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Cloning of erect, thornless, non-browsed nitrogen fixing trees of Haiti's principal fuelwood species (*Prosopis juliflora*)

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Abstract. A progeny trial in Haiti compared 70 open-pollinated families of *Prosopis* representing seed sources from Haiti, Peru, Chile, Argentina and southwestern US. At the end of 4 years growth, the tallest 6 families were of Peruvian origin. Some of these Peruvian trees (probably *P. juliflora*) were thornless, had erect habit and were non-browsed by goats, unlike other thornless *Prosopis alba* families from South America. Scions from the 5 tallest spineless and most erect trees were transported from Haiti to Texas A&I University where they were successfully grafted onto *P. alba* rootstock. These scions should have great potential for grafting onto existing weedy *Prosopis* and for grafting onto rootstock previously shown to tolerate salinities of seawater and pH values of 10.3.

Haiti is the poorest country in the western hemisphere with a per capita income of only $260/year and with three quarters of its population living in dire poverty on less than $100/year [UNDP/World Bank, 1982]. The biomass derived fuels, wood and charcoal provide 85% of Haiti's energy needs [Votaire, 1979]. The harvesting, production and sale of charcoal is an important income component for the rural people [Smucker, 1981]. The principal species used to produce charcoal is *Prosopis juliflora* (bayahonde in French or bayawon in Creole) [Smucker, 1981; Conway, 1979]. This spiny, arid-adapted, nitrogen-fixing species resprouts from the stump and is one of the few species that can take the abuse of the Haitian wood cutters and the frequent droughts that occur in much of Haiti. The prolific pods produced from *Prosopis* are high in sugar [Felker, 1979] and constitute a valuable resource as animal feed.

As there is much genetic variation in *Prosopis* for pod protein (10—17%), pod sugar (10—44%) [Oduol et al., 1986], growth rate [Felker et al., 1983] and spinelessness, we compared the performance of a broadly based genetic collection of exotic and native *Prosopis* on a lowland Haitian field site without groundwater as described earlier [Lee et al., 1991]. We collected genetic materials from all of Haiti's major regions and selected progeny of 44 representative trees to be included in this trial. Also included were *Prosopis* accessions that had previously shown to have high biomass productivity, lack of spines or high pod production from southwestern USA, Argentina, and Chile. Of special interest were progeny of 12 Peruvian *Prosopis* since this region has been postulated to be a center of genetic diversity for *Prosopis* [Felker, 1990] and as pods of these trees have been historically used to manufacture a molasses type beverage known as algarrobina. As we have noted earlier [Felker, 1990] the taxonomy of *Prosopis juliflora* and *P. pallida* is most confusing. However, these two species are uniquely distinguished from *P. alba, P. chilensis, P. glandulosa* by their complete mortality after experiencing only several hours of −6 °C temperatures which cause minimal damage to the latter species. Until a definitive worldwide taxonomic treatment of *P. juliflora* and *P. pallida* is available we will report them as *P.* spp. or *P. juliflora.*

The trees were planted in August 1987 in a randomized complete block design with 4 replicates of 5 trees per replicate on a 3.0 by 4.5 m spacing. In the summer of 1988 goats penetrated the solar-powered electrical fence and consumed all of the thornless *Prosopis alba* trees and a thornless *Leucaena pulverulenta* accession but the thornless Peruvian material was not browsed. Biomass estimates were obtained from basal diameter measurements using previously described [Lee et al., 1991] regression equations.

The height measurements taken at nearly 4 years of age in Table 1 confirm the 2-year-old measurements of Lee et al. [1991] that the Peruvian accessions had greater height and dry biomass than Haitian, Argentinean, Chilean or North American accessions. Peruvian accessions in the 500 series were all thorny, were slightly more bushy and were faster growing than the Peruvian accessions in the 400 series which were collected about 3 degrees latitude further north. Figure 1 illustrates the greatly improved form of the Peruvian *Prosopis* over that of the native Haitian *Prosopis.*

