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Genetic Improvement Program of *Prosopis* in Northeastern Brazil

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ABSTRACT

This paper reports the strategies of the genetic improvement program carried out by EMBRAPA, for the *Prosopis* species. The results obtained with the introduction of species from different ecological zones in the world are presented, as well as the techniques of asexual propagation to establish a clonal seed orchard. Sixteen species of *Prosopis* from several provenances were introduced from Peru, Argentina, Chile, Senegal, Pakistan, Mexico, Cape Verde, Paraguay, Honduras and United States of America, from 1984 to 1994. The best species established in terms of survival and growth were *P. juliflora, P. pallida, P. velutina, P. glandulosa, P. cineraria* and *P. affinis*. Aspects of wood and fodder production and quality of some *Prosopis* species are also presented.

1. INTRODUCTION

Prosopis naturally occurs in Brazil, in the southeastern areas of the State of Rio Grande do Sul as *P. affinis* and *P. nigra*, and in the extreme south of the State of Mato Grosso do Sul as *P. rubriflora, P. ruscifolia* and *P. friebrigii* (Allen and Valls, 1987; Silva, 1988). Although *Prosopis* occurs naturally in those areas, the principal cultivation and use of the species of this genus are found in the northeastern region, in the semi-arid zone of Brazil. In the mid 1980s the preference for *P. juliflora* increased among other dry farming crops in the region, because of its importance as fuelwood and charcoal, fences, livestock, forage and human nutrition amongst the rural population. Due to its economic

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importance for the region and considering the hypothesis of its restricted genetic base (Pires *et al.*, 1988), it is necessary, in short and middle terms, to establish a genetic improvement program to increase the variability among the trees and reduce the risk of inbreeding in the existing population, besides increasing the wood and fodder production by the use of selected trees.

For *Prosopis*, EMBRAPA initiated a genetic improvement program in 1981, through the Agriculture and Livestock Research Center for the Semi-Arid Tropic (CPATSA). This paper reports on the strategies of introduction, evaluation, '*ex situ*' conservation and asexual techniques for *Prosopis* species in a program for genetic improvement of this genus in Northeastern Brazil.

2. BASIS OF THE PROGRAM

The main purpose of this project is to introduce, evaluate and select species and provenances of *Prosopis* for different sites; to carry out '*ex situ*' genetic conservation of the best materials and, through asexual propagation establish a clonal seed orchard for commercial seed supply. The program is coordinated by CPATSA, located at Petrolina, State of Pernambuco, at 09°09' latitude south and 40°22' longitude west, at an altitude of 365 m. The program of *Prosopis* is financed by the Brazilian Government, but during four years, January 1987 to December 1990, EMBRAPA received financial help from the International Development Research Center (IDRC).

2.1 Area of Study

The program was carried out in the semi-arid zone of Brazil, which represents 75 per cent of Northeastern Brazil (between the latitude of 1° and 18°30' S and longitude 30°30' and 48°20'W). The semi-arid zone represents 13 per cent of the total area of Brazil. Petrolina, where CPATSA is located, is situated in the landscape called 'Depressao Sertaneja'. This landscape comprises 22 per cent of the Northeastern region and it is characterized by a gently undulating area broken by a few rocky hills and a narrow valley with a dissect slope. In general, the soils are shallow Latosols with a low water-holding capacity and a low organic content. They are generally deficient in phosphorous and have pH values ranging from 5 to 7.

According to the Koppen climatic classification, the climate of the region is the BSh type with irregular rainfall, concentrated during 2–4 months of the year, with distinct wet and dry seasonal stations. The annual dry season usually begins in May–April and extends to December. Droughts are frequent. The annual rainfall average varies from 350 to 500 mm and the temperature average is 27°C.

2.2 Methodology

The procedures for introduction of species, provenances, progeny trials and '*ex situ*' conservation of *Prosopis* of this program were according to Ferreira and Araujo (1981), Shimizu *et al.* (1982) and Palmberg (1980). The programme had the phases of (a) selecting species and provenances; (b) selecting superior trees within the provenances; and (c) crossing among superior trees for seed production supply.

In the process of selection of superior trees, the first step is to test their ability to survive, grow and reproduce in the environmental conditions of the introduction site. The most used method of selection of forest species in Brazil is the 'independent levels of selection'. It is based on the establishment of a minimum level for each character where all the individuals below that level are discarded without taking into consideration other characters. This method is indicated when genetic correlations between the characters of interest for the selection are positive and significant (Higa *et al.*, 1991).

