

Genetic variation in *Astronium fraxinifolium* populations in consortium**

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ABSTRACT

Two progeny tests of two gonalo-alves (*Astronium fraxinifolium*) populations were evaluated in March 1996 at Selvria, Mato Grosso do Sul State, Brazil. A randomized complete block design with 30 treatments (progenies) and five replications was used. Plots were formed by 10 plants arranged in a alternate single rows. Spacing was 3.0m between plants within rows and between rows. Data on 10 silvicultural traits were obtained to help in “*ex situ*” efforts of genetic conservation of the species. The progenies had excellent performance in the used growing system. Both populations presented genetic variability for all analyzed traits, although no significant difference between the populations was detected. It is therefore recommended that both populations be considered as a single population for “*ex situ*” genetic conservation purposes. In a genetic breeding program involving those populations, plant height is the trait with greater chances of obtaining the selection gain in level of average of families.

KEY WORDS: Tree species, genetic breeding, progeny test, genetic parameters, genetic conservation.

INTRODUCTION

Tropical biomass has large species diversity and species specialization to the colonized environments. However, intense deforestation and lack of knowledge on tropical tree species have caused concern for both “*in situ*” and “*ex situ*” conservation of these species.

Natural populations in different tropical biomass seldom exist in isolation, neither do the factors that shape the genetic structure of a population. Nature provides a wide range of habitats over time and space and, as a result, the process of managing genetic diversity is the dynamic (Yeh, 2000). Therefore, the genetic processes and their natural dynamic are fundamental when considering “*ex situ*” or “*in situ*” conservation forms and the use of forest resources. The reduction in the number of populations or individuals has led many species to reach an evolutionary standstill as result of the loss of genetic variability, which precludes their adaptation to

environmental changes.

The “*in situ*” conservation of genetic resources would certainly be the most suitable, since, in such situation, the whole community of species that have potential value is being maintained along with the target species of economic value or research interest (Kageyama et al., 2001). However, some tropical biomasses are not well represented, with only small fragments surviving in the middle of large agricultural areas. Only the “*in situ*” conservation cannot contribute greatly to the survival of some species. The *Astronium fraxinifolium* (gonalo-alves) species of the Anacardiaceae family, whose occurrence has been restricted to highway verges and small ecological reserves, can be considered one of these species. It has become restricted to a few individuals in habitats totally degraded by man.

The *Astronium* genus consists of 13 species and eight varieties, distributed from Mexico to Argentina, including the Isles of Trinidad and Tobago in the

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Caribbean. According to the literature, 12 species occur from Northern to Southern Brazil, occupying various habitats such as the Cerrado areas in the Mato Grosso Wetlands, Caatingas forests and surrounding areas, river belt woods, the Amazon forest and the Atlantic rain forest (Santin, 1989). *A. fraxinifolium* is considered the species with widest distribution in Brazil.

From the economic point of view, they are trees of very dense (1.09g/cm³), compact, rigid, hard to work wood, with differentiated white auburn, excellent quality and high tannin content, which makes them very resistant to rotting when in contact with the soil for long periods. This wood is used for civil and naval construction, carpentry, sleeper manufacture, hand rails, balustrades, pillow blocks, structures, hydraulic wheels and finely finished doors (Lorenzi, 1992). The tree has a medium stand and a lovely canopy, which makes it very valuable for general landscape gardening, with the single disadvantage of losing leaves in winter. It is found on rocky dry land forming discontinuous clusters.

A large quantity of seeds that are easily disseminated by the wind is annually produced (Lorenzi, 1992). According to Allem (1991), the *A. fraxinifolium* tree has male and female flowers on the same plant (monoecious) or on different plants (diecious), which are predominantly pollinated by insects. The wind plays a small role in the fertilization process but plays an important role in seed dispersal, as *A. fraxinifolium* trees annually produce many seeds easily disseminated by the wind (Allem, 1991).

Procedence and progeny tests involving this forest species in consortium with others are essential for a better understanding of the biological behavior and the genetic structure of the populations. They are also important to generate suitable management strategies for species conservation.

According to Kageyama and Gandara (2000), restoration planting or procedence and progeny testing must take into consideration the species classification based on ecological and silvicultural performance. Therefore, grouping the species in two large collections is desirable: pioneers or shade-providers (species with rapid growth) and non-pioneers or shaded (species with slow growth). The *A. fraxinifolium* belongs to the shaded group, that is, this species develops well in association with a quick growing pioneer species and with other species of the shaded group (Aguiar et al., 1999; Fonseca et al., 1998).

