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Variação da densidade básica da madeira, volume e matéria seca do tronco de *Pinus tecunumanii,* procedência de Mount Pine Ridge, Belize, em Planaltina, Distrito Federal, Brasil

Variation in wood density, stem volume and dry matter of the Mountain Pine Ridge, Belize, provenance of Pinus tecunumanii *grown at Planaltina, Brazil*

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RESUMO: O volume, a densidade básica e o peso da matéria seca da madeira de 168 árvores, de sete famílias de polinização aberta, procedência de Mountain Pine Ridge (MPR), Belize, de *Pinus tecunumanii* (Schwd) Equiluz & Perry foram estimados aos 12 anos de idade, em experimento instalado em Planaltina, Distrito Federal, Brasil. A produtividade média da procedência de MPR foi de 21 m³/ha/ano, com sobrevivência de 98% aos 12 anos de idade. Para todos os parâmetros analisados, houveram diferenças significativas para as famílias. A densidade básica da madeira dos indíviduos e das famílias variou de 0.38 a 0.59 g/cm³ e de 0.40 a 0.45 g/cm³, respectivamente. A correlação fenotípica entre volume e densidade básica foi significante porém baixa (r=0.24). As herdabilidades a nível de indíviduo para volume, peso da matéria seca e densidade básica da madeira foi 0.33, 0.39 e 0.45, respectivamente. Consideráveis ganhos em melhoramento podem ser obtidos em volume e densidade básica com material de MPR, Belize, na região do Cerrado. Porém, será necessário trabalhar com populações de base genética mais ampla.

PALAVRAS-CHAVE: Pinus, Melhoramento, Ganho genético, Herdabilidade, Matéria seca, Cerrado.

ABSTRACT: One hundred and sixty-eight trees of seven open-pollinated families from the Mountain Pine Ridge (MPR), Belize provenance of *Pinus tecunumanii* (Schwd) Equiluz & Perry were assessed for volume growth, wood density and dry matter at 12-years of age at Planaltina, Federal District, Brazil. The average productivity of MPR source was 21 m³/ha/yr with 98% survival at 12 years of age. Family differences for all traits were significantly different. Individual and family wood density varied from 0.38 to 0.59 g/cm³ and 0.40 to 0.45 g/cm³, respectively. There was a positive, but weak, phenotypic correlation (r=0.24) between volume and wood density. Individual heritability for volume growth, dry matter index and wood density were 0.33, 0.39 and 0.45, respectively. Sizable improvement in both volume and wood density can be made in the MPR, Belize population in the Cerrado region but a larger genetic base is needed.

KEYWORDS: Pine, Tree improvement, Genetic gain, Heritability, Wood dry matter, Cerrado

INTRODUCTION

The Mountain Pine Ridge (MPR) is a natural upland pine area of approximately 70,000 hectares that is located west of the Maya Mountain Divide in central Belize (17° N latitude). Approximately 80% of the pine forests are *Pinus caribaea* var. *hondurensis* (Sénécl) Barr. & Golf., and 20% *Pinus tecunumanii* (Schwd) Eguiluz and Perry. The *Pinus tecunumanii* trees usually occur in small stands of several hectares in size and are located at altitudes of 450 to 800 m in areas where annual precipitation is approximately 1560 mm. Destruction by natural fires and periodic hurricanes have been important forces that have influenced the evolution of pine forests in the MPR (Hunt, 1962). These natural disturbances have caused hybrid habitats to form between *P. caribaea* var. *hondurensis* and *P. tecunumanii*. The fact that the monoterpene content of the MPR *P. tecunumanii* is different from other sources of the species (Squillace and Perry, 1993) and that it has longer internodes than most other *P. tecunumanii* provenances (Birks and Barnes, 1990) suggests a past history of introgression with *P. caribaea* var. *hondurensis*.

Pinus tecunumanii from the MPR has been tested extensively in the tropics and subtropics by the Central America and Mexico Coniferous Resources Cooperative (CAMCORE), North Carolina State University, and the Oxford Forestry Institute (OFI), University of Oxford. Brazil has been one of the primary depositories for these provenance and progeny tests (Dvorak and Donahue, 1992; Birks and Barnes, 1990). Provenances of *P. tecunumanii* from a range of altitudes in Central America have done very well in tropical and subtropical Brazil. Those from approximately 1000 m altitude in Central America seem especially well adapted to local conditions. However, before the MPR provenance can be accepted for reforestation in the Cerrado region, more information needs to be obtained on its wood quality in the region. This paper reports on the growth aspects, wood density and dry matter index of open-pollinated families of *P. tecunumanii* from MPR, Belize, established in the area of Cerrado near Planaltina, Federal District, Brazil.