The main purpose of a base population of *Prosopis* species is to maintain the original genetic variability and to allow races to be formed. Variability can be maintained in different provenances by keeping them separate from each other or by mixing them for recombinations to occur. Although selection eliminates part of this variability, selected trees will be grouped into one population for crosses and selection. The cross system may be of open or controlled pollination.

The methodology for seed collection consisted of getting the seeds from a minimum of 25 randomized mother trees spaced at 50–100 m. In each tree, the same amount of seeds are collected. The provenance seedlot was constituted by mixing seeds of 25 trees. Before storage, the seeds were fumigated to control insects and fungi, and stored at a temperature of 8–10 °C and 30–40 per cent of relative humidity, in a plastic bag. In the region, the presence of *Mimosets mimose* (F), harming seeds of *Prosopis*, is very common.

3. *PROSOPIS* INTRODUCTIONS

The references regarding the establishment of the first *P. juliflora* population in Northeast are contradictory. Officially, this species was introduced in Serra Talhada, State of Pernambuco, in 1942, with seeds from Piura, Peru (Azevedo, 1961; Gomes, 1961). Two other introductions were made in 1947 and 1948, in Angicos, State of Rio Grande do Norte, with seeds from Peru and Sudan, respectively (Azevedo, 1955). According to Azevedo (1982a), the seedlings planted at Serra Talhada were destroyed when the planting was young. However on the same site a small population of *P. juliflora* planted in 1942 is still growing probably due to natural regeneration and planting.

Lima and Silva (1991), selecting *P. juliflora* trees for progeny test at Serra Talhada, found some trees with fruits different from the morphological characteristics described for the species. Analyses of the botanical material collected from those trees were identified as *P. affinis*. It suggests that in the seedlot introduced in 1942, there were seeds from *P. juliflora* and *P. affinis* trees, or even, from hybrids of those species. At that time, there was no genetic control in the process of collecting the seeds. According to Gomes (1961), the *Prosopis* seedlot introduced in 1942 from Peru was obtained from stables, after the pods had been given to horses for feeding.

For the genetic improvement program of *Prosopis* in the region, the other point to be considered is the number of trees that originated the whole population of *P. juliflora* in the Northeast. According to Azevedo (1982a), only four trees started the population of Angicos, because of the low survival in the phase of planting. Assuming that the planting at Serra Talhada was destroyed and that only four trees constituted the origin of all *P. juliflora* population of Northeastern Brazil, and that Pires *et al.* (1988) found a low genetic variability for growth characteristics in open pollinated *P. juliflora* progeny trial, it is presumed that there is the existence of a narrow genetic base of this species in the region.

The first *Prosopis* seed introduction by EMBRAPA was made in 1982 with seedlots of *P. tamarugo, P. alba* and *P. chilensis* from Chile, *P. velutina* and *P. glandulosa* var. *torreyana* from USA, and *P. pallida* from Peru. The seeds of *P. tamarugo, P. chilensis* and *P. alba*, from Chile, were collected by Instituto Forestal de Chile (INFOR) and Corporation Nacional Forestal de Chile (CONAF) in collaboration with EMBRAPA.

In 1985, a second introduction was made. *P. alba, P. chilensis, P. argentina, P. torquata, P. nigra, P. flexuosa* and *P. strombulifera* were introduced from Argentina. The seeds were collected by EMBRAPA in collaboration with the Universidad de Catamarca and Estancias del Conlara SA. Table 1 shows the seedlots of *Prosopis* studied by EMBRAPA-CPATSA. Other institutes had sent seeds for testing in the region, like FAO and Danida Forest Seed Centre (DFSC). With these materials, it was possible to start the program and establish trials for selecting species and provenances of *Prosopis* for the region.

3.1 Establishment of Species

Ten *Prosopis* trials have been conducted by CPATSA, in order to define the best species and provenances for the region. Three introduction trials of different *Prosopis* species, one provenance test of *P. juliflora*, and two progeny tests of *P. alba* and *P. chilensis* from Chile were established in Petrolina site. The other *Prosopis* trials were established in Pedro Avelino, State of Rio Grande do Norte, Quixada, State of Ceara and in Contendas do Sincora, State of Bahia. All the experiments were set up in a randomized complete block design and *P. juliflora* was used as control.

The seedlings were produced by direct sowing in black polyethylene bags with 8 cm of diameter and 15 cm of height. At the time of planting, a 100g/plant dosage of NPK (5-14-3) was applied. During the first year of establishment, hoeing was carried out on three occasions to prevent weeds from competing with the seedlings. The methodology developed for *Prosopis* seedling production is described by Lima (1993).

