VOLUME AND WOOD DENSITY RESULTS FOR PINUS TECUNUMANII AT EIGHT YEARS OF AGE IN COLOMBIA

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Abstract.--A broad genetic base of Pinus tecunumanii (Schw.) Equiluz et Perry from high and low elevation populations in Mexico and Central America has been established in Colombia by Smurfit Carton de Colombia. The species has exhibited good growth in pilot plantings in Colombia and compares favorably with other pines established on a commercial scale in the region. However, P. tecunumanii's susceptibility to stem breakage and poor seed production may limit its potential. Four provenance/progeny tests of P. tecunumanii, that included 12 provenances and 122 half-sib families from Mexico and Central America, were established at San Jose, Colombia (2°30'N latitude) and were assessed at 8 years of age for volume and wood density. Results indicated that provenances and families differed significantly for individual tree volume ($p<0.01$) but not for wood density. Trees from the Mexican provenances showed greater volume per tree (overbark) than the Central American provenances (0.257 m^3 versus 0.245 m^3). Density per tree was higher for the Central American provenances than the Mexican sources (358 kg/m^3 versus 330 kg/m^3). Montebello (Mexico) and San Jeronimo (Guatemala) were the best provenances in growth and also ranked high for wood density. More than 40 trees from 31 families of P. tecunumanii were selected in the four trials using a combined family and within family selection index. The mean volume for the selected trees was 0.520 m^3 versus 0.252 m^3 for the population. The estimated genetic gain in volume from family and within family selection was 32%.

Keywords: Pinus tecunumanii, provenances, genetic gain

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INTRODUCTION

In the 1980s, Smurfit Carton de Colombia (SCC) established a number of provenance/progeny trials of tropical and subtropical pines. The seed was mainly obtained from the Central America and Mexico Coniferous Resources Cooperative (CAMCORE), North Carolina State University, through mother tree seed collections in Guatemala, Honduras and Mexico. One of the species most widely tested at the provenance and family level by SCC is *Pinus tecunumanii* (Schw.) Equiluz et Perry.

In its native range, *Pinus tecunumanii* occurs from 450 to 2700 m elevation, in a series of small, disjunct populations from Mexico to northern Nicaragua (Dvorak et al 1989). Populations of P. *tecunumanii* have been classified according to altitude as high elevation (>1500 m) and low elevation provenances (<1500 m) (Dvorak 1986). Recently, phylogenetic analysis using RAPD markers showed genetic differentiation at the DNA sequence level between the high and low elevation ecotypes of P. *tecunumanii* (Grattapaglia et al 1993). As a member of CAMCORE, SCC has planted 20 genetic trials with approximately 700 half-sib families from 28 provenances of both elevational types.

Results from P. *tecunumanii* trials planted between 1400 m and 2200 m elevation in Colombia indicate that it has better growth potential than traditionally planted species like P. *patula* Schiede & Deppe and P. *oocarpa* Schiede (Ladrach 1986; Dvorak et al 1989; Wright 1992; Wright and Osorio 1992). However, *P.tecunumanii's* susceptibility to wind damage (Dvorak et al 1993) and its poor seed production in Colombia (Dvorak and Lambeth 1993), could limit the species potential for large scale commercial plantings. Pulp and papermaking wood properties of trees from low elevation provenances of P. *tecunumanii* have been researched and documented (Dvorak and Kellison 1991; Wright 1987; Palmer and Gibbs 1976). However, little information on wood properties are available for trees from the high elevation provenances.

This paper presents results on the growth (volume) and wood density of P. *tecunumanii* from high elevation provenances assessed at eight years of age in four studies in Colombia. The limitations of P. *tecunumanii* are discussed in terms of their implication for further species development and breeding.

MATERIALS AND METHODS

In 1984, four provenance/progeny tests of P. *tecunumanii* were established on one site at San Jose, Department of Cauca, Colombia. The trial site was located at an altitude of 1750 m with mean annual rainfall of 2060 mm. Tests 02E and 06A included sources of P. tecunumanii from southern Mexico, tests 16B and 11C contained provenances from Central America. One hundred and twenty-two half-sib families were represented in all four tests. A common P. tecunumanii control, made up of a mixture of seed from selected trees from San Jeronimo, Guatemala (#200) was included in all four sets. The P. oocarpa check lot (#206) from a seed stand in Brazil was included in the Central American tests. The experimental design was a randomized complete block with nine replications and six tree family row plots. The spacing was 3.0 m x 2.5 m and all seedlings were fertilized at the time of planting. The climatic and geographic data for the test sites are presented in table 1.

