Genetic Potential of *Prosopis* in Argentina for its Use in Other Countries

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Intragenus Diversity of *Prosopis* in Argentina

The Republic of Argentina (Figure 1), at the southern tip of South America, is 4,025,695 km^2 (2,795,695 km^2 without the Argentina Antarctic) in area, reaching from 21° S latitude to 55° S latitude in the continent and to the Pole, in Antarctica (Cabrera, 1976).

Because of its great latitudinal expanse, which ensures a variety of climates, Argentina has 28 of the 44 species of *Prosopis* known in the world. These are distributed between the 22° S and 48° S, either in the plains or up to 3000 m above sea level, and from zones with 80 mm annual rainfall to zones with 1400 mm of rain per year (Roig, 1993). Even though the genus occurs over most of Argentina, with the exception of Misiones and south of Patagonia, the majority of the species grow in the arid and semiarid zones that are 70% of the country's surface. Sixteen of the species are trees and the others are shrubs, although some arboreal species can occur as a shrub. In the chaqueña zone (mesopotamica and xerica), phytogeographic region of Argentina (Figure 2), the trees of the *Prosopis* genus (*P. alba, P. nigra, P. hassleri, P. ruscifolia, etc.)* prevail over shrubs, which are rare. In contrast, the number of arboreal species diminishes in the Pampeana and Preandina zones. In the Monte zone there is a clear domain of shrubs, and trees disappear in the Patagonica zone (Roig, 1993). The distribution of some of the most important species in the country are shown in Figures 3, 4, 5, 6, and 7.

Intraspecific Diversity

In addition to the great diversity of species naturally growing in Argentina, there exists great intraspecific morphologic variability especially in those species that have wide distribution in the country. Despite the enormous intraspecific genetic variation for *Prosopis*, probably attributable to the great edaphic and climatic varibility in Argentina, there have been few studies to develop these genetic resources. In addition, the fact that several species of the *Algarobia* section (Burkart, 1976), such as *P. chilensis, P. flexuosa* (Simpson, 1977; Masuelli & Balboa, 1987) and *P. nigra* (Palacios & Bravo, 1981) are not self-compatible and, therefore, of obligated outcrossing, would guarantee a high recombination and wide genetic variation in the natural populations (Hunziker et al., 1986).

Saidman and Vilardi (1987) while studying isoenzymes with seven enzymatic systems in populations of seven native species of *Prosopis*, found an average percentage of loci polymorphic (P) of 45%, with maximum values of 50% for *P. flexuosa* and minimum of 38% for *P. ruscifolia*. These authors determined the heterozygosis mean values by locus and by individual (H) of 18%. These results, based on the study of 20 to 23 loci, demonstrated a high genetic variability in several of these species (mainly the arboreal species). In addition, isoenzymatic and chromatography of phenolic compounds studies demonstrated the existence of intraspecific hybrids (Hunziker et al., 1986), that, although present in low percentages, had pods with viable seeds. These previous studies, combined with the high morphologic variation, suggested that a selection program could be successful in spite of the considerable extinction of the "elite" trees undergone by most of the species belonging to this genus (Hunziker et al., 1986).

Morphologic and isoenzymatic studies recently done, more thoroughly, with different populations of *P. chilensis* and *P. flexuosa* in the arid Chaco, confirmed the existence of fertile genetically intermediate forms (hybrids), that could be morphologically identified (Verga, 1995).

Program for Conservation and Improvement of *Prosopis* Native Species in Argentina

Even though laboratory studies proved strong evidence to support the existence of intraspecific genetic variability, there were no field studies to confirm it. In 1990, supported by the IDRC, a program was developed in Argentina for "Conservation and Improvement of the native species of *Prosopis*" (Cony, 1993). Its short-term goal was to assess the existing variability in the growth and development traits within four of the most important arboreal species of this genus: *P. chilensis* and *P. flexuosa* in the phytogeographic province of the Monte (arid zone) and *P. alba* and *P. nigra* in the phytogeographic province of Chaco (semiarid and subhumid zone). The program had the following objectives:

- Identify genetic material areas (GMA) or sampling areas within the natural area of distribution of these species. (We presumed the GMAs would be sufficiently isolated by the orography in the mountainous valleys and by distance in the plains that the gametic exchange between areas would be restricted.)

- Select individuals within each area with the only criterion that they differed between them from a morphological viewpoint

- Obtain a germplasm collection from the GMAs and the individuals

Finally, the program completed the collection of three of these species, with the exception of *P. nigra*, having selected and harvested 84 *P. chilensis* trees in 9 GMAs, 86 *P. flexuosa* in 13 GMAs (Figure 8), and 57 *P. alba* in 8 GMAs (Figure 9). A portion of the collected seeds was conserved in refrigerated chambers, and the other portion was used to establish family-provenances trials. In Mendoza (Monte) work was done with *P. chilensis* and *P. flexuosa*, and in Santiago del Estero (Chaco), with *P. alba*.

Family-Provenance Trial in Mendoza

In 1991 and 1992, 84 families from *P. chilensis* and 86 from *P. flexuosa* trials were set up in the center of the Monte phytogeographic province. A randomized complete block design with five replicates was used. The families were planted in three-tree row plots. Thus, with 5 replications, 15 half-sib families from each family were evaluated. Spacing in the trials was 4 m x 4 m, with a single buffer row surrounding each trial. Because the water table stood at 3-m depth, the trees were watered monthly during the year, giving a total of 500 mm in addition to the rainfall (an average of 200 mm per year), until the roots reached the phreatic level. Afterwards, watering was discontinued.

The assessed traits were: height and basal diameter, branching, straightness, and thorniness, even though for the three last traits the results presented are only for *P. flexuosa.*

Data obtained were submitted to variance analysis and the means separated according to the multiple-comparison Duncan test. Restricted maximum-likelihood variance components were also estimated. In order to estimated the influence of the variation owed to the provenances effect and families within provenances, the proportion of each variation was calculated with respect to their sum.

Heritabilities at individual and family level for all the *P. flexuosa* traits, and height and basal diameter for *P. chilensis* were estimated using the following equations, according to Pires (1984):

$$H_i^2 = \frac{4V_f}{V_f + V_{Rf} + V_e}$$

$$H_F^2 = \frac{V_f}{\frac{V_e}{KR} + \frac{V_{Rf} + V_f}{K}}$$

where:

H_i^2	=	**heritability in narrow sense at individual level**
H_F^2	=	**heritability in narrow sense at family level**
V_f	=	**families variance**
V_{Rf}	=	**family x replication interaction variance**
V_e	=	**variance error**
K	=	**mean number of trees per plot**
R	=	**replication number**

Also, genetic and phenotypical correlations were estimated between all the *P. flexuosa* traits.

The trials after being established for 34 months for *P. flexuosa* and 42 months for *P. chilensis*, showed the existence of high variability for all traits studied, at the provenance level as well as at the family level within provenances.

For example, for the height trait, the *P. flexuosa* and *P. chilensis* trees that came from the northernmost parts, Bolsón de Fiambalá and Bolsón de Pipanaco, had greater growth, while those from the southernmost, Río Colorado-General Conesa and Llanos de Angaco-Lavalle, had the lowest growth (Tables 1 and 2). Similar results occur with basal diameter, although in the case of *P. flexuosa* there were provenances from intermediate latitudes with smaller diameters (Tables 3 and 4).

When analyzing the remaining traits for *P. flexuosa*, Río Colorado-General Conesa the southernmost provenance stands out again, as it has more branching and fewer straight trees. No provenance possessed low thorniness (Figure 10).