3.2 Evaluation of Species Performance

Lima (1985 and 1988) and Andrade *et al.* (1993) established *Prosopis* trials in Northeastern Brazil.

Tables 2 and 3 show the survival percentage and height of plants for each species at Pedro Avelino and Petrolina sites, where the first experiments were

Table 1. Species and provenances of *Prosopis* used in the program of CPATSA, Northeast Brazil

Species	Country	Provenance	Seedlot number		Latitude	Longitude	Altitude (m)	Rainfall (mm)
			Origin	CPATSA				
P. affinis	Peru	Piura	*	SF 02/89	5°12'S	80°38'W	22	
P. africana	Senegal			SF 02/87	14°40'N	17°26'W		
P. argentina	Argentina	Catamarca	*	SF 01/85	27°30'S	64°55'W		
P. alba	Argentina	Catamarca	*	SF 02/85	27°30'S	64°55'W		
	Chile	Fundo Refresco, Tirana, Pampa del Tamarugal	INFOR-20-26/82	SF 12-18/82				
P. alba var. *panta*	Argentina	Catamarca	*	SF 03/85	27°30'S	64°55'W		
P. chilensis	Argentina	La Rioja	*	SF 07/85	29°30'S	67°00'W		
	Chile	Lampa	DFSC - 1161/83	SF-01/86	37°17'S	71°53'W	500	306
		Lampa	INFOR - 43/82	SF-30/82	37°17'S	71°53'W		
		Santiago	INFOR - 27-37/82	SF/19-29/82	33°27'S	70°40'W	520	
		Ovalle	CONAF - 38-40/82	SF-31-33/82				
		Combarbala	CONAF - 41/82	SF-34/82				
P. cineraria	Pakistan	D.I. Khan	DFSC - 1235/84	SF 02/86	31°15'N	70°45'E	330	300
P. flexuosa	Argentina	La Rioj	*	SF-04/85	29°30'S	67°00'W		
	Chile	Copiado	DFSC - 1457/84	SF-03/86	27°18'S	70°45'W	300	15
P. glandulosa var. *juliflora*	Mexico	La Muralla	DFSC - 1205/83	SF-04/86	26°45'W	101°32'W	880	
P. glandulosa var. *torreyana*	Mexico	Concepcion del Oro	DFSC - 1211/83	SF-05/86	24°49'N	101°25'W	1650	

(Contd)

Table 1 Contd.

Species	Country	Provenance	Seedlot number		Latitude	Longitude	Altitude (m)	Rainfall (mm)
			Origin	CPATSA				
P. glandulosa var. *torreyana*	USA	Texas		SF-01/83	27°31'N	97°52'W		
P. juliflora	Honduras	Comayagua	OFI - 49/83	SF-08/86	14°21'N	87°37'W	600	880
	Cabe Verde	Trindade		SF-01/94	14°55'N	23°31'W		
	Mexico	Cananez	DFSC - 1214/	SF-06/86	24°13'N	104°28'W	890	
	Senegal			SF 01/87				
P. kuntsei	Paragaui			SF 03/87				
P. nigra	Argentina	La Rioja		SF 05/85	29°30'S	67°00'W		
P. pallida	Peru	Ocucaje	DFSC - 1156/83	SF-07/86	14°20'S	75°40'W	420	35
		Ica		SF 01/89	14°20'S	75°30'W		
		Piura		SF 43-46	5°12'S	80°38'W	22	
P. strombulifera	Argentina	La Rioja		SF 06/85	29°30'S	67°00'W		
P. torquata	Argentina	La Rioja		SF 08/85	29°30'S	67°00'W		
P. velutina	USA	Texas		SF 02/83	27°31'N	97°52'W		
P. tamarugo	Chile	Pampa del Tamarugal	INFOR-12-19/82	SF-35-42/82				
	Chile	Fundo Refresco	INFOR - 1-11/82	SF-01-11/82	25°19's	$69^{O}52$'W	1000	

*Seeds collected by CPATSA.

Table 2. Survival and height of *Prosopis* species after 12, 36 and 60 months at Pedro Avelino, RN

Species	Provenance	CPATSA seedlot	Survival (%)			Height (m)		
			12	36	60	12	36	60
P. alba	Chile	SF 12–18/82	91	71	65	0.97	1.66	2.06
P. chilensis	Chile	SF 19–29/82	96	85	56	0.80	1.93	2.12
P. juliflora	Brazil	*	98	96	89	1.02	2.01	2.96
P. pallida	Peru	SF 43–46/82	95	86	77	0.76	1.70	2.54

*Seeds from Petrolina, PE.
Source: Andrade *et al.* (1993).