MATERIAL AND METHODS

Seeds were collected by CAMCORE from seven mother trees of *P. tecunumanii* in the Mountain Pine Ridge, Belize at 17° 00'N latitude and from 610 to 680 m altitude. This collection was a subset of a much larger mother tree seed collection made by CAMCORE in 1981 and 1992 of nearly 100 mother trees and has been reported on by others (Lima et al., 1990; Osorio and Dvorak, 1993).

This material was tested together with provenances and families of *P. oocarpa* Schiede established in Brazil by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) at Planaltina (latitude 15° 35' S, altitude 1000 m, and mean annual rainfall 1554 mm), Federal District, Brazil. The test was established in 1983 at 3 m x 3 m spacing in a balanced six tree plot design with nine replications. The trial was assessed at 12 years of age for stem volume, wood density and dry matter. Volume was calculated from a general formula for juvenile trees derived by Ladrach (1986) as volume (m^3) = 0.00003 d^2h.

Increment cores of 5.5 mm diameter were taken bark to bark at breast height from every tree in each plot in four replications of the study (24 trees per family and 168 trees in total). The maximum moisture content method was used for assessing density (Smith, 1954). To derive dry matter, the individual volume was multiplied by the individual wood density.

For the analyses of variance (ANOVA) all traits were considered random. The Statistical

Analysis System (SAS) Generalized Linear Model (GLM) procedure type III sums of square (SAS, 1990) was used for the analysis. Variance components were estimated by the VARCOMP procedure (SAS, 1990). Individual, family and within family heritability for all traits were calculated in the usual way except that the coefficient of relationship was assumed to be 0.33 instead of 0.25 for half-sib analysis because 1) there was a high probability that this material was inbred to some extent, and 2) it is likely that the open-pollinated families are not truly half-sib, but contain some full-sibs.

The formula used to estimate heritability were:

Individual tree heritability

$h^2_i = (3 \cdot s^2_f) / (s^2_f + s^2_{rf} + s^2)$;

Family heritability

$h^2_f = s^2_f / (s^2_f + s^2_{rf} / r + s^2 / nr)$;

Within family heritability

$h^2_w = (2 \cdot s^2_f) / (s^2_{rf} + s^2)$;

where:

s^2_f = Components of variance for families;

s^2_{rf} = Components of variance for block . family;

s^2 = Error component of variance;

n = Number of trees in plot;

r = Number of blocks.

The best trees in the study were selected based on dry matter using an index that combines the individual value with the family performance and weighs them based on family and within-families heritability (Balocchi, 1990). The index has the form of:

$I = m + (h^2_{(f)} P_{(f)} + h^2_{(w)} P_{(w)})$

where:

I = Index value

m = family mean;

$h^2_{(f)}$ = family mean heritability

$P_{(f)}$ = deviation of a family mean from the overall mean

$h^2_{(w)}$ = within-family heritability

$P_{(w)}$ = deviation of an individual value from the family mean.

RESULTS

The survival of the MPR source was 98% at 12 years of age. This compares well with both *P. caribaea* var. *hondurensis* and *P. oocarpa* that is grown in the region (Moura and Dvorak, 1997; Moura et al., 1998). This high survival and growth rates, indicates that this material is highly adapted to the Cerrado environmental conditions and has a high potential for reforestation programs in the region.

The results of the analyses of variance are presented for volume growth, wood density and dry matter index in Table 1. Family means were significantly different ($p > 0.001$) for all the traits.

The family mean stem volume for *P. tecunumanii* from MPR was 0.23 m^3 at 12 years of age and is of the same magnitude as the San Jeronimo provenance, the best of *P. tecunumanii* from high altitude in Central America established in the cerrado (Moura and Dvorak, 1998). The productivity of the MPR prove-nance was approximately 21 m^3/ha/yr.

Trees from the MPR provenance have an average wood density of 0.42 g/cm^3. Individual trees and family wood density varied from 0.38 to 0.59 g/cm^3 and from 0.40 to 0.45 g/cm^3, respectively.