The families, in both species, did not always behave similar to the provenances. While the *P. chilensis* provenance from the Bolsón de Pipanaco has the greatest mean height, the 13 *P. chilensis* families within this provenance ranged in family rank for height from 1 to 75 (Table 6). Similarly, while the *P. flexuosa* provenance from the Bolsón de Pipanaco had the greatest mean height, the eight families within this provenance ranged in rank for height from 2 to 30 (Table 5). This dissimilar behavior of the families within the provenances was accounted for by the high proportion of intraprovenance genetic variations (Tables 7 and 8). This same phenomenon has been detected by Cony and Trione (1996a, 1996b) when evaluating the germination capacity of *P. flexuosa* and *P. chilensis* at low temperatures and low water potentials. Lopez, C. (1995, pers. com.) has observed very similar behavior in performance of progeny trials for *P. alba*.

In reafforestation programs of arid lands with multipurpose trees, the rapid production of aerial biomass is an important objective. If we take into account that the height as well as the basal diameter are directly proportional to the aerial biomass (Stewart et al., 1992), the provenances from Bolsón de

Fiambalá, for *P. flexuosa*, and from Bolsón de Pipanaco, for *P. chilensis*, would be recommended since they ranked first both in height or in basal diameter. This great variation found between families for all the assessed traits would diminish the risks of inbreeding, if reafforestation was done with only one provenance.

The heritabilities at family level were high for all the traits in both species, while for *P. flexuosa* the heritability at individual level for basal diameter and branching were low (Tables 9 and 10). The high values of heritability at individual level for height and thorniness in *P. flexuosa*, would permit genetic advances in the short term with use of mass selection programs for the tallest and least thorny plants. For other traits, the selection should be carried on at family level, because their values of family heritability increased in high proportion with respect to the individual level.

Even though there are clues of stability in the growth heritability traits (Solanki et al., 1992; Cony, unpublished data), there is a need for future evaluations before deciding the best improvement strategy to be followed.

For *P. flexuosa* high positive genetic and phenotypic correlations were found for height with basal diameter (Table 11). Thus, given the multistemmed and very thorny nature of this species, it seems reasonable to use only height as a selection criteria for aboveground biomass.

Conclusions and Perspectives

The results presently reached in Argentina about the genetics of different Prosopis species show the existence of high variability at all levels studied (genus, species, provenances, families, and individuals). This, added to the existence of interspecific hybrids that give more variability to the wild genetic pool, increases the probabilities for success to obtain improved germplasm of these species. Outstanding traits, like straightness, fast growth, lack of thorns, high biomass production, abundant pod production and resiliency to different causes of stress are available in the gene pool. When these genetic resources are combined with the best management techniques for rainfall catchment, drought avoidance, establishment methods under hydric deficit, successful vegetative propagation, and the choice of the right sites, reforestation programs with *Prosopis* species in different arid and semiarid zones of the world will have excellent probabilities for success.

Establishment of a national network of family-provenances trials of the most important species of *Prosopis* will permit us, in relatively short time frames, to assess this important native germplasm resource to be used in different arid and semiarid zones of the world.

References

Burkart, A., 1976. A monograph of the genus *Prosopis* (Leguminosae subf. Mimosoideaea). *Journal of Arnold Arboretum* 57:(3)217-247 and (4)450-525.

Cabrera, A., 1976. Regiones fitogeográficas Argentinas. Enciclopedia Argentina de Agricultura y Jardinería. Segunda Edición. Tomo II. Fascículo I. 85 pp.

Cony, M.A., 1993. Programa de conservación y mejoramiento de especies del género *Prosopis* en la Provincia Fitogeográfica del Monte, Argentina. In: Contribuciones Mendocinas a la Quinta Reunión Regional para América Latina y el Caribe, de la Red de Forestación del CIID, pp. 37-72. Unidades de Botánicay Fisiología Vegetal, IADIZA (eds.).

Cony, M.A. and Trione, S.O., 1996. Germination with respect to temperatures of two argentinian *Prosopis* species. *Journal of Arid Environment* 33:225-236.

Cony, M.A. and Trione, S.O., 1996. Germinación bajo estrés hídrico y salino de dos especies nativas de algarrobo. Su variabilidad genética. Actas de la XXI Reunión Argentina de Fisiología Vegetal. pp. 130-131.

Hunziker, J.H.; Saidman, B.O.; Naranjo, C.A.; Palacios, R.A.; Poggio, L. and Burghardt, A.D., 1986. Hybridization and genetic variation of Argentina species of *Prosopis*. or *Forest Ecology and Management* 16:301-315.

Masuelli, R.S. and O. Balboa, 1989. Self-incompatibility in *Prosopis flexuosa* D.C. *Plant Cell Incompatibility Newsletter* 21:44-48.

Palacios, R.A. and Bravo, L.D., 1981. Hibridación natural de *Prosopis* (Leguminosae) en la región chaqueña Argentina. Evidencias morfológicas y cromatográficas. *Darwiniana* 23:3-35.

Pires, I.E., 1984. Variabilidade genetica on progies de uma populaao de Algarobo, *Prosopis juliflora* (S.W.) D.C., da regiao de Soledade, Paraiba. Rese de Mestrado. Escola Superior de Agricultura, Universidade de Sao Paulo, Brasil.

Simpson, B.B., 1977. Breeding Systems of dominant perennial plants of two disjunct warm desert ecosystems. *Oecologia* (Berl.) 27:203-226.

Roig, F.A., 1993. Informe nacional para la selección de germoplasma en especies de *Prosopis* de la República Argentina. In: Contribuciones Mendocinas a la Quinta Reunión Regional para América Latina y El Caribe de la Red de Forestación del CIID. pp 1-37. Unidades de Botánica y Fisiología Vegetal, IADIZA (eds.)

Saidman, B.O. and Vilardi, J.C., 1987. Analysis of the genetic similarities among seven species of *Prosopis* (Leguminosae: Mimosoideae). *Theor. Appl. Genet.* 75:109-116.

Solanki, K.B.; Kakers, N.L.; Singh, M.; and Jindal, S.K., 1992. Genetic improvement of *Prosopis cineraria*. Collection of germplasm, its evaluation and explotation. In: R.W. Dutton (ed.). *Prosopis* Species. Aspects of Their Value, Research and Development. Proceedings of the *Prosopis* Symposium. pp. 157-174. Univ. of Durham, U.K.

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

Verga, A., 1995. Genetische Untersuchungen an *Prosopis chilensis* und *Prosopis flexuosa* (Mimosaceae) im trockenen Chaco Argentiniens. *Göttingen Forstgenetische Beritchte,* 19. (*Göttingen Research Notes in Forest Genetics* 19). Universität Göttingen.