From the more than 1,000 trees in the trial, the 4 tallest, most erect and spineless trees and the single tallest spiny tree were selected for further propagation. These trees occurred in 3 of the 4 blocks and were from accessions 419 and 420. These trees ranged from 3.8 to 4.3 m in height and from 7.0 to 8.7 cm in basal diameter. Cloning was necessary due to the high genetic variation in *Prosopis* [Hunziker et al., 1986] and the obligately outcrossed breeding mechanism [Simpson, 1977]. Cloning techniques such as rooting of cuttings have not been reliable for mature trees [Klass et al., 1984]. Despite great efforts by several laboratories [Tabone et al., 1986; Jordan and Balboa, 1985; Batchelor et al., 1989] it has not been possible to multiply *Prosopis* by tissue culture. A review of asexual propagation techniques for *Prosopis* is available [Felker, 1992].

Fortunately, cleft grafting of *Prosopis* has been found to have greater than 80% success in an interspecific graft compatibility trial [Wojtusik and Felker, in press]. In this trial virtually 100% graft compatibility was observed between North American species i.e. *P. glandulosa* and *P. articulata,* South American species i.e. *P. alba* and *P. chilensis* and tropical *P. juliflora.*

a

b

Fig. 1. (a) Typical form and growth of native Haitian *Prosopis.* (b) Growth and form of Peruvian *Prosopis* accession number 0538 (spiny).

Table 1. *Prosopis* ranked according to height after 46 months growth near Thomazeau, Haiti.

Accession number	Species	Location of origin	Height (m)		Dry biomass (kg)	
			Mean +	CI	Mean +	CI
545	P. spp.	Sullana, Peru	3.7	± 0.6	10.0	± 4.0
552	P. spp.	Alredores de Piura, Peru	3.6	± 0.4	9.0	± 1.3
537	P. spp.	Sullana, Peru	3.4	± 0.4	6.7	± 2.3
559	P. spp.	Alredores de Piura, Peru	3.4	± 0.6	7.5	± 2.7
544	P. spp.	La Union, Peru	3.3	± 0.8	8.7	± 2.8
419	P. spp.	Trujillo, Peru	3.0	± 1.1	7.0	± 4.6
H02	*P. juliflora*	Passe Catabois	2.9	± 1.5	6.2	± 1.4
H39	*P. juliflora*	Croix de Bouquette-Thomazeau	2.9	± 1.2	5.8	± 3.6
420	P. spp.	Trujillo, Peru	2.8	± 0.8	5.1	± 1.4
538	P. spp.	La Union, Peru	2.7	± 1.4	6.3	± 4.4
H49	*P. juliflora*	Molle St. Nicholas	2.7	± 0.5	5.6	± 3.8
B2V50	*P. alba*	California	2.7	± 1.8	6.7	± 6.2
H30	*P. juliflora*	Port-au-Prince — St. Marc	2.7	± 0.3	6.7	± 3.0
H10	*P. juliflora*	North Bassin Bleu	2.6	± 0.3	6.4	± 1.2
H40	*P. juliflora*	Croix de Bouquette-Thomazeau	2.6	± 0.3	6.8	± 4.6
H41	*P. juliflora*	Croix de Bouquette-Thomazeau	2.6	± 0.4	6.0	± 2.9
H24	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.6	± 0.9	3.4	± 3.3
H38	*P. juliflora*	Croix de Bouquette-Thomazeau	2.6	± 1.1	6.3	± 6.8
H54	*P. juliflora*	Jean Rabel	2.6	± 0.7	5.4	± 2.7
H32	*P. juliflora*	Port-au-Prince — St. Marc	2.5	± 0.6	7.0	± 3.5
H55	*P. juliflora*	South of Jean Rabel	2.5	± 0.6	5.4	± 4.1
H34	*P. juliflora*	Port-au-Prince — St. Marc	2.5	± 0.8	5.5	± 3.9
H19	*P. juliflora*	Port-au-Prince	2.5	± 0.5	6.3	± 3.3
H43	*P. juliflora*	Downtown Port-au-Prince	2.5	± 0.5	5.3	± 1.1
H36	*P. juliflora*	Croix de Bouquette-Thomazeau	2.5	± 0.3	5.7	± 1.3
H18	*P. juliflora*	Port-au-Prince	2.5	± 0.4	6.4	± 2.3
H44	*P. juliflora*	South Anse Rouge	2.4	± 0.5	7.2	± 2.7
H03	*P. juliflora*	Passe Catabois	2.4	± 0.6	5.6	± 1.6
422	P. spp.	Contumaza, Peru	2.4	± 0.5	4.8	± 1.5
H09	*P. juliflora*	North Bassin Bleu	2.4	± 0.5	5.3	± 2.3
H25	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.4	± 0.7	6.3	± 2.9
423	P. spp.	Contumaza, Peru	2.3	± 0.5	6.3	± 4.0
H14	*P. juliflora*	Gonaive	2.3	± 0.4	4.7	± 1.4