Table 3. Survival, height, diameter at breast height (DBH) and crown diameter of *Prosopis* species at Petrolina, at eight years of age (Trial I)

Species	CPATSA seedlot	Survival (%)	Height (m)	Diameter at 0.30 m (cm)	DBH (cm)	Crown Diameter (m)
P. alba	SF 12–18/82	57	4.71	18.05	14.40	5.36
P. chilensis	SF 19–29/82	45	3.67	13.44	7.64	3.84
P. glandulosa	SF 01/83	64	2.33	10.90	6.11	3.69
P. juliflora	local	99	6.48	16.50	15.66	6.46
P. pallida	SF 43–46/82	95	5.12	13.90	12.96	6.38
P. velutina	SF 02/83	88	3.30	11.13	4.97	4.49

established. For semi-arid regions, the resistance to drought is a very important characteristic to be observed in plant selection. All the plants of *P. tamarugo*, from Chile, in both trials, Petrolina and Pedro Avelino, have died. The survival percentage in one year after planting showed the non adaptability of this species to the region. In Pedro Avelino, the plants died six months after planting, and in Petrolina, the survival was 1 per cent at one year of age.

The seedlots which originated the plants of the Pedro Avelino trial are the same which originated the plants of the Petrolina trial. On comparing the performance of trees in both trials, the best growth is observed in plants growing in the Petrolina site, for all species. Maybe the influence of fertility or physical characteristics of the soil have helped the performance of the plants. Both sites belong to the same climatic zone, according to Golfari and Caser (1977).

The survival of *P. velutina* and *P. glandulosa* observed in the Petrolina trial shows the adaptation of these species to this environment. High survival is found in *P. pallida*, coming from Peru, in the sites introduced (Table 3). *P. juliflora* and *P. pallida* had the best average for height and a good survival at Pedro Avelino environment, five years after planting. But trees of those species did not bear flowers and fruits during this period. In this region, it is common to find *P. juliflora* trees bearing fruits at two years of age. In the Petrolina site, *P. juliflora, P. velutina* and *P. pallida* started bearing fruits at around 21 months of age. *P. glandulosa* and *P. alba* started bearing fruits three years after planting and a few plants of *P. chilensis* at five years of age. The pod production of *P. alba* and *P. chilensis* was very irregular during nine years of observation.

Tables 4 and 5 show the results obtained with *Prosopis* planted in Petrolina, in two field trials with different spacing, with 56 and 48 months of age, respectively. *P. pallida* and *P. affinis*, introduced from Peru, showed a good performance in both trials. The survival of the species introduced from Chile was 8 per cent for *P. flexuosa* and 26 per cent for *P. chilensis*. The fruit formation started in the second year after planting. *P. glandulosa, P. juliflora, P. pallida* and *P. cineraria* were the species that showed regular fruit bearing.

Table 4. Survival and height of some species and provenances of *Prosopis* at 56 months of age in Petrolina site (Trial II)

Species	Provenance	CPATSA seedlot	Survival (%)	Height (m)	Diameter at 0.30 m	Crown Diameter (m)
P. alba	Argentina	SF 02/85	50	3.22	10.72	5.38
P. alba	Argentina	SF 03/85	62	2.48	6.42	2.93
P. chilensis	Argentina	SF 07/85	39	2.70	7.77	3.62
P. chilensis	Chile	SF 01/86	26	2.94	7.63	3.12
P. cineraria	Pakistan	SF 02/86	81	2.71	7.41	3.87
P. flexuosa	Argentina	SF 04/85	67	2.44	5.96	2.81
P. flexuosa	Chile	SF 03/86	8	2.37	6.65	3.15
P. glandulosa	Mexico	SF 05/86	76	2.46	5.15	3.08
P. juliflora	Brazil	local	87	4.25	10.04	5.38
P. nigra	Argentina	SF 05/85	56	2.07	4.55	2.77
P. pallida	Peru	SF 01/82	79	4.48	11.04	5.81
P. pallida	Peru	SF 43–46/82	89	4.20	9.23	4.95

Table 5. Survival and height of *Prosopis* species at 48 months of age, spaced 3 × 2.5 m in Petrolina–PE (Trial III)

Species	CPATSA seedlot	Survival (%)	Height (m)
P. affinis	SF 02/89	100	2.84
P. alba	SF 03/85	96	1.63
P. cineraria	SF 02/86	96	1.55
P. flexuosa	SF 04/85	96	1.57
P. juliflora	local	100	2.80
P. kuntsei	SF 03/87	78	0.67
P. nigra	SF 05/85	100	1.01
P. pallida	SF 43–46/82	100	2.18