In this study, the genetic variability between and

within two *A. fraxinifolium* populations were assessed through the estimation of genetic parameters of silvicultural traits to provide a better understanding of the genetic structure of the species for fostering and genetic conservation purposes.

MATERIAL AND METHODS

Seeds from the progenies included in the progeny tests of two *A. fraxinifolium* and one jacarandá-caroba (*jacaranda cuspidifolia*) populations were obtained in September 1995. They were collected from 30 randomly chosen open pollinated trees located more than 100 meters apart. One *A. fraxinifolium* population was obtained from the verges of the SP 595 highway, between the counties of Ilha Solteira and Santa Fé do Sul in São Paulo (SP) State and the other *A. fraxinifolium* population was obtained from the verges of the MS 158 highway, in the county of Selvíria in Mato Grosso do Sul (MS) State. It is worth pointing out that the two sampled *A. fraxinifolium* populations are separated by the lake formed by the Ilha Solteira electric plant, on the River Paraná, between the counties of Selvíria - MS and Ilha Solteira - SP.

The experiment was carried out on the School and Research Farm of the UNESP Faculty of Engineering - Ilha Solteira, located on the right bank of the Paraná river, at the geographic coordinates 20° 19'S, 51° 26'W and 327 m altitude, in the county of Selvíria - MS. The original vegetation found in the area is Cerrado-type. The soil was classified as Distrophic Red Lattosol, clay texture (Embrapa, 1999).

The consortium progeny tests were set up on March 26 1996, and each *A. fraxinifolium* population was associated to progenies from the *J. cuspidifolia* population.

A randomized complete block design with 30 treatments (progenies) and five replications was used. Each plot was formed by a single row with 10 plants spaced at 3.0m. Row spacing was also 3.0m. Row planting was alternated between the species in consortium. All *A. fraxinifolium* plants were used for data recording.

Silviculture data recording began in 1997 when the plants were one year old. The total plant heights of the *A. fraxinifolium* trees were obtained in 1997, 1998, 1999 and 2000 (ALT1, ALT2, ALT3, ALT4, respectively). Mean canopy diameter (DMC), stem diameter at 30cm from the soil (DA3), stem form

(FOR), bark thickness (ESP), basic bark density (DBC) and survival rate (SOB) were collected only in 1999. The trunk shape (FOR) was assessed based on a scale of scores ranging from 1 to 10 (Aguiar, 2001).

Estimates of the genetic and statistical parameters were obtained based on the methodology proposed by Vencovsky and Barriga (1992), using the analyses of variance of the means for the quantitative trait analyzed.

Tables 1 and 2 show the sources of variation and the expected mean squares for the individual and joint analyses of the *A. fraxinifolium* populations.

The mathematical model adopted in the individual

analyses within populations, was

$$Y_{ijl} = m + r_j + f_i + d_{l(ij)} + e_{ij}, \text{ where,}$$

Y_{ijl} is the observation on the l^{th} tree of the i^{th} progeny in the j^{th} replication; m is the general mean, r_j is the effect of the j^{th} replication, where $j = 1, 2, \dots, r$; f_i is the effect of the i^{th} progeny, where $i = 1, 2, \dots, f$; $d_{l(ij)}$ is the deviation of the l^{th} tree from the ij^{th} plot, with $l = 1, 2, \dots, n$; e_{ij} is the experimental error.

The mathematical model used in the joint analyses, taking the experimental effects as fixed and the

Table 1. Design of Individual analysis of variance of silvicultural traits of *A. fraxinifolium* populations including the following sources of variation (FV): replications (R), progenies (F) experimental error (E) and within plot error (D).

FV	GL	QM	E(QM)	F
R	(r-1)	Q ₁	-	-
F	(f-1)	Q ₂	$(1/\bar{n})\sigma_d^2 + \sigma_e^2 + r\sigma_p^2$	Q ₂ /Q ₃
E	(r-1)(f-1)	Q ₃	$(1/\bar{n})\sigma_d^2 + \sigma_e^2$	-
D	(n-1)fr	Q ₄	$(1/\bar{n})\sigma_d^2$	-

\bar{n} is the harmonic mean of the number of plants within plots.

Table 2. Design of joint analysis of variance of *A. fraxinifolium* populations for each silvicultural traits including the following sources of variation (FV): replication within populations (R/P); populations (P); within population progenies (F/P); mean error (E/P) and within plot error (D).