Family mean for dry matter varied significantly from 0.07 to 0.12. The best ranked families for stem volume were also the best-ranked in dry matter (Table 2). Individual and family heritability and standard errors for all traits are presented in Table 3.

Tabela 1

Análise da variância dos dados de volume, densidade da madeira, indíce de matéria seca de famílias da procedência de Mountain Pine Ridge de *P. tecunumanii*, coletados em Planaltina, Distrito Federal, Brasil.

Analysis of variance for families of the Mountain Pine Ridge provenance of P. tecunumanii*, assessed for volume, wood density and dry matter index in Planaltina, Federal District, Brazil at 12 years of age.*

Source	Volume density			Wood matter		Dry	
	DF	MS	F	MS	F	MS	F
Block(Bl.)	3	0.090	11.6***	0.002	1.7ns	0.019	12.4***
Family(Fam.)	6	0.030	3.93***	0.006	4.7***	0.007	4.4***
Bl. x Fam.	18	0.008	1.1ns	0.001	0.85ns	0.002	1.1ns
Residual	136	0.001			0.001		
Total	163						

ns = pr < .05; * = pr > .05; ** = pr > .01; *** = pr > .001;

Tabela 2

Média dos dados de volume, de densidade da madeira e do índice de matéria seca para famílias da procedência de Mountain Pine Ridge, de *P. tecunumanii*, coletados aos 12 anos de idade, em Planaltina, Distrito Federal, Brasil.

Family means of Mountain Pine Ridge, Belize, provenance of P. tecunumanii *, assessed for volume, wood density and dry matter index at 12 years of age, at Planaltina, Federal District, Brazil.*

Family	Volume (m^3)	Wood density (g/cm^3)	Dry matter
452	0.27	0.45	0.12
461	0.28	0.42	0.12
482	0.23	0.44	0.10
448	0.22	0.42	0.09
444	0.23	0.40	0.09
487	0.20	0.43	0.08
462	0.18	0.41	0.07
Mean	0.23 m^3	0.42 g/cm^3	0.10

Tabela 3

Estimativa das herdabilidades para volume, densidade da madeira e índice de matéria seca, a nível individual (h^2_i) com erro padrão (SE), para família (h^2_f) e dentro de famílias (h^2_w) em *P. tecunumanii* testado em Planaltina, Distrito Federal, Brasil, aos 12 anos de idade.

Individual tree heritability (h^2_i) and standard error (SE), within-family (h^2_w) and family heritability (h^2_f) for volume, wood density and dry matter index of P. tecunumanii *growing in Planaltina, Federal District, Brazil at 12 years of age.*

Traits	h^2_i	SE (h^2_i)	h^2_w	h^2_f
Volume	0.33	0.23	0.24	0.73
Wood density	0.43	0.26	0.33	0.81
Dry matter index	0.39	0.25	0.29	0.77

The h^2_i values were 0.33, 0.39 and 0.43 for stem volume, wood density and dry matter respectively and were similar to those reported by other researchers for other tropical pines. The high standard errors associated with these h^2_i values (Table 3) are a result of the small num-ber of degrees of freedom for families.

There was a positive and statistically significant correlation between individual volume growth and wood density (r= 0.20; p > 0.01). However, such was not the case for family means, even though, two families were best ranked for wood density (Table 2). There was also a significant and positive correlation

between wood density and dry matter (r= 0.38 p > 0.0001) and between stem volume and dry matter (r= 0.98, p > 0.0001).

DISCUSSION

The mean wood density of *P. tecunumanii* from the MPR at Planaltina is similar to values found for the same provenance established at other sites of the Cerrado (Moura et al., 1991) but lower than values found elsewhere in the tropics and subtropics at the same age (Table 4). Two of the best MPR families at Planaltina had high wood density value near 0.445 g/cm³ which suggests that improvements can be made through selection but a larger genetic base is needed. In the Cerrado region, wood density of *P. tecunumanii* from the MPR provenance varies with age and plantation site. Its mean value increased by 0.02 g/cm³ from 8 to 12 years of age (Moura and Santiago, 1991) and increased by 0.03 g/cm³ from Planaltina, Federal District, elevation 1000 m to Jaciara, Mato Grosso do Sul, elevation 480 m (Moura et al., 1991).