Eight year assessments were made on total tree height (nearest 0.5 m), outside bark diameter (dbh to the nearest 0.5 cm), and stem straightness and branch diameter (1 to 3 scale with 3 being the best). Assessments were made for stem breakage, foxtail and forks and scored as a "yes" or "no". Wood samples were taken from a total of 27 trees per family from sets 02E (Mexico) and 11C (Central America) using an 8 mm increment borer at 1.3 m stem height. Overbark volume for juvenile trees was calculated using an equation developed by Ladrach (1986): Vol (m^3)= $0.00003D^2H$. Density was determined using green volume and dry weight. Waller-Duncan tests were used to detect differences among provenance means. Data analyses were done using SAS (SAS, 1992).

Table 1. Provenances and control lots of Pinus tecunumanii included in four genetic tests at San Jose farm, Colombia.

Provenances	Country	Latitude	Elevation (m)	Annual Rainfall (mm)
Jitotol	Mexico		1705	1701
Chempil	Mexico	16°45'N	2120	1146
San Jose	Mexico	16°42'N	2322	1252
Las Piedrecitas	Mexico	16°22'N	2430	1252
Montebello	Mexico	16°06'N	1705	1909
San Lorenzo	Guatemala	15°05'N	2000	1700
San Vicente	Guatemala	15°05'N	1945	1700
San Jeronimo	Guatemala	15°03'N	1735	1200
Km 47	Guatemala	14°35'N	2100	1543
La Soledad	Guatemala	14°31'N	2427	1543
Celaque	Honduras	14°33'N	1785	1273
Las Trancas	Honduras	14°07'N	2130	1579

Control Lot 200: P. tecunumanii - San Jeronimo (Guatemala)
Control Lot 206: P. oocarpa - Agudos (Brazil)

Individual and within family heritabilities were calculated in the standard way using methods described by Becker (1986). Family heritability was calculated using an adjusted estimate of additive variance proposed by Finney (1956), in Shelbourne (1969). The adjustment takes into account the effect of making selections in native stands of small population size. The adjusted family heritabilities h^2_{fa} are a more conservative estimate than values obtained in the normal way. Family and within family selections were made in the field using an index developed by the CAmCORE Cooperative: $I = h^2(f)\,P(f) + h^2(w)\,P(w)$ where I was the index value, $h2fa$ the adjusted family heritability, P(f) the family deviation from the test mean, $h^2(w)$ the within-family heritability, and P(w) the deviation of the individual from the family mean. The selection index was based on volume. Those trees not meeting the threshold values for stem straightness and branch diameter or had defects were rejected (Balocchi 1990). Estimates of genetic gain from family and within family selection were calculated in the normal way (Shelbourne 1969). Selection intensity for families and trees within families was 1.266 and 2.286, respectively. Genetic correlations for height and volume assessed at age 5 and age 8 were obtained using formulae described by Becker (1986).

RESULTS AND DISCUSSION

The analysis of variance indicated significant differences ($p<0.01$) in mean tree volume among provenances in sets 02E (Mexico) and 11C(Central America), but not for those in sets 06A and 16B. No differences in density were found among provenances in the sampled sets, but families within provenances were statistically different ($p<0.05$) in every test for individual tree volume and wood density.

On the average the Mexican provenances, sets 06A and 02E, showed slightly greater tree volume (0.257 m^3) than the Central American provenances, (0.245 m^3), sets 16B and 11C (table 2), but wood density was higher for the Central American provenances (tables 3 and 4).

Table 2. Mean volume for P. <u>tecunumanii</u> at eight years of San Jose, Colombia.

Test No.	No. Families	No. Tree	Survival (%)	Mean Height (m)	C.V. (%)	Mean DBH (cm)	Tree Volume (m3)
06A	28	1312	87	16.8	17.3	22.3	0.272
02E	39	1819	87	15.9	23.6	21.4	0.247
16B	41	1930	88	17.0	16.2	21.4	0.256
11C	34	1743	88	15.6	17.9	21.4	0.233

Table 3. Individual tree volume and wood density for provenances of Pinus tecunumanii from Central America at San Jose, Colombia.

Provenances	Test 11C Tree Volume' (m3)	Test 11C Density (Kg/m3)	Test 16B Tree Volume'
Control 200	0.289 a	373	0.304
San Jeronimo	0.284 a	364	0.277
San Vicente	0.216 b	360	0.262
Control 206	0.226 b	367	0.261
Km 47			0.256
San Lorenzo	0.215 b	367	0.255
Celaque	0.223 b	360	0.252
Las Trancas	0.202 b	341	0.234
La Soledad	0.232 b	345	
Test Mean	0.233	358	0.256

[a] Different letters mean significance at the probability level of 0 05

[b] No significant differences among provenances

[c] Does not include control lots.

Table 4. **Individual** tree volume and density for provenances of **Pinus tecunumanii** from Mexico at San Jose, Colombia.

