluation in replicated trial in the Province of Mendoza, Argentina in a zone where no O. *ficus-indica* survived long term due to freeze damage (Guevara et al., 2003).

Results and Discussion

Examples of previously described, cold hardy spineless forage types O. ellisiana 1364 (cold hardy to USDA zone 7) and O. spp 1233 (cold hardy to USDA zone 8) are shown in Figures 1 and 2 respectively. Figure 1 illustrates four year's rainfed growth of *O. ellisiana* in Kingsville, Texas (Han and Felker, 1997). While this planting was less than 1.5 m tall, with this close spacing of 1.0 m x 1.5 m, after the plants reached a leaf area index of 2.0, the productivity was 14.2 and 17.7 Mg/ha dry matter in years 3 and 4 (Han and Felker, 1997). In contrast, Figure 2 shows a one-year old plant of *O*. spp 1233 that produced more than 100 new cladodes under rainfed conditions in Argentina.

Figure 1. Four year's growth of O ellisiana in Kingsville, Texas where the dry matter productivity in years 3 and 4 were 14.2 and 17.7 Mg ha^{-1} dry matter respectively.

Figure 2. Example of one year's growth in Argentina at 650 mm/yr of more than 100 cladodes from O. spp 1233 that is cold hardy to USDA cold hardiness zone 8.

In the Argentine field trial examining all progeny of the O. *ficus-indica* 1281 x O. *lindheimerii* 1250 cross, at 4 years of age, many of the bluish, spineless, progeny resembling the cold-hardy male parent had many fold greater productivity than O. *ellisiana* growing in an unreplicated trial 5 meters away. An example of a 3-year-old spineless progeny between *O. ficus-indica* and *O. lindheimerii* that possessed cladode shape and color of the male *O. lindheimerii* phenotype is presented in Figure 3.

Figure 3. Three year old thornless segregant #80 of cross between *O ficus indica* 1281 and *O lindheimerii* 1250 with many characters of cold hardy Texas native male parent with potential for forage production.

A comparison of the biomass and cold hardiness of the ten spineless progeny currently being evaluated in the Argentine central arid zone at lat 33º S by Juan Carlos Guevara of IADIZA (Felker et al., 2009) is shown in Table 1. Clones 42, 46, 80, 83 and 150 had much greater biomass productivity than the most cold-hardy spineless clone to date. i.e. O. *ellisiana* and all of the progeny had less frost damage than O. *ficus-indica*. One clone (46) had zero damage (equal to O. *ellisiana)* and various clones had minimal damage i.e. 83 and 94. Guevara (2009 pers comm.) is currently examining the influence of various N and P fertilization application rates on the biomass productivity, cladode protein content, and cold hardiness of these clones.

Table 1. Biomass and frost damage at El Divisadero Cattle and Range Experiment Station, Mendoza, Argentina in a trial with 4 replications to accurately rank growth of *Opuntia ficus indica* 1281, *O. ellisiana*,and spineless progeny of a cross between *Opuntia ficus indica* (1281) x *O. lindheimerii* (1250).

Clone	Predicted fresh wt plant^{-1} (kg)	95% CI plant^{-1}	Mean frost damage (%)	95% Confidence interval
42	6.33	1.94	6.15	11.0
46	7.99	0.81	0.00	0.0
64	4.37	1.92	8.63	7.8
80	5.59	0.34	1.73	1.7
83	6.16	1.52	0.93	1.1
85	2.99	0.84	5.03	8.7
89	3.98	0.96	1.43	1.9
94	3.90	0.58	0.85	1.1
97	3.39	0.67	3.73	3.0
150	9.54	2.36	2.85	1.9
O. ellisiana	3.74	0.66	0.00	0
O. ficus indica 1281	5.66	0.71	15.73	13.0

Note: The trial contained 4 randomized blocks with 5 plants per repetition on a 3 x 5 m spacing. In the first year 100 g of 15-15-15 was applied per plant. Total biomass as plant fresh weight (PFW) corresponding to two years of growth was estimated using the regression equation: PFW = -1,466 + 0.407 (PCN) (Han and Felker, 1997). For determining the PFW of *O. ficus indica*, several cladodes were weighed and an average weight was multiplied by the number of cladodes per plant.

Guevara *et al*. (2009) have recently proposed that technical packages containing fertilization to overcome the low natural N inputs of about 2 kg N ha^{-1} yr^{-1}, and herbicides for weed control could achieve 40 t dry matter ha^{-1} of 9.2 % crude protein forage with 600 mm rainfall in 16 months. In Argentina where the plantations were large enough (>200 ha) to minimize fixed costs of fencing, the internal rate of return for these technical packages was approximately 17 %. Furthermore Guevara *et al*. (2009) suggested that in 600 mm yr^{-1} rainfall regions, given a daily fresh weight requirement of 40 kg for cattle, and from 3 kg to 9 kg for sheep and goats, 1 ha would support 25 cattle, and from 113 to 340 goats or sheep.

We would like to suggest that these 10 spineless progeny of *O ficus-indica* x *O lindheimerii* be tested for productivity and protein content as a function of fertilization and weed control in Mexico at high elevation locations in the states of Zacatecas, Durango, Sonora and Chihuahua as well as low elevation regions of the most northern states that experience 10 year record low temperatures close to -12 C. These genetic materials are available in the USA from the USDA National Arid Land Plant Genetic Resource Unit (NALPGRU) in Parlier, California as well as from J. C. Guevara of IADIZA in Mendoza, Argentina who could provide additional useful information on the management of these clones in range ecosystems in USDA cold hardiness zones 7 and 8.

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