Trees from provenances of *P. tecunumanii* that occur below 1500 m in Central America like Yucul, Nicaragua, grow well in the Brazilian Cerrado and have wood density values that are very comparable with other tropical

Table 4

Densidade da madeira de *Pinus tecunumanii* de Mountain Pine Ridge, testado em vários locais nos trópicos e subtrópicos.

Wood density of P. tecunumanii *from the Mountain Pine Ridge, Belize, grown at various sites throughout the tropics and the subtropics.*

Site	Country	Latitude	Altitude (m)	Sample Size	Density (g/cm³)	Age (yr)	Source
Melvile Island	Australia	11º 25'S	49	9	0.400	5.9	Birks and Barnes, 1990
Agudos	Brazil	22º 23'S	550	12	0.403	6.3	Birks and Barnes, 1990
Planaltina	Brazil	15º 35'S	1000	168	0.420	12.0	authors
Planaltina	Brazil	15º 35'S	1000	30	0.393	12.0	Moura *et al*, 1991
Serranópolis	Brazil	17º 53'S	850	30	0.412	12.0	Moura *et al*, 1991
Jaciara	Brazil	16º 02'S	480	30	0.419	12.0	Moura *et al*, 1991
Aracruz	Brazil	19º 48'S	40	522	0.377	4.0	Lima *et al*., 1990
Morada Nova	Brazil	18º 45'S	570	522	0.395	4.0	Lima *et al*., 1990
La Arcadia	Colombia	2º 30'N	1750	757	0.377	8	Dvorak and Wright 1994
Conocotto	Ecuador	0º 16'S	2500	12	0.403	6.3	Wright *et al.*, 1990
Nabou	Fiji	17º 59'S	30	30	0.406	6.9	Birks and Barnes, 1990
Turbo	Kenya	0º 38'N	1700	12	0.406	7.6	Birks and Barnes, 1990
Anasco	Puerto Rico	18º 20'N	175	15	0.391	5.7	Birks and Barnes, 1990
Wilge-boom	South Africa	24º 58'S	1000	15	0.404	7.5	Birks and Barnes, 1990
Wilge-boom	South Africa	24º 58'S	1000	10	0.509	12.0	Wright, 1987
K'nambi	South Africa	28º 45'S	65	15	0.376	6.1	Birks and Barnes, 1990
K'nambi	South Africa	28º 45'S	65	10	0.494	12.0	Wright, 1987
Tweefontein	South Africa	-	-	10	0.423	16.0	Malan e Hoon, 1991
Chum-porn	Thailand	10º 52'N	70	6	0.383	6.5	Birks and Barnes, 1990
Barinas	Venezuela	8º 12'N	150	8	0.412	10	Gimenez, 1982
Ndola	Zambia	13º 00'S	1300	6	0.414	6.1	Birks and Barnes, 1990

and subtropical pines (Moura et al., 1991; Wright, 1990a; Wright et al., 1986, and 1989; Birks and Barnes, 1990).

The h^2_i estimate for wood density in this study is slightly lower than the one found by Dvorak and Wright (1994) for the MPR provenance of *P. tecunumanii* at La Arcadia, Colombia (0.48), for a sample size ten times larger than the one used in this test. Hodge and Purnell (1993) assessing wood properties of *P. elliottii* in northern Florida and southern Georgia, age 17 to 25 years, also found high standard errors (0.12- 0.18) for low h^2_i (0.04-0.32) for wood properties.

Tree dry weight was much more closely related to volume than to wood density, suggesting that dry weight production could be increased most substantially by improvement of volume growth.

The significant and positive correlation between individual wood density and stem growth indicates that genetic gains in growth would have a tendency to bring corresponding increases in wood density. Considerable genetic gain can be achieved through the selection of the best individuals**,** in this small population, due to the high individual and family heritability, for volume and wood density. However, it is not prudent to make selections only in a population of this size. In addition, it would be desirable to increase the genetic base by obtaining a larger number of families from Belize.

CONCLUSIONS

The best ranked families in stem volume were also the best-ranked in dry matter. The family mean wood density of *P. tecunumanii* from MPR is similar to values found for the same provenance in other sites of the cerrado and is very acceptable for wood and wood products in the region. There was a significant and positive association between individual wood density and stem growth, indicating that genetic gains in growth would have a tendency to bring corresponding increases in wood density. However, the best opportunity for improvement of the MPR source in the cerrado would be for EMBRAPA to obtain additional MPR CAMCORE selections of *P. tecunumanii* to enlarge its existing genetic base and potential selection intensity.

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