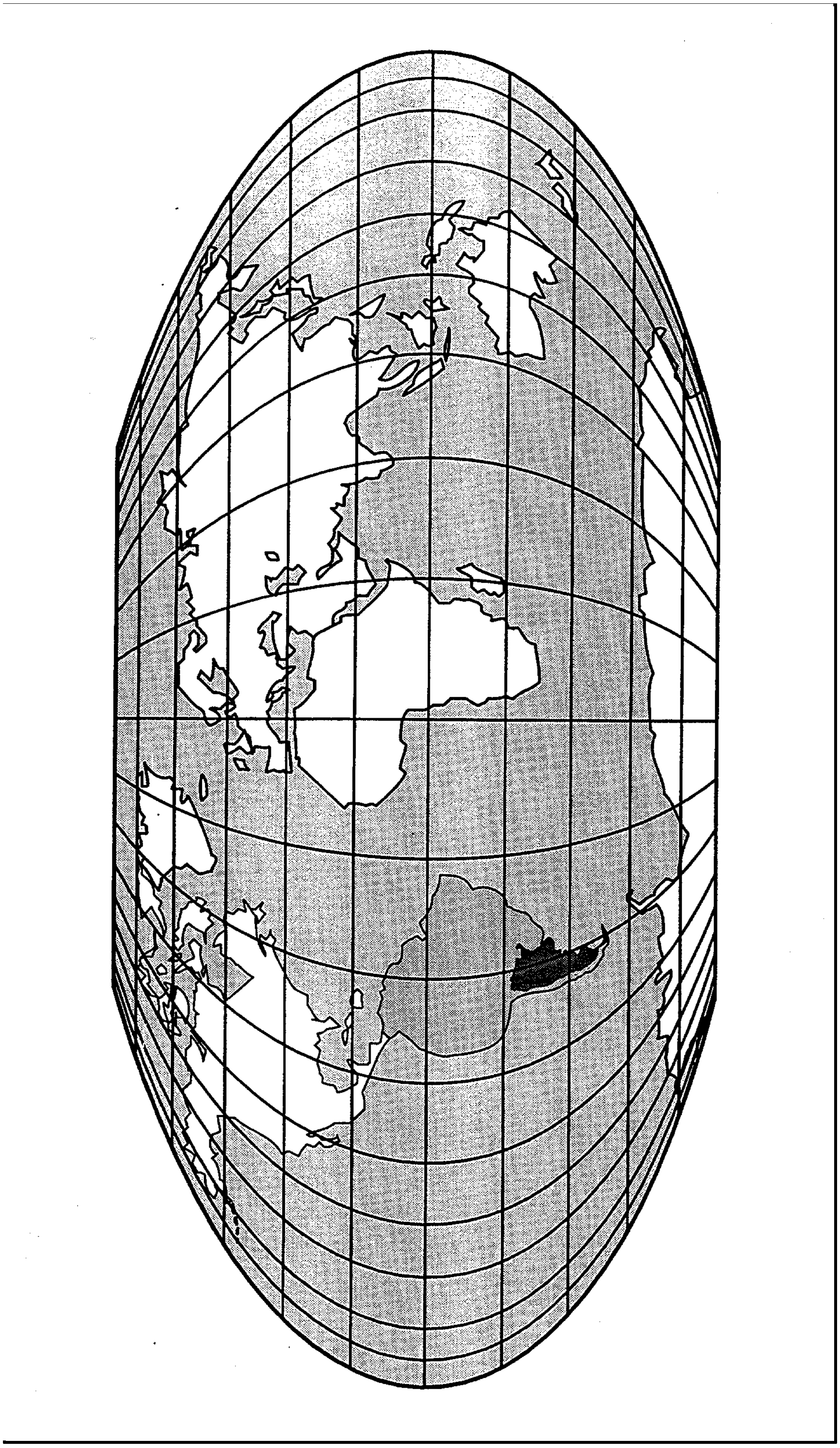

Figure 1. Where is Argentina in the World?