Table 6 shows survival, height, crown and diameter at 0.30 m of *P. juliflora* from Honduras, Mexico and Senegal, used for increasing the genetic base of this species in the region. The performances of trees from seeds introduced from Senegal are very similar to Brazil, but trees raised from Mexico and

Table 6. Survival and height of *Prosopis juliflora* provenances in Petrolina – PE at 54 months of age

Provenance	CPATSA seedlot	Survival (%)	Height (m)	Crown Diameter (m)	Diameter at 0.30 m (cm)	No. of stems at 0.30 m
Honduras	08/86	80	1.60	4.85	*	4
Senegal	01/87	68	3.62	5.42	9.42	2
Mexico	04/86	44	2.12	3.18	5.05	3
Brazil	local	44	4.06	5.83	10.14	3

* Not evaluated.

Honduras seeds showed different characteristics in pod production and pattern of growth. Trees originating from Mexico seedlot produced reddish pods similar in colour to *P. affinis* pods, and trees from Honduras had an initial growth in the first two years with pronounced plagiotropic shoots more or less hortizontal and long thorns.

Although the seedlots are said to be of *P. juliflora*, the morphological characteristics of the provenances do not correspond to the description given by Burkart (1976) for this species. Additional taxonomic studies are necessary on *Prosopis*, mainly on *P. juliflora*. According to Stewart *et al.* (1992), *P. juliflora* links the two centres of diversity in the genus and is the only species native to Central America. It is closely related to the species in South America, including *P. pallida* and *P. affinis*, and in North America, including *P. laevigata* and *P. glandulosa*.

The taxonomy used for some *Prosopis* is uncertain. In most of the literature, *P. glandulosa* is designated as *P. juliflora* (National Academy of Science, 1979). According to Ferreyra (1987), the species denominated *P. juliflora* that grows in Peru do not correspond in morphological aspects to the species denominated *P. juliflora* that grows in Central America.

3.3 Wood Production

The data for biomass produced in *Prosopis* is presented in Table 7. The biomass production was found to be the maximum in *P. juliflora* trees: 27.1 tons per hectare. This value is significantly higher compared to the other species introduced in the trial. *Prosopis pallida*, with a yield of 15.7 tons per hectare, is the second species in the rank. There was no statistical difference among *P. chilensis, P. alba, P. glandulosa* and *P. velutina* for wood production. The percentage contribution of leaf biomass to total biomass ranged from 5.6 to 17.3 per cent. Higher percentage of leaves was found in *P. glandulosa*. Analysis of dry matter weight in different diameter classes showed *P. juliflora* and *P. alba* as the species with the lowest percentage of woody dry material in classes under 3.0 cm of diameter.

In all other species more than 50 per cent of their woody dry matter is found in classes under 3.0 cm of diameter. The basic density of the wood found in *Prosopis* planted at Petrolina ranged from 0.66 to 0.91 g/cm^3 among

Table 7. Dry wood biomass (ton/ha) of *Prosopis* species at eight years of age by diameter classes in Petrolina–PE

Classes Stem and branches	*P. alba*	*P. chilensis*	*P. glandulosa*	*P. juliflora*	*P. pallida*	*P. velutina*
< 1 cm	1.556 (25)	0.924 (32)	1.517 (43)	4.609 (17)	4.653 (30)	1.431 (33)
1.1–3.0	1.173 (19)	0.765 (26)	1.108 (31)	5.828 (21)	3.330 (21)	1.540 (35)
3.1–5.0	1.066 (17)	0.581 (20)	0.441 (12)	6.230 (25)	2.726 (17)	0.822 (19)
5.1–7.0	0.765 (12)	0.246 (8)	0.159 (5)	3.985 (15)	2.052 (13)	0.191 (4)
7.1–9.0	0.608 (10)	0.179 (6)	0.166 (5)	2.982 (11)	1.363 (9)	0.196 (5)
> 9.0	1.104 (17)	0.237 (8)	0.138 (4)	2.982 (11)	1.535 (10)	0.170 (4)
Total (ton/ha)	6.272 c	2.932 c	3.529 c	27.109 a	15.666 b	4.350 c

Note: Numbers in parentheses show the mean percentage related to the total. Means followed by the same letter in a row do not differ statistically at the 5% level by Duncan test.

the species. The highest value was found in *P. juliflora*. This value increases the advantage of this species for firewood production.