H45	*P. juliflora*	Baie de Heine	2.3 ± 0.5	4.9 ± 1.7
H22	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.3 ± 0.4	4.9 ± 1.2
H28	*P. juliflora*	Port-au-Prince — St. Marc	2.3 ± 0.6	4.8 ± 0.8
H50	*P. juliflora*	Molle St. Nicholas	2.3 ± 0.2	8.1 ± 5.5
H21	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.3 ± 0.5	5.9 ± 4.0
H23	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.3 ± 0.2	4.1 ± 1.4
436	*P* spp.	Trujillo, Peru	2.3 ± 0.6	3.6 ± 4.4
H26	*P. juliflora*	Port-au-Prince — St. Marc	2.2 ± 0.3	7.1 ± 2.5
H31	*P. juliflora*	Port-au-Prince	2.2 ± 0.5	4.3 ± 2.7
H15	*P. juliflora*	Gonaive-Anse Rouge	2.2 ± 0.4	5.7 ± 4.5
H12	*P. juliflora*	South of Gros Marne	2.2 ± 0.5	6.6 ± 3.7
H01	*P. juliflora*	Passe Catabois	2.2 ± 0.7	5.2 ± 2.6
H08	*P. juliflora*	North Bassin Bleu	2.2 ± 0.4	5.8 ± 1.4
H16	*P. juliflora*	Gonaive	2.1 ± 0.1	4.2 ± 1.4
H07	*P. juliflora*	Passe Catabois-Bassin Bleu	2.1 ± 1.1	3.8 ± 2.0
H20	*P. juliflora*	Croix de Bouquette-Dom. Rep.	2.1 ± 0.4	3.6 ± 1.3
H11	*P. juliflora*	Bassin Bleu — Gros Marne	2.1 ± 0.7	4.2 ± 1.4
H04	*P. juliflora*	Passe Catabois	1.9 ± 0.6	5.0 ± 3.8
H35	*P. juliflora*	Port-au-Prince — St. Marc	1.9 ± 0.8	3.8 ± 1.9
H05	*P. juliflora*	Gonaive	1.9 ± 0.3	3.3 ± 1.7
H37	*P. juliflora*	Croix de Bouquette-Thomazeau	1.9 ± 0.3	3.7 ± 1.4
H13	*P. juliflora*	Gonaive	1.9 ± 0.4	3.9 ± 2.4
425	P. spp.	Trujillo, Peru	1.9 ± 1.1	1.4 ± 1.2
1134	*P. alba* var. *panta*	Argentina	1.8 ± 0.5	4.0 ± 1.3
450	*P. velutina* (0032)	UC Riverside, California	1.8 ± 0.3	3.6 ± 1.3
1111	*P. glandulosa* var. *glandulosa*	Kingsville, Texas	1.7 ± 0.2	3.7 ± 1.3
457	*P. velutina* (0025)	UC Riverside, California	1.6 ± 0.6	3.8 ± 2.4
166	*P. alba*	Thermal-Coachella, California	1.6 ± 1.2	3.4 ± 3.0
475	*P. glandulosa* var. *torreyana*	UC Riverside, California	1.5 ± 0.6	2.0 ± 1.0
1117	*P. alba/flexuosa*	Chile, Atacama Desert	1.5 ± 1.3	4.3 ± 1.2
H06	*P. juliflora*	Passe Catabois	1.5 ± 0.9	2.9 ± 3.0
901	*P. alba* (0037)	UC Riverside, California	1.4 ± 0.4	2.6 ± 1.0
591	*P. alba* (0039)	Imperial Valley, California	1.3 ± 1.2	3.2 ± 4.9
1012	*P. flexuosa*	Catamarca, Argentina	1.1 ± 1.5	1.2 ± 2.0
999	*L. pulverulenta*	Kingsville, Texas	0.9 ± 0.6	0.3 ± 0.1
1135	*P. nigra*	Argentina	0.6 ± 0.4	0.6 ± 0.3
1015	*P. tamarugo*	Chile	0 ± 0	0 ± 0

Those accession numbers preceded by an H were collected in Haiti. The confidence intervals are 95% confidence intervals.