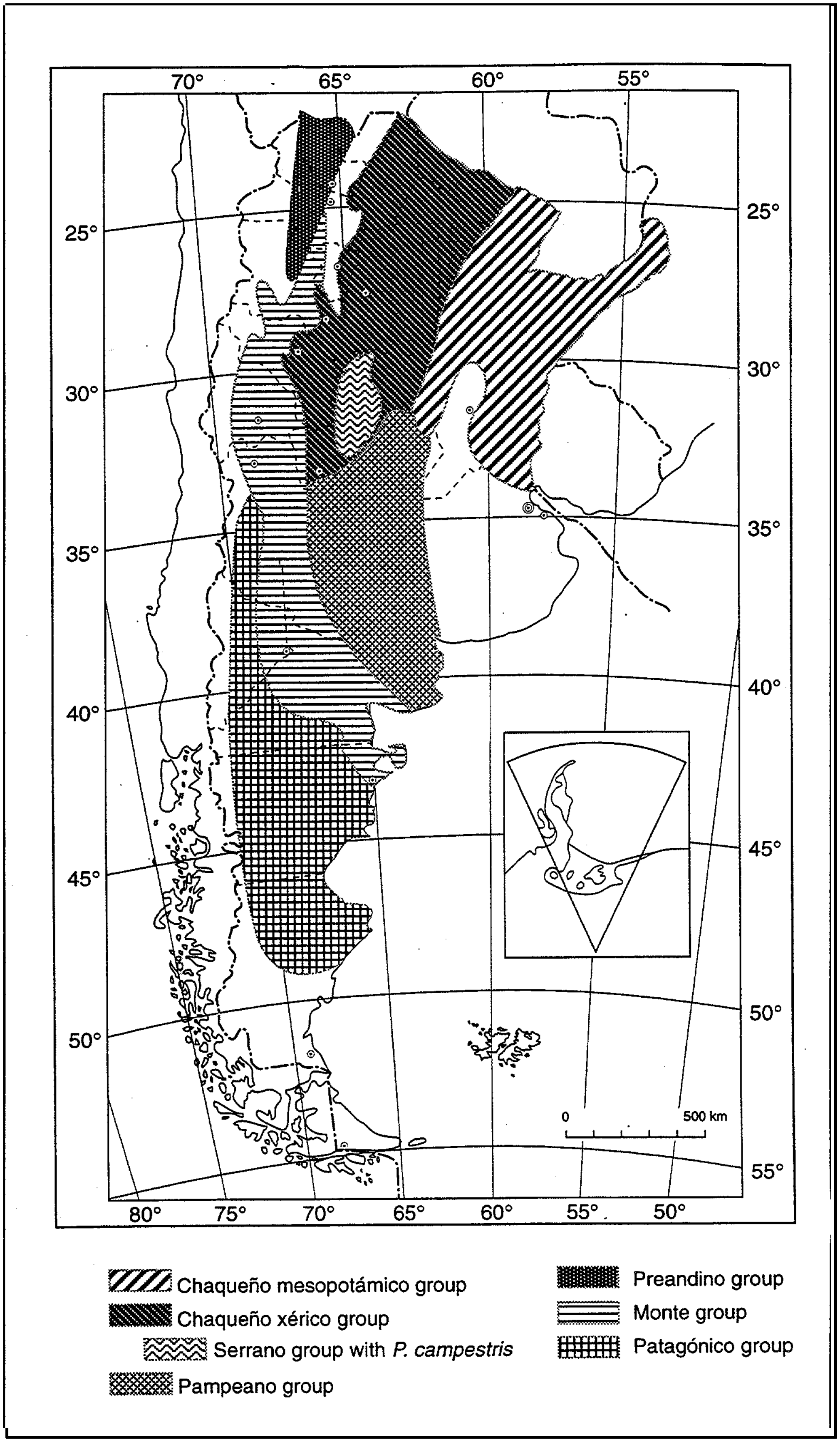

Figure 2. Argentinian *Prosopis* Grouping According to the Landscape

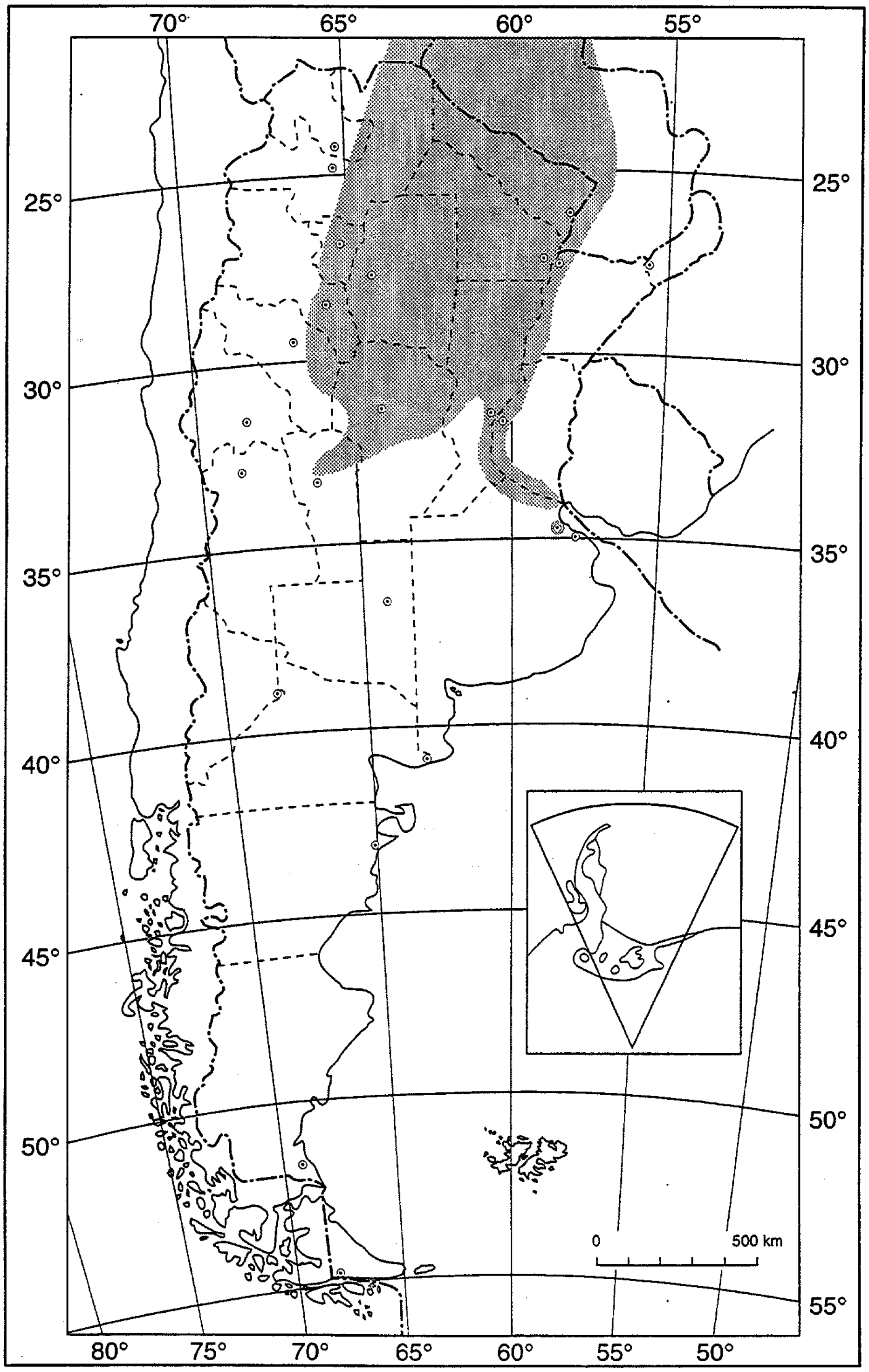

Figure 3. ***Prosopis alba*** **Distribution in Argentina**

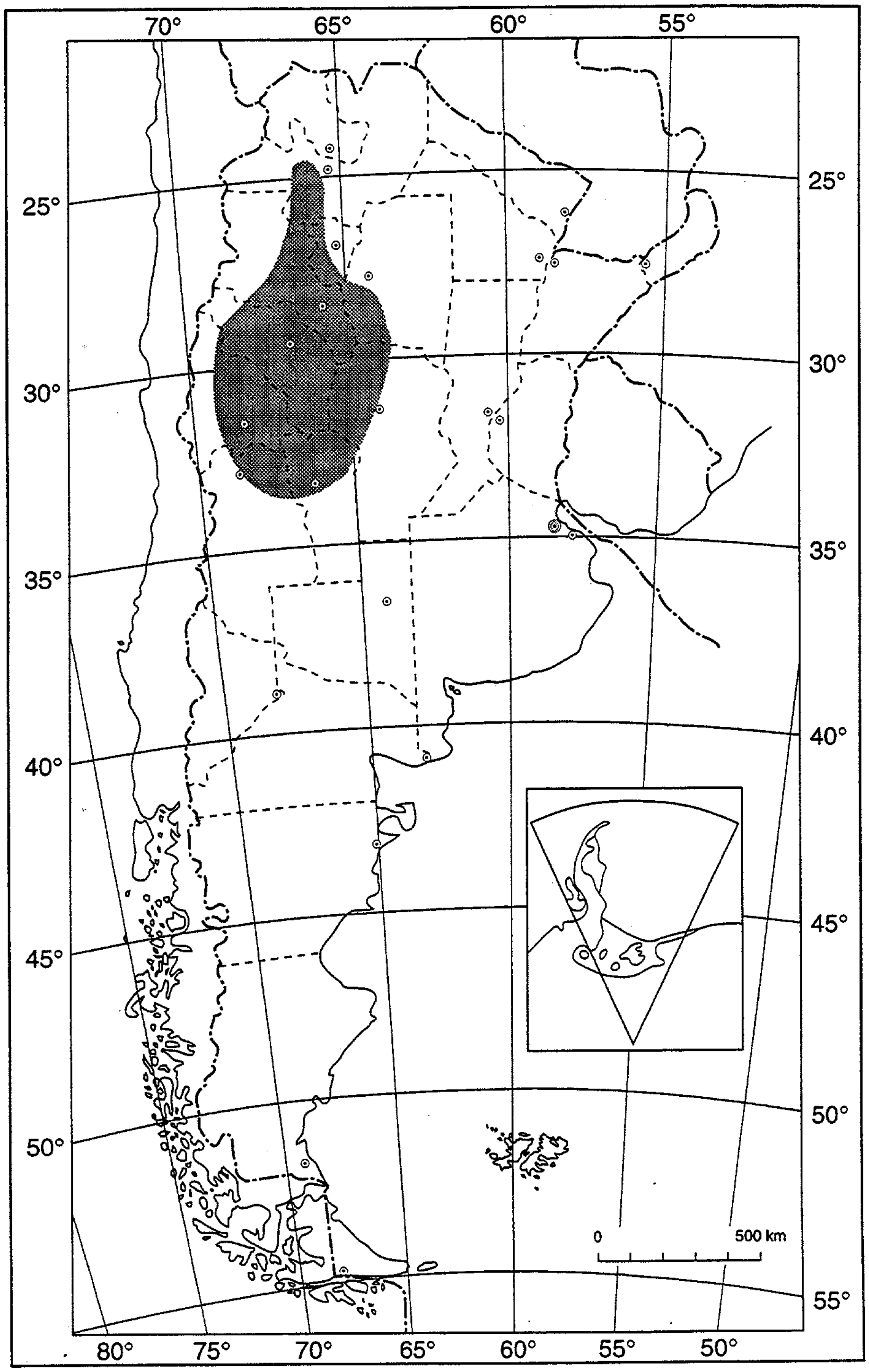