FV	GL	QM	E(QM)	F
R/P	(r-1)p	Q ₁	$(1/\bar{n})\sigma_d^2 + \sigma_e^2 + f\sigma_r^2$	Q ₁ /Q ₆
P	(p-1)	Q ₂	$(1/\bar{n})\sigma_d^2 + \sigma_e^2 + r\sigma_r^2 + f\sigma_r^2 + fr\sigma_p^2$	$(Q_2+Q_6)/(Q_1+Q_3)$
F/P	(f-1)p	Q ₃	$(1/\bar{n})\sigma_d^2 + \sigma_e^2 + r\sigma_f^2$	Q ₃ /Q ₆
F/P _i ^{1/}	(f _i -1)	Q ₄	$(1/\bar{n})\sigma_{di}^2 + \sigma_e^2 + r\sigma_{fi}^2$	$\frac{[Q_4 + (1/\bar{n})Q_9]}{[Q_6 + (1/\bar{n})Q_7]}$ ^{2/}
F/P _s ^{1/}	(f _s -1)	Q ₅	$(1/\bar{n})\sigma_{ds}^2 + \sigma_e^2 + r\sigma_{fs}^2$	$\frac{[Q_5 + (1/\bar{n})Q_9]}{[Q_6 + (1/\bar{n})Q_8]}$
E/P	(f-1)(r-1)p	Q ₆	$(1/\bar{n})\sigma_d^2 + \sigma_e^2$	-
D _i	(d _i -1)f _i r	Q ₇	\hat{h}^2	-
D _s	(d _s -1)f _s r	Q ₈	σ_{ds}^2	-
D ^{3/}	(d-1)frp	Q ₉	$(\hat{\sigma}_p^2)$	-

^{1/} Pi: Ilha Solteira *A. fraxinifolium* population; PS: Selvíria *A. fraxinifolium* population; ^{2/} degrees of freedom associated to the F estimates for populations and progeny/population; ^{3/} within variance not obtained in the analysis of variance; (\bar{n}) is the harmonic mean of the number of plants within plots; $f = f_i + f_s$.

progeny effects as random was

$$Y_{ijkl} = m + r_{j(k)} + p_k + f_{i(k)} + d_{l(ijk)} + \bar{e}_{ij(k)}$$

Y_{ijkl} is the observation in the l^{th} tree, in the k^{th} population, i^{th} progeny and j^{th} replication; m is the general mean; $r_{j(k)}$ is the effect of the j^{th} replication within the k^{th} population, where $j = 1, 2, \dots, r$; p_k is the effect of the k^{th} population, where $k = 1, 2, \dots, f$; $f_{i(k)}$ is the effect of the i^{th} progeny within the k^{th} population where $i = 1, 2, \dots, f$; $e_{ij(k)}$ is the experimental error of the ij^{th} plot within the k^{th} experiment; and, $d_{l(ijk)}$ is the deviation of the l^{th} tree in the ij^{th} plot of the k^{th} experiment, where $l = 1, 2, \dots, n$.

RESULTS AND DISCUSSION

Table 3 shows that the Selvíria *A. fraxinifolium* population presented the highest means for the silvicultural traits. It also shows that the magnitude of the F-test values of the silvicultural traits was higher for the Ilha Solteira *A. fraxinifolium* population, indicating greater among progeny genetic variability. Fonseca et al. (1998), performed progeny tests with three native species including *A. fraxinifolium* and obtained the total height of 3.50m, 3.21m and 3.90m for *A. fraxinifolium*, *Myracrodruon urundeuva* and *Terminalia argentea*, respectively, in three year old trees at the same location of the present study. Table 3 shows that the average *A. fraxinifolium* development in the third year after planting was superior to that reported by the previously quoted authors, mainly for the Ilha Solteira population. These results suggest that the *A. fraxinifolium* consortium to a faster developing species, such as the *J. cuspidifolia*, increases its growth rate.

The DBC and DMC means for the *A. fraxinifolium* progenies are in line with those obtained by Freitas (1999) for *M. arundeuva* (0.59 g/cm³ and 1.86m).

The species presented the very low shape mean of 4.58 for the Ilha Solteira *A. fraxinifolium* population and 4.75 for the Selvíria. This reflects the many branches and twists of the stems. Freitas (1999) obtained better results for 4.5 year old *M. urundeuva* (5.90) trees in different planting systems.