Provenances	Test 02E Tree Volume' (m3)	Test 02E Density' (kg/m³)	Test 06A Tree Volume' (m3)
Control 200	0.313 a	350	0.294
Montebello	0.290 ab	337	0.288
Jitotol	0.238 c	331	0.280
Chempil	0.263 be	329	0.275
Las Piedrecitas	0.239 c	329	0.245
San Jose	0.204 d	323	
Test Mean	0.247	330	0.272

[a] Different letters mean significance at the probability level of 0.05

[b] No significant differences among provenances

[c] Does not include control lots

The mean tree volume for the high elevation provenances from each test ranged from 0.233 to 0.272 m^3 and compared favorably with values found for the low elevation provenance of Mountain Pine Ridge, Belize, and San Rafael del Norte and Yucul, Nicaragua (0.207 to 0.281 m^3) planted in other tests in the same regions of Colombia (Wrigth 1992; Wright and Osorio 1992).

At an altitude of 2400 m in Colombia, the high elevation provenances of San Jeronimo and San Lorenzo, Guatemala, were 45% and 55% less productive, respectively, in mean tree volume than at 1750 m altitude. Such interactions were also found by Dvorak et al (1989).

The best high elevation provenances for individual tree volume also ranked at the top in density. Wood density estimates were lower for the Mexican and Central American provenances than for the low elevation provenance of Mountain Pine Ridge, Belize (Wright and Osorio, 1992).

Volume productivity was adversely affected by stem breakage with large increases between ages 5 and 8 for tests 02E and 11C (table 5). Preliminary results suggest a direct relationship between stem breakage percent and branch size (Dvorak et at 1993). The authors also found the trait of stem breakage was under moderate genetic control and improvement should be possible through selection and breeding.

Table 5. Mean stem breakage (%) at 5 and 8 years of *P. tecunumanii* from Central America and Mexican provenances in four tests in Colombia.

Stem Breakage (6)			
Test No.	Mean (5 years)	Mean (8 years)	Provenance Range (8 years)
02E	18	32	23-38
06A	20	27	19-37
16B	12	15	12-20
11C	13	38	30-45

Genetic correlations between total height at 5 and 8 years were moderate (range 0.60 - 0.71) in all sets except 06A which was extremely low (0.17). Volume correlations between ages 5 and 8 were also moderate (0.57 - 0.79). Individual tree heritability (h2i) decreased from age 5 to 8 (table 6). Results suggest that the best time to select trees of P. *tecunumanii* to maximize genetic gain may be in younger rather than an older genetic tests.

Forty-one trees in 31 families were selected in the four trials using the selection index. The mean individual tree volume for the selected trees was 0.520 m^3 versus the test mean of 0.252 m3. Estimated gain for volume over the population mean was 32%. The 31 selections made in the four provenance/progeny tests of P. *tecunumanii* compliment those made previously in 8 years old tests in Colombia.

Table 6. Individual tree (h^2_i), family (h^2_{fa}) and within family (h^2_w) heritabilities for P. tecunumanii at 5 and 8 years in four tests in Colombia.

	5 years			8 years		
Test No.	h^2_i	h^2_{fa}	h^2_w	h^2_i	h^2_{fa}	h^2_w
06A	0.21	0.57	0.10	0.12	0.51	0.09
02E	0.44	0.50	0.30	0.31	0.58	0.25
16B	0.31	0.55	0.24	0.11	0.56	0.08
11C	0.47	0.49	0.29	0.35	0.57	0.31

Despite the potential for good genetic gains in volume for P. tecunumanii, the large scale use of this species in Colombia is jeopardized by the fact that it is a poor seed producer. Results from a survey on P. tecunumanii conducted throughout the tropics and subtropics showed that seed production for the species was poor close to the equator (<8 filled seeds/cone), but was reasonable (20-40 filled seeds/cone) between 17° and 28°S latitude, (Dvorak and Lambeth 1993). Trees from high elevation provenances appeared to be poorer producers than those from low elevation provenances. Commercial seed supplies of P. tecunumanii from Central America and Mexico appear uncertain in the future because of the wide-spread cutting of pine forests in the region and poor funding levels for national seed banks. The San Jeronimo provenance, which is one of the best sources for Colombia, has been reduced to 50% of its original size in Guatemala since 1980, (Dvorak and Donahue 1992).

CONCLUSIONS

Pinus tecunumanii has great growth potential in Colombia. Heritabilities were high for volume and good gains can be made through family and within family selection. The wood density of the species seems acceptable, but more information is needed on the pulping and paper making qualities of trees from the high elevation provenances. Top stem breakage averaged 28% at eight years in the four trials at San Jose. This, combined with poor seed production, may reduce the potential value of P. tecunumanii in Colombia. Alternate strategies to minimize these local limitations include the establishment of P. tecunumanii plantings in areas protected from strong seasonal winds and to locate seed orchards in countries where seed production is more rapid, abundant and consistent from year to year.

ACKNOWLEDGEMENTS

The authors would like to thank Pedro Arboleda and Hugo Espana for their help in the field and Liliana Perafan, Amelia Quiroz, and Kemp Ross for their assistance with data management and analyses.

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