Figure 4. *Prosopis chilensis* Distribution in Argentina

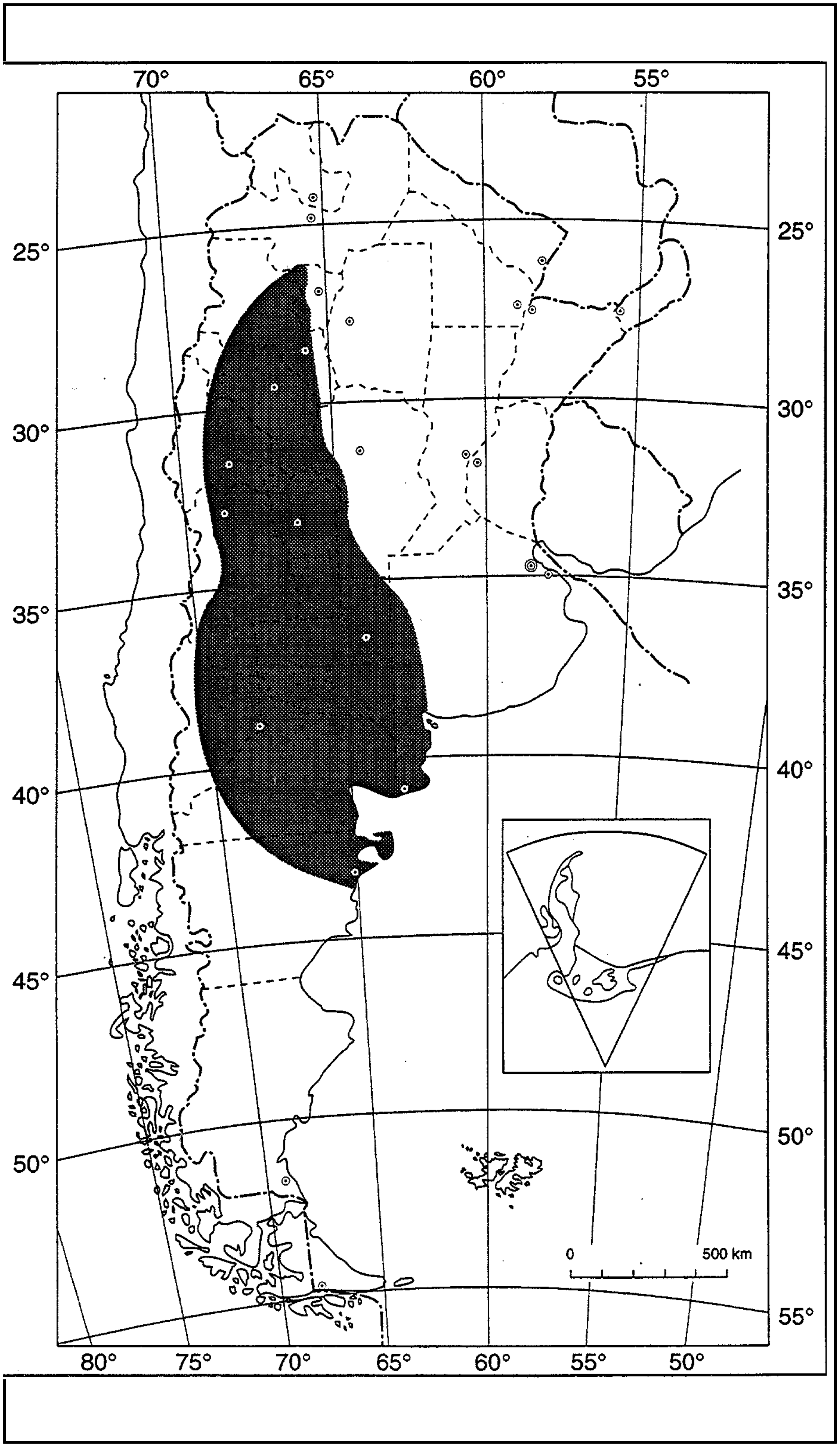

Figure 5. *Prosopis flexuosa* Distribution in Argentina

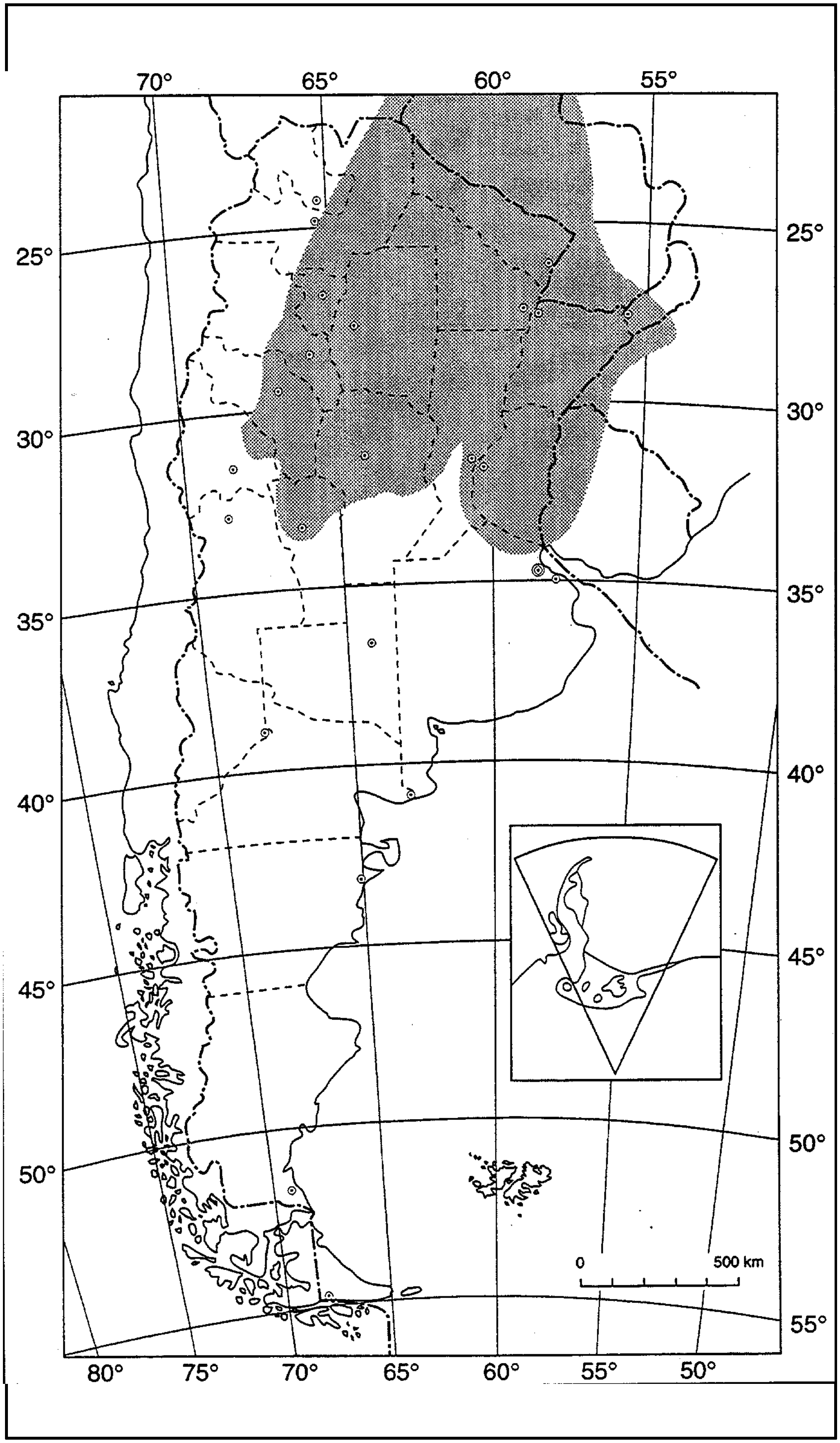

Figure 6. *Prosopis nigra* Distribution in Argentina

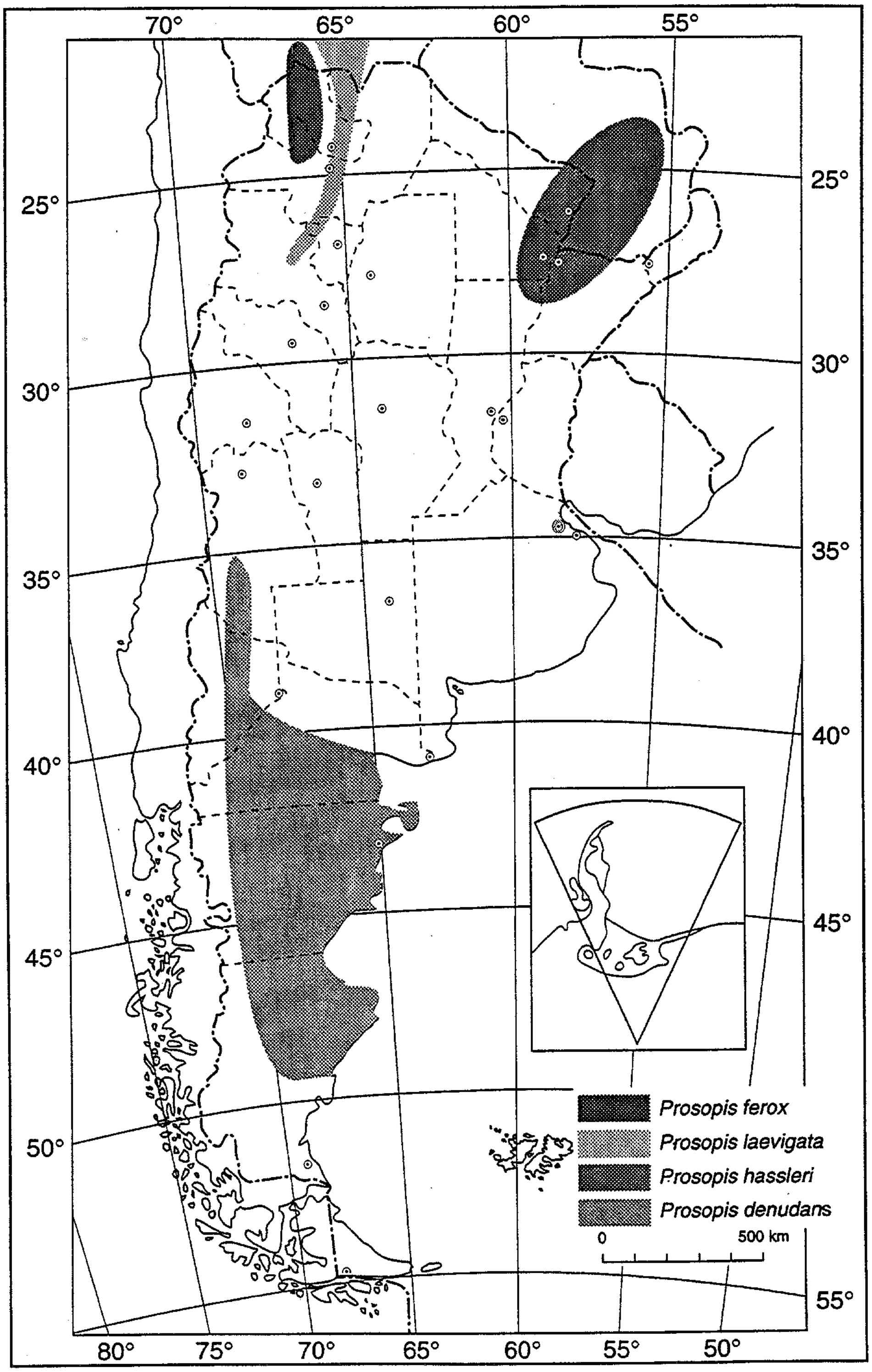