The coefficients of experimental variation (CV_{exp}) for the silvicultural traits varied from 4.84% to 12.69% and from 5.66% to 16.37% for DBC and ALT1, respectively, for the Selvíria and Ilha Solteira *A.*

fraxinifolium populations (Table 3). These results showed that the microenvironment influence was greater on the Ilha Solteira population traits, mainly on those assessed at the initial developmental stages, which are obtained with less precision and may have contributed to the experimental error. The fact that these traits are more sensitive to microenvironmental variability cannot be disregarded.

The CV_{exp} values obtained for the plant height trait (ALT1, ALT2, ALT3, ALT4) can be considered low when compared to data from studies of Sebbenn et al. (1998), Sebbenn et al. (1999a) and Ettori et al. (1996) for the same traits in other species.

Table 3 shows significant among progeny genetic variability in the two *A. fraxinifolium* populations for all the silvicultural traits, except for the survival trait, which was uniform (80%) within the populations.

As for these plants survival, Sebbenn et al. (1998) detected a lower survival rate (74.5%) for four year old *Mayroxylon peruiferum* (cabreúva) trees. According to Sebbenn et al. (1999b), plant survival and reproductive capacity are indicators of the species adaptation to a given environment. Therefore, the survival results suggest that the species have good adaptation to the experimental locations. Oliveira et al. (2000) found high plant survival rates when assessing *M. arundeuva* survival in consortium (97.22%) and homogeneous (97.44%) planting systems, which are higher than those reported for *A. fraxinifolium*.

Table 4 shows that the two *A. fraxinifolium* populations were not genetically different, although they were separated by the lake formed by the construction of the Ilha Solteira Hydroelectric Plant.

The joint analysis detected highly significant progeny effect within populations for all the silvicultural traits. Large variability was observed within populations rather than between populations (Table 4). Sebbenn et al. (1999a) working with *Grevilea robusta* populations from three different locations were obtained similar results.

Most studies with native trees have shown large within population variability. Nogueira et al. (1986b) detected significant among progeny differences within *Astonium urundeuva* populations. Nogueira et al. (1986a) studied progenies from four *Pterogyne nitens* Tul. (amendoim) populations and detected significant among progeny genetic variability in two populations. Siqueira et al. (1986a) studied *Peltophorium dubium* populations in Pederneiras and

Table 3. Means and analyses of variance results of silvicultural traits of two *A. fraxinifolium* populations (from Selvíria, MS and Ilha Solteira, SP) assessed in Selvíria, MS ^{1/}.

Traits	Populations							
	SELVIRIA-MS				ILHA SOLTEIRA-SP			
	Means	CV _{exp} (%)	F	Pr > F	Means	CV _{exp} (%)	F	Pr > F
ALT1 (m)	1.55	12.69	1.92	0.0080	1.43	16.37	3.66	0.0001
ALT2 (m)	2.96	10.20	2.91	0.0001	2.78	14.64	2.47	0.0004
ALT3 (m)	3.88	9.94	3.27	0.0001	3.58	13.34	2.66	0.0001
ALT4 (m)	4.71	9.94	4.07	0.0001	4.34	13.35	2.97	0.0001
DMC (m)	1.94	11.30	2.73	0.0001	1.86	12.50	3.62	0.0001
DA3 (cm)	6.43	10.68	2.85	0.0001	5.96	13.36	2.52	0.0003
FOR	4.75	12.16	3.12	0.0001	4.58	13.36	3.35	0.0001
ESP (mm)	11.97	10.29	3.70	0.0001	10.78	13.16	5.08	0.0001
DBC (g/cm ³)	0.64	4.84	1.25	0.2037	0.67	5.66	7.87	0.0001
SOB (%) ⁽¹⁾	81.33	8.14 ⁽¹⁾	1.10 ⁽¹⁾	0.3491	80.53	11.09 ⁽¹⁾	1.43 ⁽¹⁾	0.0816

^{1/} Data was transformed to $\sqrt{x + 0.5}$ for the statistical analyses; total height at the first (ALT1), second (ALT1), third (ALT1), and fourth (ALT1) year after planting; mean canopy diameter (DMC); stem diameter at 30 cm from the soil (DA3); stem form (FOR); bark thickness (ESP); basic bark density (DBC); and, survival rate (SOB).

Table 4. Estimated F-test values for population (P) and within population (F/P) effects in the joint analysis of variance for silvicultural traits of the two *A. fraxinifolium* populations (from Selvíria, MS and Ilha Solteira, SP).