3.4 Fodder Production

The variation in *Prosopis* pod production and pod characteristics like size and protein content is large in the region. According to Azevedo (1982b), the pod production of *Prosopis* in the semi-arid environment ranges from 2 to 3 ton/ha/year and in the humid zones 8 tons has been recorded in Northeastern Brazil.

Lima (1987) studied the correlation between the pod production and the environment in *P. juliflora* cultivated at Petrolina. High temperature, low rainfall and low relative humidity stimulated pod production but varied in yields. In 15-year old trees spaced 10 × 10 m pod production ranged from 5 to 192 kg/tree. The average pod production was 78 kg/tree/year. Felker (1982) found in 5-year old progenies of *P. velutina* pod production ranging from zero to 12.6 kg/tree. In Piura, Peru, Valdivia (1982) concluded that the selected trees of *P. pallida* can produce 60 to 80 kg of pods/tree/year.

Pod production of *P. juliflora* planted in Petrolina during different years of growth is shown in Table 8. In the silvicultural system, as is evident, *P. juliflora* and *P. pallida* showed decrease in pod yield and number of trees producing fruits with age. This is due to narrow spacing and the closure of crown which affected pod production. For *P. velutina* and *P. glandulosa*, the pod yield and number of trees bearing fruits increased with age due to shruby growth.

Table 8. Pod mean yield of *Prosopis* species (g/tree) up to seven years in Petrolina - PE

Species	Age (years)					
	2	3	4	5	6	7
P. glandulosa	0	10.2	72.8	293.5	455.5	1359.3
P. juliflora	399.7	93.0	93.2	141.9	80.2	22.3
P. pallida	361.2	232.6	346.9	1245.6	1270.0	459.5
P. velutina	23.8	84.9	601.3	1503.0	1761.6	1742.1

Oliveira and Pires (1988) studied the reproductive system and pollination efficiency as the possible cause for low fruit output per inflorescence in *P. juliflora*. They found 269 to 456 flowers per inflorescence. The pollination efficiency in relation to the number of inflorescence and in relation to the number of flowers was 29 and 1.5 per cent, respectively. It is also important to know the pollinating agents, the pollen release period and stigma receptivity to explain the low pollination efficiency in *Prosopis* in the region.

Crude protein (CP) and *'in vitro'* dry matter digestibility (IVDMD) of *Prosopis* species are, in general, superior to some native fodder species (Table 9). The *'in vitro'* rumen fermentation technique is used for estimating relative digestion rates in ruminants and for measuring nutritional value of forages.

Another important point analysed in fodder nutritional status is the tannin level. The determination of tannin content in leaves is important because of its ability to combine with plant proteins in the rumen and its implications in reducing bloat and improving protein utilization. Plant tannins are complex phenolic polymers which vary in chemical structure and biological activity. Two groups of natural tannins are found: hydrolysable tannins, which occur mainly in fruit pods and plant galls, and condensed tannins, commonly found in forage.

Table 9. Data of Crude Protein (CP), *'in vitro'* dry matter digestibility (IVDMD) and tannin content in leaves and pods of *Prosopis* species in Petrolina-PE

Species	Pods		Leaves		
	CP (%)	IVDMD (%)	CP (%)	IVDMD(%)	Tannin (%)
P. alba	–	–	23.27	57.06	1.97
P. chilensis	–	–	24.03	31.63	4.37
P. glandulosa	10.36	79.65	21.24	60.16	2.25
P. juliflora	7.82	74.59	18.49	59.06	1.89
P. pallida	8.08	67.91	17.83	55.55	2.01
P. velutina	11.35	71.40	23.59	57.94	2.25

Source: Lima, 1994.

Hydrolysable tannins, but not condensed tannins, are digested by animals (McLeod, 1974). The tannin levels in the leaves of *Prosopis* varied among species (Table 9).

4. ASEXUAL PROPAGATION

Self-incompatibility in *Prosopis* results in the formation of outcrossed trees. In order to obtain seedlings with genetically identical characters of the mother tree it is essential to develop asexual propagation techniques.

The technique used at CPATSA consists of selecting trees on the basis of architecture, pod quality, pod production, disease and insect resistance. The main objective is to establish a clonal seed orchard using seedlings raised by rooting cuttings of superior mother trees. Lima (1988b) described the technique developed at CPATSA. Techniques of grafting were carried out, but the success is not satisfactory. Grafting *P. juliflora* onto *P. juliflora*, produced a sucess rate of only 5 per cent. There is a need to examine further graft compatibility between *P. pallida* and *P. juliflora*, and between *P. cineraria* and *P. juliflora*. The success of this process will permit to change population of *P. juliflora* with low pod production onto trees with desired characteristics.