Figure 7. ***Prosopis ferox, P. laevigata, P. hassleri,*** **and** ***P. denudans*** **Distribution in Argentina**

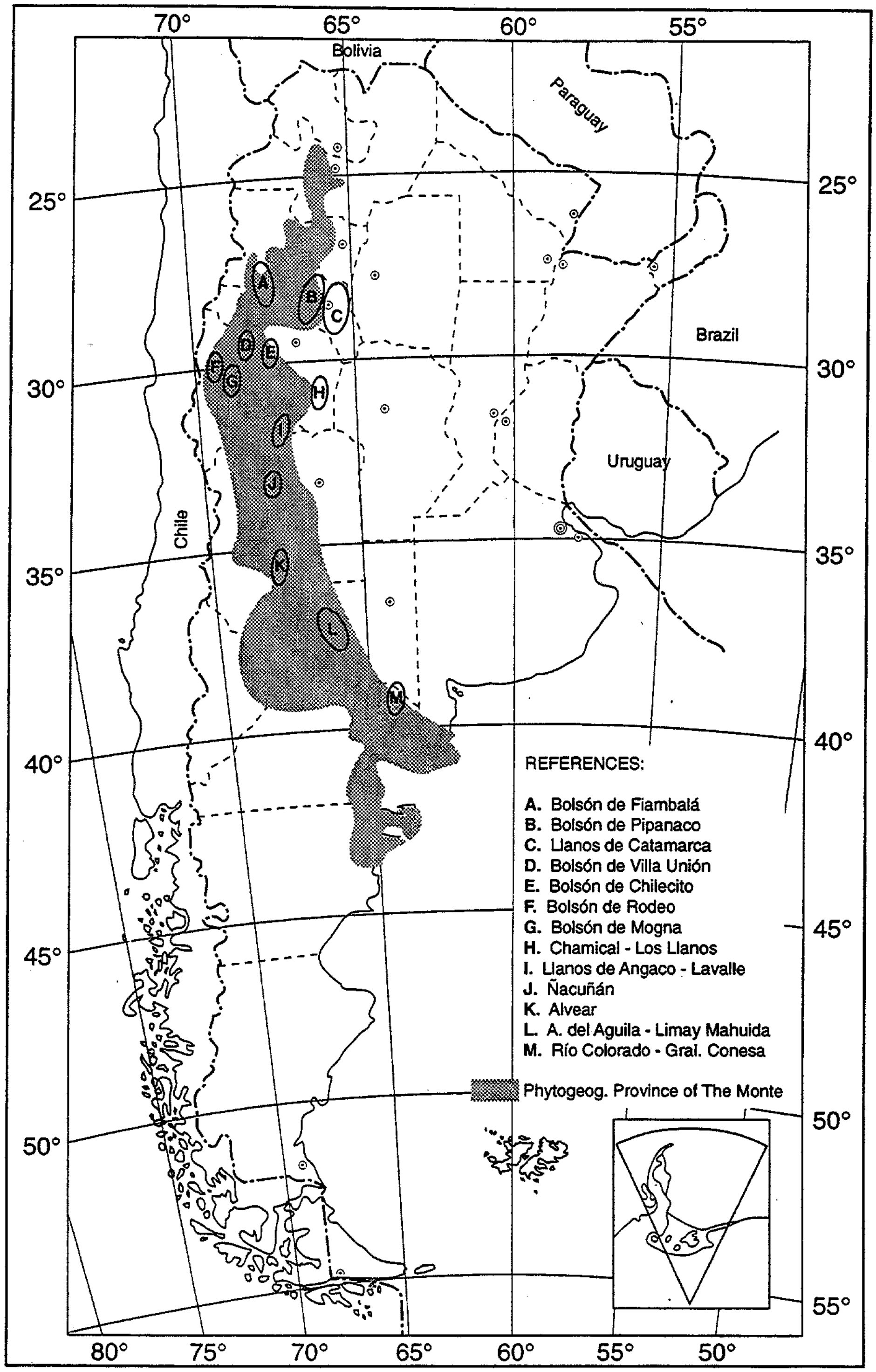

Figure 8. *Prosopis flexuosa* and *P. Chilensis* Genetic Material Areas in The Monte Phytogeographic Province