FV	Silvicultural traits									
	ALT1	ALT2	ALT3	ALT4	DMC	DA3	FOR	ESP	DBC	SOB ⁽¹⁾
P	0.53	0.48	1.01	1.14	0.34	1.35	0.80	1.60	0.27	0.14
F/P	2.94**	2.62**	2.89**	3.40**	3.19**	2.66**	3.24**	4.49**	6.35**	1.01

^{1/} indicate significance at the 5% and 1% levels of probability, respectively; 1. Data was transformed to $\sqrt{x + 0.5}$; for the statistical analyses; Plant height at the first (ALT1), second (ALT2), third (ALT3) and fourth (ALT4) years after planting, mean canopy diameter (DMC), stem diameter at 30cm from the soil (DA3), stem shape (FOR), bark thickness (ESP), bark basic density (DBC) and survival rate (SOB).

Luiz Antônio (SP) and detected significant among progeny differences within populations in both locations. Etori et al. (1996) reported significant genetic differences among progenies in one out of two *Tabebuia heptaphylla* (Vell.) Tol. populations. Moraes et al. (1992) assessed two *M. arundeuva* populations of different origins but did not find any significance among origin differences for plant height of seven year old trees.

The coefficient of genetic variation (CV_g) of the silvicultural traits ranged from 1.08% to 7.92% (for DBC and FOR) and from 6.63% to 11.94% (DBC

and ALT1) for the Selvíria and Ilha Solteira *A. fraxinifolium* populations, respectively (Table 5). The Ilha Solteira *A. fraxinifolium* population presented larger CV_g values (mean of 8.89%) compared to the Selvíria (mean CV_g of 6.22%). These results indicate that there was larger among progeny variability in the Ilha Solteira population. This was probably due to the fact that mother trees from the Ilha Solteira *A. fraxinifolium* populations were located farther away from each other than those from the Selvíria population, which causes an increase in the genetic variability. According to Futuyama (1992), greater

distances in the population will result in larger differences in allele frequencies and in the genetically controlled phenotypic traits, although a strict correlation may not be frequently detected. The degree of divergence is extremely variable. This approach may be directed to individuals as well, especially to those species where the pollinator meets barriers (distance) to reach some plants.

As for the total height coefficient of genetic variability obtained in the first four years, a different performance was detected in both populations over the years. In the Selvíria population, CV_g tended to increase with age. CV_g magnitude was more variable in the Ilha Solteira population, starting high then decreasing and rising again with age. Thus, it is clear that although most variability is found within population, each population has its own strategy for expressing genetic variation.

Native species are generally slow growers and the CV_g estimated for some traits, mainly those greatly affected by the environment, may change in time. They may or may not express genetic variation at more advanced ages, when the trees reach reproductive maturity. Ideally new assessments should be made at more advanced ages to obtain better knowledge of the genetic variation in these species (Sebbenn et al., 1998). Siqueira et al. (1993) reported that, although they had data for 13 year-old (*Dipteryx alata*) cumbaru, longer testing periods were required by the genetic resource conservation studies to allow a better understanding of the population genetic structure. Even so, the results reported for height are comparable with those found for *D. alata* by Siqueira et al. (1993) and for (*Tabebuia vellosii*) ipê-amarelo by Etori et al. (1995), which ranged from 0.0 to 14.39% and from 5.32% to 21.48%, respectively. On the other hand, these values are larger than those detected for *Tabebuia heptaphylla* (ipê roxo) by Etori et al. (1996) that varied from 0.0 to 4.19%.

Fonseca et al. (1997) obtained CV_g of 5.65% and 3.19% for *Eugenia dysenterica* (cagaita) seedling height. For the *Cordia trichotoma* species (louro-pardo) the CV_g for stem diameter at breast height (DAP) ranged from 5.58% to 8.42% from the second to the seventh years after planting (Etori et al., 1997). Nodari et al. (1993) assessed *Euterpe edulis* procedence and detected for the traits diameter at stem base height, total height, leaf insertion height and number of leaves, CV_g values ranging from 5.7 to 6.9, 7.1 to 9.1, 6.2 to 8.1 and 0.0 to 7.0, respectively.

The CV_g estimates quoted by Sampaio and Venturieri (1990) for *Copaifera multijuga* (30.65%), *Hymenaea courbaril* (27.50%), *Apuleia leiocarpa* (16.94%) and *Hymenobolium* sp. (23.50%) were higher than the values obtained for height in the species assessed in the present study. According to Vitti et al. (1992), the high CV_g estimates may be due to sampling data from several populations instead from a single one. The definition of the size of the population and the area it covers is the key point to obtain more reliable results and within the usual average. This, however, is very difficult in forest species since some populations may reach very large or very small areas.