5. FINAL CONSIDERATIONS

The process of genetic improvement of *Prosopis* in Northeastern Brazil is in the first stage, with the introduction and selection of species and provenances from natural zones of occurrence for specified sites and uses. The criteria of superior tree selection is based on survival, fast growth and the ability to produce qualitative and quantitative fodder and wood. The fodder quality is evaluated on the basis of protein and tannin content and '*in vitro*' dry matter digestibility.

The genus *Prosopis* shows variability not only in terms of a large number of species, but also in possibility of interspecific crosses (Hunziker *et al.*, 1986). Despite introduction of many species in the past, still a large number of species, provenances, varieties and hybrids needs to be tested.

Among the present introductions the best species for increasing wood yield are *P. pallida* and *P. affinis* from Peru; while for pod production, *P. glandulosa* and *P. velutina* from Mexico and USA, and *P. cineraria* from Pakistan are best.

The process of genetic conservation needs to be carried in a cooperative way, involving the maximum possible number of participants which will provide diversity of genotypes. Although a good technical cooperation exists among the Brazilian institutions, it is necessary to develop relations with international agencies and research and development institutions for exchange of ideas, materials and suggestions. Based on the results of the programme, *P. juliflora* and *P. pallida* should have priority for breeding and genetic conservation. Other species need further studies in order to know their potential.

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REFERENCES

Allen, A.C. and Valls, J.F.M. 1987. Recursos forrageiros nativos do Pantanal Matogrossense. Documentos. EMBRAPA CEMARGEM, Brasilia **8**: 1–339.

Andrade, G. de C., Cristo, R.C. de, Henriques, O.N. and Lima, P.C.F. 1993. Introducao e selecao de especies de *Prosopis* na regiao semi-arida do Rio Grande do Norte. *In*: Floresta para o desenvolvimento: Politica, ambiente, tecnologia e mercado. 7 th Congresso Florestal Brasileiro, 17–24 Sptember 1993, Curitiba, Brazil. Sao Paulo: SBS/SBEF, v.1, 134–136.

Azevedo, G. de 1955. Algaroba. Natal. 13 pp.

Azevedo, G. de 1961. Algaroba. Rio de Janeiro:Servico de Informacao Agricola. (Serie SIA, 843) 31 pp.

Azevedo, G. de 1982a. Como e porque a algarobeira foi introduzida no Nordeste. *In*: Algaroba. I Simposio Brasileiro sobre Algaroba, 5–7 October 1982, Natal, Brazil. Natal: EMPARN, (EMPARN, Documentos, 7). 300–306.

Azevedo, C.F. 1982b. Algarobeira na alimentacao animal de humana. *In*: Algaroba. I Simposio Brasileiro sobre Algaroba, 5–7 October 1982, Natal, Brazil. Natal: EMPARN, (EMPARN. Documentos, 7). 283–299.

Burkart, A. 1976. A monograph of the genus *Prosopis* (Leguminosae subfam. Mimosoideae). *J. Arnold Arboretum* **57**(3): 219–249.

Felker, P. 1982. Selecao de fenotipos de *Prosopis* para a producao de vagens e de combustiveis de madeira. *In*: Algaroba. I Seminario Brasileiro sobre Algaroba, 5–7 October 1982, Natal, Brazil. Natal: EMPARN, V.2. (EMPARN, Documentos, 8). 7–24.

Ferreira, M. and Araujo, A.J. de. 1981. Procedimentos e recomendacoes para testes de procedencias. Curitiba, EMBRAP-URPFCS, EMBRAPA-URPFCS. Documentos, 6, 28 pp.

Ferreyra, R. 1987. Estudio sistematico de los algarrobos de la costa norte de Peru. Lima: CONCYTEC/CIID. 31 pp.

Golfari, L. and Caser, R.L. 1977. Zoneamento ecologico da Regiao Nordeste para experimentacao florestal. Serie Tecnica PRODEPEF, Belo Horizonte, n. 10, 116 pp.

Gomes, P. 1961. A algarobeira. Rio de janeiro. Ministerio da Agricultura, Servico de Informacao Agricola. (Serie SIA, 865). 49 pp.

Higa, A.R., Resende, M.D.V. de and Souza, S.M. de 1991. Programas de melhoramento genetico de Eucalyptus no Brasil. *In*: O Desafio. O Desafio da Florestas Neotropicais, Curitiba, Brazil. 86–100.