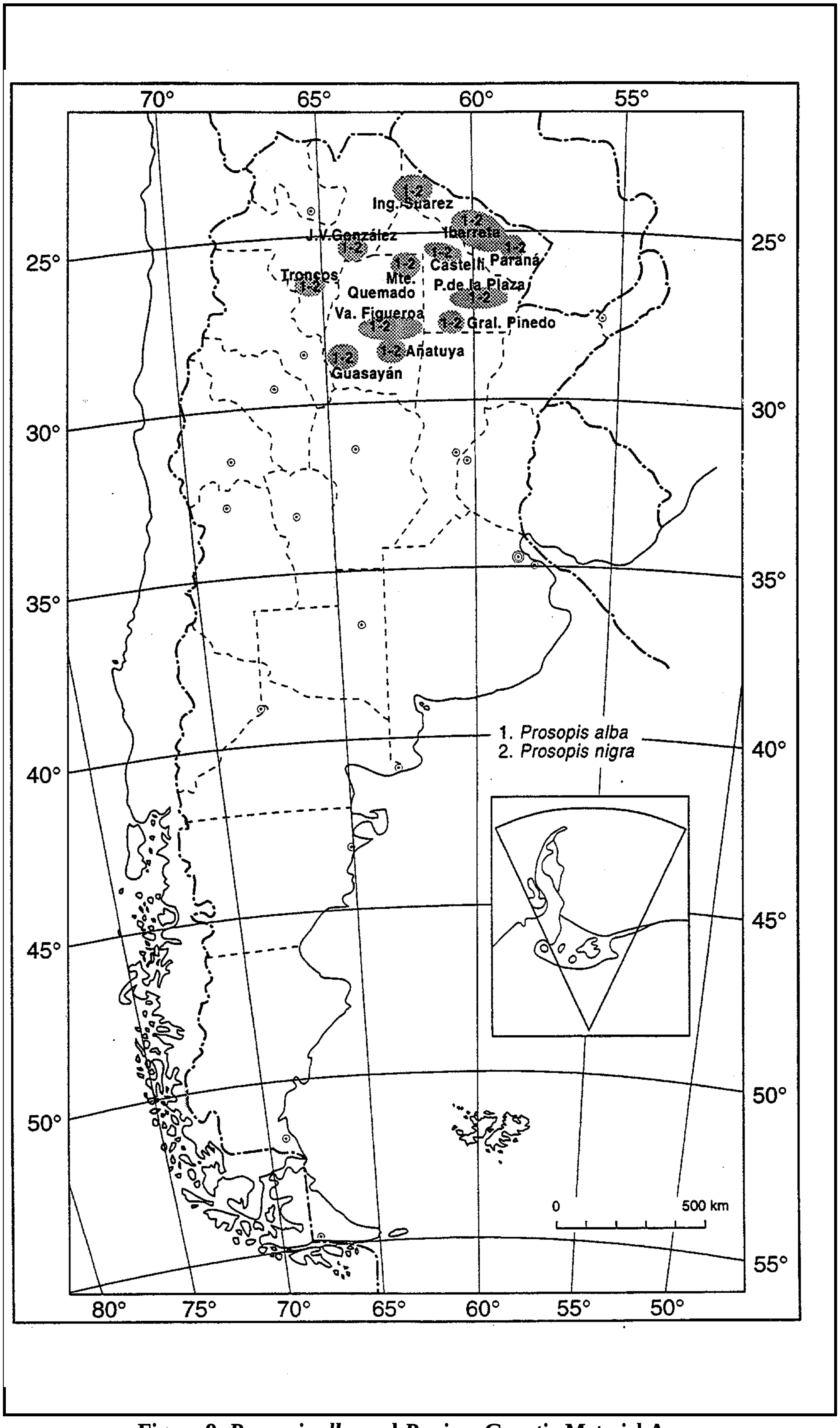

Figure 9. *Prosopis alba* and *P. nigra* Genetic Material Areas in the Chaco Phytogeographic Province

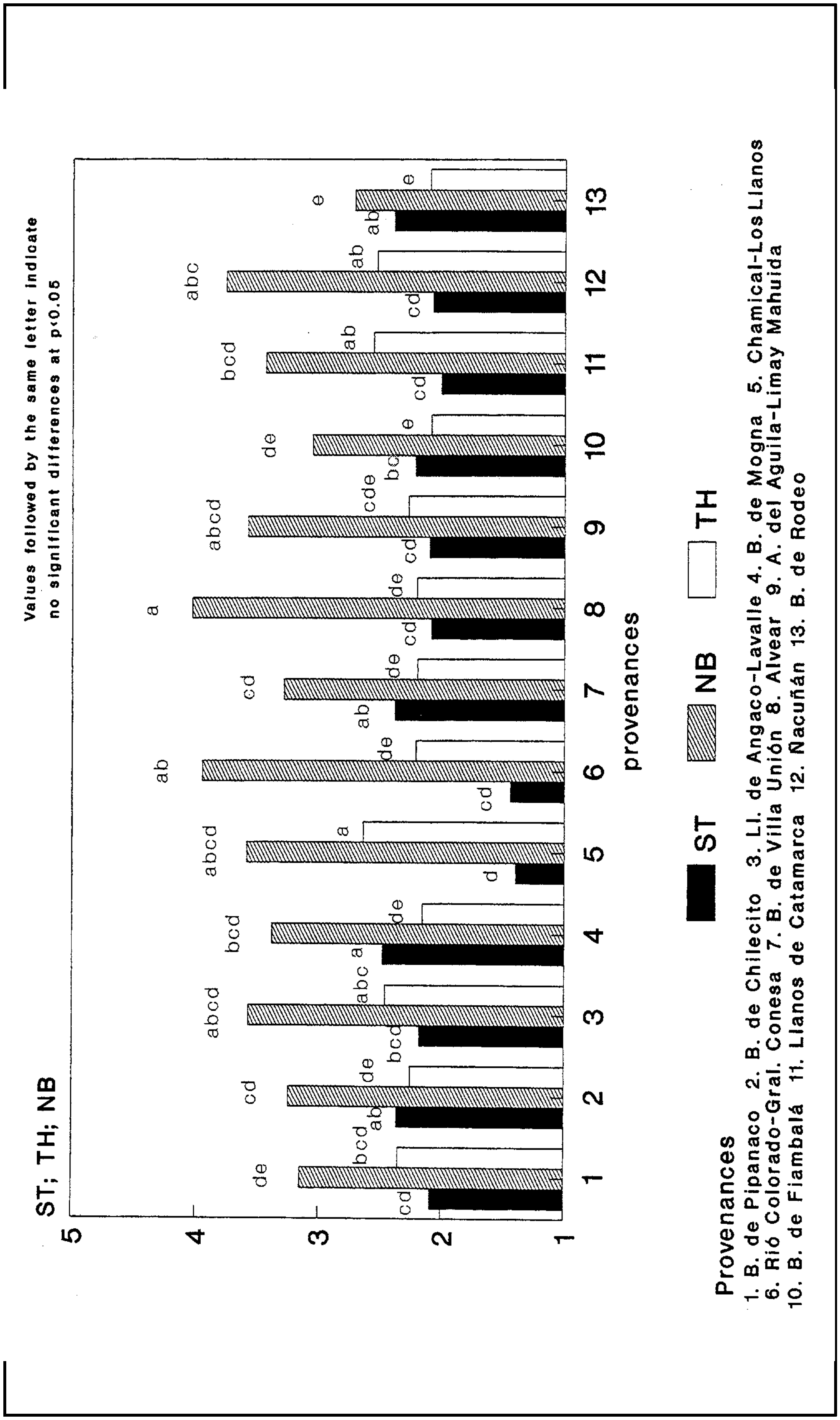

Figure 10. Straightness (ST), Number of Branches (NB), and Thorniness (TH) From Different *P. flexuosa* Provenances

Table 1. Ranking of Provenances for 34-Month Heights and Duncan Groupings in *Prosopis flexuosa*

Provenances	Mean Height (m)	Duncan Grouping*	Rank	Total Number of Families per Provenance
Bolsón de Fiambalá	1.23	a	1	6
Bolsón de Pipanaco	1.22	a	2	8
Bolsón de Mogna	1.07	b	3	12
Bolsón de V. Unión	1.06	b	4	5
Chamical-Llanos de La Rioja	1.03	bc	5	9
Llanos de Catamarca	1.02	bc	6	3
Bolsón de Chilecito	1.01	bcd	7	6
Llanos de Angaco-Lavalle	1.00	bcd	8	7
Alvear	0.94	bcde	9	5
Ñacuñán	0.93	bcde	10	5
A. Aguila-Limay Mahuida	0.89	cde	11	10
Bolsón de Rodeo	0.86	e	12	2
Río Colorado-Gral. Conesa	0.84	e	13	8

* Values followed by the same letter indicated no significant differences at $p<0.05$.