The mean of the “ \hat{b} ” quotient ($\hat{b} = CV_g / CV_{exp}$, Vencovsky, 1978) for the environmental traits in the Selvíria population was 0.59. The ALT4 trait (0.78) should be recommended for selection because it allows larger genetic gain. The mean of the “b” quotient for the analyzed traits in the Ilha Solteira population was 0.72. DBC was the highest with 1.17. It was therefore found that the most favorable traits for selection in the Selvíria population are related to tree growth (ALT4). In the Ilha Solteira population, the most favorable character for selection is a trait of importance for the wood technological area (DBC). In spite of the excellent estimate for the “b” quotient, however, this data is difficult to use due to the amount of laboratory work required.

The within progeny coefficient of variation (CV_d) ranged from average to high for all traits. There are reports of coincident results for different species (Etori et al., 1995; Oliveira et al., 2000; Sebbenn et al., 1999a; Siqueira et al., 1986a). The average CV_d of all traits for the Ilha Solteira and Selvíria populations ranged 26.85% and 23.56%, respectively, indicating larger variation within the first population.

High CV_d values imply high within progeny phenotypic variability. This is very important for genetic conservation of the species, as the conservation efficiency depends on the genetic variability among populations, among progenies, within populations and among individuals within progenies. The additive genetic variance is responsible for the resemblance among relatives (parents and offspring). Three quarters ($3/4$) of it is found within progenies, and, therefore, it becomes the hierarchical level with the largest portion of population genetic variability. High CV_d values increase the potential of a population for conservation purposes and help breeders select superior individuals

within the progenies (Sebben et al., 1999b).

Results obtained for this species are similar to those reported for other species such as *M. urundeuva* (Oliveira et al., 2000), *P. dubium* (Sebbenn et al., 1999b), *T. heptaphylla* (Ettori et al., 1996), *D. alata* (Siqueira et al., 1993).

Hamrick (1983) and Hamrick and Godt (1990) detected high within population genetic variability for most of the temperate and tropical tree species assessed with genetic marker data. According to Hamrick (1989), the type of reproductive system, the kinds of pollination and seed dispersion are the factors responsible for these results. Tropical tree populations that are cross pollinated (diecious), preferentially by entomophylic, and have long distance seed dispersion, present little divergence among themselves but maintain large within population diversity.

Sebbenn et al. (1999a) suggested that when there is a high within population variability, as in the case of the *A. fraxinifolium* populations, individuals from one

or a few origins supply the necessary variability to begin a breeding program with the species. On the other hand, as the within population genetic variability is associated with the number of mother trees supplying seeds for the experiment, the author suggests a minimum number of trees per population to meet the progress expectation of some breeding methods. Also, a minimum number of individuals have to be considered to keep the genetic variability and a large number of favorable alleles over the selection cycles.

When the genetic conservation of the species is the objective, variability becomes of greatest importance. Representative sampling from each population and from a larger number of populations is needed since both, the favorable and unfavorable alleles may play an essential role in the survival of the species. Therefore, as in the *A. fraxinifolium*, sampling other populations from different procedences would be essential in future studies since in spite of the presence of a large within population variability no between

Table 5. Estimates of the coefficient of variation for total height at the first (ALT1), second (ALT2), third (ALT3), and fourth (ALT4) years after planting, mean canopy diameter (DMC), stem diameter at 30 cm from the soil (DA3), stem shape (FOR), bark thickness (ESP) and basic bark density (DBC) in two *A. fraxinifolium* populations from Selvíria, MS and from Ilha Solteira, SP, assessed in Selvíria, MS ^{1/}.