Hunziker, J.H., Saidman, B.O., Naranjo, C.A., Palacios, R.A., Poggio, L and Burghardt, A.D. 1986. Hybridization and genetic variation of Argentine species of *Prosopis*. *For. Ecol. Mgmt.* **16**: 301–315.

Lima, P.C.F. 1985. Trabajos de investigacion com especies del genero *Prosopis* en la region semiarida del Brasil. *In:* Estado Actual del Conocimiento Sobre *Prosopis tamarugo*. Mesa Redonda Internacional Sobre *Prosopis tamarugo* Phil., 11–15 Junio 1984, Africa, Chile. Rome: FAO. 125–132.

Lima, P.C.F. 1987. Producao de vagens de algaroba. Revista da Associacao Brasileira de Algaroba, Mossoro, Vol. **2**(1): 141–170.

Lima, P.C.F. 1988a. Performance of species of the genus *Prosopis* at 24 months of age in Petrolina. *In:* The Current State of Knowledge on *Prosopis juliflora*. II Inter. Conf. *Prosopis*. 25–29 August, 1986, Recife, Brazil. Rome, FAO. 63–67.

Lima, P.C.F. 1988b. *Prosopis* vegetative propagation through cutting. *In:* The Current State of Knowledge on *Prosopis juliflora.* II Inter. Conf. on *Prosopis,* 25–29 August, 1986, Recife, Brazil. Rome: FAO. 223–227.

Lima, P.C.F. 1993. Seedling production of *Prosopis juliflora* in Northeastern Brazil. *In*: S. Puri and P.K. Khosla (Eds) Nursery Technology for Agroforestry—Applications in Arid and Semiarid Regions. New Delhi, (Winrock- Oxford & IBH series). 75–84.

Lima P.C.F. 1994. Comportamento silvicultural de especies de *Prosopis*, em Petrolina-PE, regiao semi-arida brasileira. Curitiba, Tese Doutorado. Universidade Federal do Parana. 110 pp.

Lima, P.C.F. and Silva, M.A. da 1991. Ocorrencia subespontanea de uma algaroba no Nordeste do Brasil. *Boletin de Pesquisa Florestal* (Colombo) **22/23** : 93–97.

McLeod, M.N. 1974. Plant tannnis—their role in forage quality. Nutrition Abstracts and Reviews, *Farhhan Royal* **44**(11): 803–814.

National Academy of Science. 1979. Tropical Legumes Resource for the Future. Washington, DC. 331 pp.

Oliveira, V.R. and Pires, I.E. 1988. Pollination efficiency of *Prosopis juliflora* (SW) DC in Petrolina, Pernambuco. *In:* The Current State of Knowledge on *Prosopis juliflora.* II Inter. Conf. on *Prosopis*, 25–29 August, 1986, Recife, Brazil. Rome: FAO. 233–239.

Palmberg, C. 1980. Principios y estrategia para el mejor aprovechamiento de los recursos geneticos forestales. *In*: Informe. Curso de capacitacion FAO/DANIDA sobre la mejora genetica de arboles forestales, Merida, Venezuela. Rome: FAO (Estudio FAO: Montes, 20). 27–50.

Pires, I.E., Andrade, G.de C. and Araujo, M. de S. 1988. Genetic variation for growth characteristics in *P. juliflora* progenies. *In*: The Current State of Knowledge on *Prosopis juliflora.* II Inter. Conf. on *Prosopis*, 25–29 August 1986, Recife, Brazil. Rome, FAO. 177–185.

Shimizu, J.Y., Kageyama, P.Y. and Higa A.R. 1982. Procedimentos e recomendacoes para estudos de progenies de essencias florestais. Curitiba, EMBRAPA-URPFCS, EMBRAPA-URPFCS, Documentos, 11. 34 pp.

Silva, M.A. 1988. Taxonomy and distribution of the genus *Prosopis* L. *In*: The Current State of Knowledge on *Prosopis juliflora.* II Inter. Conf. on *Prosopis*, 25–29 August 1986, Recife, Brazil. Rome: FAO. 177–185.

Stewart, J.L., Dunsdon, A.J., Hellin, J.J. and Hughes, C.E. 1992. Wood biomass estimation of Central American dry zone species. Oxford Forestry Institute, Oxford. Tropical Forestry Papers 26. 83 pp.

Valdivia, S. 1982. Assentamento e desenvolvimento rural nas zonas marginais da costa norte do Peru; Piura. *In*: Algaroba. I Simposio Brasileiro Sobre Algaroba, 5–7 October 1982, Natal, Brazil. Natal: Documentos 7. 90–111.