Table 2. Ranking of Provenances for 34-Month Basal Diameter and Duncan Groupings in *Prosopis flexuosa*

Provenance	Mean Basal Diameter (cm)	Duncan Grouping	Rank	Total Number of Families per Provenance
Bolsón de Fiambalá	1.40	a	1	6
Llanos de Catamarca	1.31	a	2	3
Chamical-Llanos de La Rioja	1.26	abc	3	9
Bolsón de Mogna	1.24	abcd	4	12
Alvear	1.19	bcde	5	5
Bolsón de Pipanaco	1.16	bcde	6	8
Llanos de Angaco-Lavalle	1.16	bcde	7	7
Ñacuñán	1.14	bcde	8	5
Bolsón de Villa Unión	1.08	cde	9	5
A. Aguila-Limay Mahuida	1.07	cde	10	10
Río Colorado-Gral. Conesa	1.07	cde	11	8
Bolsón de Chilecito	1.03	de	12	6
Bolsón de Rodeo	1.01	e	13	2

*** Values followed by the same letter indicated no significant differences at $p<0.05$.**

Table 3. Ranking of Provenances for 42-Month Heights and Duncan Groupings in *Prosopis chilensis*

Provenance	Mean Height (m)	Duncan Grouping*	Rank	Total Number of Families per Provenance
Bolsón de Pipanaco	1.83	a	1	13
Chamical-Llanos de La Rioja	1.76	ab	2	19
Bolsón de Fiambalá	1.68	ab	3	10
Bolsón de Rodeo	1.64	ab	4	1
Llanos de Catamarca	1.57	ab	5	9
Bolsón de Chilecito	1.53	ab	6	7
Bolsón de Villa Unión	1.50	ab	7	8
Bolsón de Mogna	1.50	ab	8	15
Llanos de Angaco	1.39	b	9	2

*** Values followed by the same letter indicated no significant differences at $p<0.05$.**

Table 4. Ranking of Provenances for 42-Month Basal Diameter and Duncan Groupings in *Prosopis chilensis*

Provenance	Mean Basal Diameter (cm)	Duncan Grouping*	Rank	Total Number of Families per Provenance
Bolsón de Pipanaco	2.74	a	1	13
Chamical-Llanos de La Rioja	2.42	ab	2	19
Bolsón de Rodeo	2.41	ab	3	1
Llanos de Catamarca	2.28	ab	4	9
Bolsón de Fiambalá	2.27	ab	5	10
Bolsón de Villa Unión	2.09	ab	6	8
Bolsón de Chilecito	2.04	ab	7	7
Bolsón de Mogna	1.98	b	8	15
Llanos de Angaco-Lavalle	1.87	b	9	2

*** Values followed by the same letter indicated no significant differences at $p<0.05$.**

Table 5. Spread of Family Ranking Within Provenances for 34-Month Heights in *Prosopis flexuosa*

Provenance Ranking	Provenance	Spread of 86 Family Rankings for Heights						
1	Bolsón de Pipanaco	2	3	8	16	21	23	28
		30						
2	Bolsón de Fiambalá	1	5	7	18	19	48	
3	Bolsón de Mogna	9	10	13	14	22	25	28
		43	55	63	66	76		
4	Bolsón de Villa Unión	12	26	34	40	68		
5	Chamical-Llanos de La Rioja	4	20	24	42	51	53	60
		62	69					
6	Llanos de Catamarca	27	46	52				
7	Bolsón de Chilecito	17	29	45	47	54	71	
8	Llanos de Angaco-Lavalle	6	15	32	35	49	72	85
9	Alvear	11	56	67	70	82		
10	Ñacuñán	36	50	58	64	75		
11	A. del Aguila-Limay-Mahuida	33	39	44	61	65	73	74
		77	78	80				
12	Bolsón de Rodeo	57	79					
13	Río Colorado-Gral. Conesa	31	37	59	81	83	84	86

Table 6. Spread of Family Ranking Within Provenances for 42-Month Heights in *Prosopis chilensis*

Provenance Ranking	Provenance	Spread of 84 Family Rankings for Heights						
1	Bolsón de Pipanaco	1	3	4	10	16	19	25
		30	38	52	65	67	75	
2	Chamical-Llanos de La Rioja	5	6	7	8	9	11	20
		22	23	34	37	43	44	47
		48	49	58	72	79		
3	Bolsón de Fiambalá	2	13	27	28	40	42	54
		61	66	68				
4	Bolsón de Rodeo	41						
5	Llanos de Catamarca	12	18	31	35	57	60	64
		70	81					
6	Bolsón de Chilecito	15	17	26	35	46	74	83
7	Bolsón de Villa Unión	21	29	33	53	59	63	69
		84						
8	Bolsón de Mogna	14	24	32	36	45	51	55
		56	62	71	73	76	77	78
		80						
9	Llanos de Angaco	50	82					

Table 7. Proportion of the Genetic Variation Components for Height (H) and Basal Diameter (BD) Traits in 34-Month *Prosopis flexuosa* and 42-Month *Prosopis chilensis* Populations Growing in the Monte Zone

Genetic Variation Component	*P. flexuosa*		*P. chilensis*	
	H	BD	H	BD
V_p	45	36	29	33
$V_{f(p)}$	55	64	71	66

Table 8. Extreme Values for Familiar and Individual Means for Height (H) and Basal Diameter (BD) in 34-Month *Prosopis flexuosa* and 42-Month *Prosopis chilensis* Trees

Means and Values	*P. flexuosa*		*P. chilensis*	
	H (m)	BD (cm)	H (m)	BD (cm)
M.F.M.	1.42	1.64	2.52	4.70
m.F.M.	0.52	0.79	0.60	0.88
M.I.V.	3.00	8.84	4.10	20.20
m.I.V.	0.17	0.11	0.20	0.35

M.F.M.: Maximum familiar mean
m.F.M.: Minimum familiar mean
M.I.V.: Maximum individual value
m.I.V.: Minimum individual value

Table 9. Heritabilities at Individual and Familiar Level for Height (H), Basal Diameter (BD), Straightness (ST), Branching (NB), and Thorniness (TH) in 34-Month-Old *Prosopis flexuosa* Trees

Trait	H	BD	ST	NB	TH
Heritability at individual level	0.68	0.22	0.43	0.24	0.85
Heritability at familiar level	0.67	0.40	0.61	0.45	0.76

Table 10. Heritabilities at Individual and Familiar Level for Height (H) and Basal Diameter (Bd) in 42-Month-Old *Prosopis chilensis* Trees

Traits	H	BD
Heritability at individual level	0.39	0.36
Heritability at familiar level	0.41	0.40

Table 11. Estimation of Genetic and Phenotypic Correlations For Height (H), Basal Diameter (BD), Straightness (ST), Branching (NB), and Thorniness (TH) in 34-Month-Old *Prosopis flexuosa* Trees

Trait	Correlation Coefficient	BD	ST	NB	TH
H	r_F	0.61*	0.39*	–0.24*	0.04 NS
	r_A	0.65*	0.37*	–0.42*	–0.14*
BD	r_F	-	–0.16*	0.13*	0.21*
	r_A	-	0.13*	0.07 NS	0.02 NS
ST	r_F	-	-	–0.42*	–0.56*
	r_A	-	-	–0.61*	–0.69*
NB	r_F	-	-	-	0.40*
	r_A	-	-	-	0.49*

*$p<0.01$; NS: Not significant
r_F = estimate of the phenotypic correlation coefficient
r_A = estimate of the additive genetic correlation coefficient