POP	Traits	CV _d (%)	CV _g (%)	CV _e (%)	CV _F (%)	CV _F (%)	\hat{b}
Selvíria	ALT1	28.32	5.44	7.66	29.84	7.86	0.43
	ALT2	23.35	6.30	5.91	24.90	7.78	0.62
	ALT3	23.52	6.70	5.29	25.02	8.04	0.67
	ALT4	23.12	7.79	5.50	25.01	8.97	0.78
	DMC	23.83	6.65	7.45	25.85	8.35	0.59
	DA3	24.10	6.50	6.25	25.74	8.06	0.61
	FOR	31.33	7.92	4.46	32.63	9.61	0.65
	ESP	23.75	7.57	5.58	25.54	8.86	0.74
	DBC	10.74	1.08	2.85	11.16	2.42	0.22
Ilha Solteira	ALT1	31.68	11.94	11.69	35.82	14.01	0.73
	ALT2	26.09	7.93	11.12	29.45	10.28	0.54
	ALT3	26.85	7.69	9.03	29.36	9.73	0.58
	ALT4	27.45	8.38	8.73	30.00	10.29	0.63
	DMC	26.49	9.04	7.90	29.09	10.63	0.72
	DA3	28.25	7.36	8.44	30.39	9.48	0.55
	FOR	35.55	9.16	2.05	36.77	10.93	0.69
	ESP	26.86	11.89	8.59	30.60	13.26	0.90
	DBC	12.43	6.63	2.75	14.36	7.10	1.17

^{1/} (CV_d): within progeny coefficient of variation; (CV_e): between plot error coefficient of variation; (CV_g): genetic coefficient of variation; (CV_F): phenotypic coefficient of variation at plant level; (CV_F[']): phenotypic coefficient of variation at mean level; "b" quotient ("b": CV_g/CV_{exp}).

population variability was detected.

The coefficients of variation for the among plot errors (CV_e) for ALT1, ALT2, ALT3, ALT4 were smaller for the Selvíria *A. fraxinifolium* population. Sebbenn et al. (2000) studied three *Cariniana legalis* (jequitibá-rosa) populations and observed mean CV_e values ranging from 7% to 15% for the DAP and height traits. These results are similar to those observed for height in the species studied. However, the phenotypic variability for the DA3 trait in this study was less affected by the environment than that for the DAP in Sebbenn et al. (2000).

The CV_F estimates (11.16% to 36.77%) were much lower than those obtained by Freitas (1999) and Fonseca (2000) that ranged from 25.78% to 205.81% and from 20.09% to 103.74%, respectively.

The large genetic variability estimated for the *A. fraxinifolium* populations suggests good chances of success for the “*ex situ*” conservation of this species. Considering the possibility of using the experiment to collect seeds, the genetic characteristics of the two populations can be combined to form a population with a wide genetic base.

Narrow sense heritability at mean level was estimated using three levels: \hat{h}^2 at plant level, \hat{h}_d^2 at plant within plot level; and \hat{h}_m^2 at progeny mean level for the

silvicultural traits (Table 6).

The heritability coefficient at the mean level for ALT1, ALT2, ALT3, ALT4 were considered average to high for the two populations when compared with the data reported by other authors for some native species (Giannotti et al., 1982; Siqueira et al., 1986a, 1986b; Vitti et al., 1992; Moraes et al., 1992; Etori et al., 1995, 1996; Sebbenn et al., 1998, 1999a; Freitas, 1999; Souza et al., 1999; Fonseca, 2000; Oliveira et al., 2000). The \hat{h}_m^2 were considered high for the DA3 and DMC traits when compared to the results of other authors for different species (Aguar et al., 1999; Oliveira et al., 2000; Souza et al., 1999; Silva et al., 2000; Fonseca et al., 2000). Thus, selection at the progeny mean level is recommended for these traits for greater efficiency if breeding is to be carried out in the future.

The heritability coefficients at plant, means and within family levels for the height trait in the two populations presented little variations among the years assessed (Table 6). However, height at the fourth year after planting presented the greatest heritability values. Patiño-Valera (1986) stated that the among plant competition effect diminishes the heritability and, therefore, the high levels of plant competition that often occurs in the first years after planting lowers the heredity coefficient. The author also mentions that this

Table 6. Estimates of the narrow sense heritability coefficients for the traits total height at the first (ALT1), second (ALT2), third (ALT3), and fourth (ALT4) years after planting, mean canopy diameter (DMC), stem diameter at 30 cm from the soil (DA3), stem shape (FOR), bark thickness (ESP) and basic bark density (DBC) in two *A. fraxinifolium* populations from Selvíria, MS and from Ilha Solteira, SP, assessed in Selvíria, MS ^{1/}.