Additionally, all scions produced more growth when grafted onto *P. alba* rootstocks.

As there had been 4 military governments in Haiti between the time of seed collection and the June 1991 measurement, we felt it prudent to ensure that some of the genetic material was preserved outside of Haiti. On 12 August 1991, 5 scions of each of the 5 trees were collected, dipped in a benomyl solution, placed in a thermos and transported the following day to the Texas A&I University greenhouse where they were grafted that evening. All 25 graft unions have taken and are available for distribution to Haiti and other countries. In October of 1992, budwood of these clones were successfully grafted onto *Prosopis* in the salinity trials of R. Ahmad, University of Karachi, Pakistan.

Early results of a *Prosopis* progeny trial in the Rajasthan desert in Jodhpur, India confirm the superiority of the Peruvian *Prosopis*. At 18 months of age, in a trial with 130 *Prosopis* families approximately equally distributed between *P. alba, P. chilensis, P. nigra, P. flexuosa*, and Peruvian *Prosopis*, the exact same Peruvian families (419 and 420) that contained the tallest, straightest, thornless trees in the Haitian trials were also the tallest (>2 m), straightest and thornless in the Indian trials (Harsh and Felker, unpublished).

The improved clones from the Haitian trials could be very useful to graft onto rootstock that survived the same salinity as seawater [Rhodes and Felker, 1987] and that have been used in the reclamation of extremely high pH soils (10.4) in India [Singh et al., 1989]. The fact that this genus has been reported to fix nitrogen at leaf water potentials of 3.8 MPa [Felker and Clark, 1982] and photosynthesize at leaf water potentials of 4.8 MPa [Nilsen et al., 1981] put it in a drought hardy class far beyond the annual legumes.

While use of this species as a prime firewood species is poorly documented in the scientific literature, one of us has observed widespread utilization of this tree for fuelwood in Senegal, Sudan, Pakistan and India. Personal communications from former Peace Corps volunteers, and CARE employees in Chad, Senegal and Niger indicate that *Prosopis* was a important fuelwood tree in these regions. *Prosopis juliflora* has performed well in CARE sponsored reforestation efforts in Somalia [Zollner, 1986]. In India it has been reported to be a significant fuelwood resource in the states of Uttar Pradesh, Madhya Pradesh and Tamil Nadu (W. Stewart, Ford Foundation, pers. comm., 1986). It is also very highly regarded in the semi-arid regions of northeastern Brazil where it is never harvested for fuel because of the dry season pod production that is used for animal feed (C. A. Ferreira, pers. comm., 1991).

Prosopis is one of the few species that readily naturally regenerates in the African Sahel [El Houri, 1986]. In many locations there are considerable numbers of seedlings present. A unique opportunity presents itself to graft onto these naturally occurring seedlings with these superior genetic materials. This would avoid problems with nurseries, seedling establishment, and browse protection that are causal factors associated with high mortalities in many reforestation projects.

We believe that the naturalized *Prosopis juliflora* that occurs on over half of India, southern Pakistan and much of the Sahel, had its origin in a Peruvian/Ecuadorian center of diversity [Felker, 1990]. The clonal material identified here has considerable potential in other frost-free tropical areas where *Prosopis juliflora* has been naturalized and should be immediately multiplied and field tested in these locations. Given the striking performance of the Peruvian sources in this trial, considerable priority should be given to collection and evaluation of all the Peruvian *Prosopis*. In the meantime, we will make research quantities of clonal material from the erect thornless trees in this trial available. When a resolution of the political crises in Haiti resulting from the coup of September 30 1991 is achieved, we plan to return to distribute these genetic materials.

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