Traits	Populations					
	Selvíria			Ilha Solteira		
	\hat{h}^2	\hat{h}_m^2	\hat{h}_d^2	\hat{h}^2	\hat{h}_m^2	\hat{h}_d^2
ALT1	0.13	0.48 (0.15) ^{1/}	0.11	0.44	0.73 (0.08) ^{1/}	0.43
ALT2	0.26	0.66 (0.10)	0.22	0.29	0.55 (0.12)	0.28
ALT3	0.29	0.70 (0.09)	0.24	0.27	0.62 (0.11)	0.25
ALT4	0.39	0.75 (0.07)	0.34	0.31	0.66 (0.10)	0.28
DMC	0.26	0.63 (0.11)	0.23	0.39	0.72 (0.08)	0.35
DA3	0.26	0.65 (0.10)	0.22	0.25	0.60 (0.11)	0.20
FOR	0.24	0.68 (0.09)	0.19	0.24	0.70 (0.09)	0.20
ESP	0.35	0.73 (0.08)	0.31	0.60	0.80 (0.06)	0.59
DBC	0.04	0.20 (0.23)	0.03	0.85	0.87 (0.04)	0.85

^{1/} (\hat{h}^2): plant level heritability; (\hat{h}_m^2): mean level heritability; (\hat{h}_d^2): heritability at plant within progeny level; 1 - error of heritability at mean level.

situation can be reversed with tree maturity. On the other hand, great stability of the heritability coefficients along the years indicates that the progeny sampling was efficient in preserving a good amount of genetic variability and, therefore, greater gains can be expected from plant selection (Sebbenn et al., 2000).

The \hat{h}_m^2 presented slight but general tendencies to increase with the age of the *A. fraxinifolium* plants, indicating that more genes are being expressed as plants develop. According to Sebbenn et al. (1998), Moraes et al. (1992), Etori et al. (1996) and Souza et al. (1998), height heritabilities in tropical tree species tend to be low at the beginning of plant development, to increase until a certain stage and later to stabilize or decline, sometimes reaching nullity. Vencovsky and Barriga (1992) stated that the genetic parameters of a single trait can change with age due to genotype-environment interaction.

The heritability coefficient at the mean plot level (\hat{h}_m^2) ranged from 0.20 to 0.75 and from 0.59 to 0.87 for the silvicultural traits, in the Selvíria and Ilha Solteira *A. fraxinifolium* populations, respectively. Souza et al. (1998), working with *A. fraxinifolium* in association with *Pinus* sp obtained heritability values at the mean plot level (\hat{h}_m^2) of approximately 0.20 for plant height. Souza et al. (1999) observed similar results working with *A. fraxinifolium* in several planting systems (0.33). Fonseca et al. (1998), estimated genetic parameters of several native species in consortium, which included *A. fraxinifolium*, and obtained high heritability values ($\hat{h}_m^2 = 0.65, 0.78$ and 0.79) for *M. arundeuva*, *A. fraxinifolium* and capitão (*Terminalia argentea*).

The traits that expressed greater \hat{h}_d^2 and \hat{h}_m^2 values were height (ALT1, ALT2, ALT3, ALT4) and bark thickness (ESP). These traits are the most indicated to be submitted to a selection program.

CONCLUSIONS

The *A. fraxinifolium* populations presented genetic variability for all analyzed traits, especially the Ilha Solteira population. There was no difference between the two populations, indicating that the geographic barrier placed between them has not contributed effectively for any divergence between the populations yet. Thus the two populations studied could form a single population with a wide genetic base for *ex situ* genetic conservation.

The detection of the genetic variability is an essential

first step before starting a forest-breeding program. Selection should be made at the progeny mean level for trait height and bark thickness, preferably for height first since this trait is easier to assessed.

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RESUMO

Variabilidade genética em populações de *Astronium fraxinifolium*

Dois testes de progênes, envolvendo duas populações de gonçalo-alves (*Astronium fraxinifolium*) foram instalados em março de 1996, no município de Selvíria-MS. O delineamento utilizado foi o de blocos completos casualizados, com 30 tratamentos (progênes) e 5 repetições, em uma disposição linear com 10 plantas por parcela de forma alternada, no espaçamento de 3.0 x 3.0 m. Foram avaliados dez caracteres silviculturais, procurando-se, dessa forma, fornecer subsídios para a conservação genética *ex situ* dessa espécie. As progênes apresentaram excelente performance no sistema de plantio utilizado. As populações estudadas apresentaram variabilidade genética para os todos caracteres analisados, porém não houve diferença entre as populações. Recomendase assim, que as mesmas sejam consideradas uma única população para fim de conservação genética *ex situ*. Em um eventual programa de melhoramento genético, nessas populações, deve ser eleito o caráter altura de plantas como aquele com maiores chances de obter ganhos na seleção em nível de média de famílias.

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