Eight Year Results from Provenance Trials of *Pinus caribaea* var. *hondurensis*, *P. oocarpa* and *P. tecunumanii* in the Valle del Cauca, Colombia[1]

*J.A. Wright**

ABSTRACT

Five trials of provenances and families within provenances of *Pinus caribaea* var. *hondurensis*, *P. oocarpa* and *P. tecunumanii* were planted in 1982 at sites in the department of Valle del Cauca, Col., using seed supplied by the Oxford Forestry Institute. The eight-year measurements were analyzed to evaluate provenance and family differences for height, diameter outside bark and volume under bark. Families and provenances were significantly different ($p<0.01$) for the three traits in every trial. The provenances of Rafael and Yucul from *P. tecunumanii* produced, respectively, 34% and 54% more volume per tree than the commercial control of *P. oocarpa* from Mal Paso, Gua. The provenances of *P. caribaea* var. *hondurensis* generally did not produce as much volume per tree as the commercial control of *P. oocarpa*.

COMPENDIO

En 1982 se establecieron en el departamento del Valle del Cauca, Col., cinco ensayos con familias de *P. caribaea* var. *hondurensis*, *P. oocarpa* y *P. tecunumanii*. Se analizaron las mediciones a los ocho años de edad por diferencias de procedencias y familias para las características: altura, diámetro con corteza y volumen por árbol sin corteza. Las familias y las procedencias fueron diferentes estadísticamente ($p<0.01$) para las tres en cada sitio. Las procedencias Rafael y Yucul de *P. tecunumanii* produjeron, respectivamente, 34% y 54% más volumen por árbol en comparación con el testigo de *P. oocarpa* de Mal Paso, Gua. Las procedencias de *P. caribaea* var. *hondurensis* produjeron menos volumen por árbol que el testigo de *P. oocarpa*.

INTRODUCTION

One of the first stages in a tree improvement program is the testing of species and provenances. Trials of this type with exotic and native species have been underway at *Smurfit Carton de Colombia* (SCdeC) for over twenty years (5, 11, 15). Coordinated collections and distribution of seed for trials of pines have been undertaken by numerous organizations, including CAMCORE (Central America and Mexico Coniferous Resources Cooperative) and the Oxford Forestry Institute (OFI). Seed for the trials reported in this paper was collected and distributed by the OFI, an effort they have undertaken since 1963 (1).

In contrast to many agricultural crops, the taxonomy and natural ranges of many tropical pine species are imperfectly documented at present. This is especially true of the pines indigenous to Mexico, the Caribbean and Central America. One example of this is the species *P. oocarpa* Schiede. Several of the original OFI collections of this species (8) have now been reclassified as *P. patula* Schiede and Deppe spp. *tecunumanii* (Eguiluz and Perry) Styles (2, 14) while other authorities would refer to this species as *P. tecunumanii* (6). Debate about taxonomic classification will understandably continue, being essential for the employment of taxonomists. However, the acceptable growth rates and form characteristics of *P. tecunumanii* indicate its potential across a range of sites (3, 4, 17, 18, 21, 22, 23). In addition, the wood density of *P. tecunumanii* has been shown to be adequate (16) and its pulp and papermaking properties compare favorably with other pine species grown under similar conditions (20).

MATERIALS AND METHODS

Trials of family within provenance of *P. caribaea* var. *hondurensis* Barrett and Golfari, *P. oocarpa* and *P. tecunumanii* were planted in 1982 in the department of Valle del Cauca, Col. Details of the trial sites are listed in Table 1. Provenance details are included in Table 2 while full descriptions are given in Greaves (7, 8).

The trial design was six-tree line plots with three to nine replications at a spacing of 3.0 m by 2.5 m. The trees were fertilized at planting and weed competition was controlled with herbicides.

1 Received for publication 10 January 1992

* Manager, Forestal Research, Smurfit Carton de Colombia AA 6574, Cali, Col

Table 1. Climatic and geographic details of trial sites in the department of Valle del Cauca, Colombia.

Species	Site	Lat. (°N)	Alt. (masl)	Mean Ann. Precip. (mm)	Mean Ann. Temp. (°C)
P. caribaea var. *hondurensis*	Aguaclara	3.67	1 400	1 000	19
	La Suiza	3.83	1 500	1 200	20
P. oocarpa and *P. tecunumanii*	La Suiza	3.83	1 600	1 200	20

Table 2. Climatic and geographic details of provenances included in trials in the department of Valle del Cauca, Col.

Species	Provenance	No. Fam.	Lat. (°N)	Alt. (masl)	Mean Ann. Precip. (mm)	Mean Ann. Temp. (°C)
P. caribaea var. *hondurensis*	Alamicamba	4	13.57	20	2 610	27.3
	Araslaya	3	15.75	10	2 654	-
	Culmi	8	15.10	600	1 325	24.3
	Guanaja	16	16.47	50	2 308	27.1
	Karawala	16	12.97	10	3 897	26.4
	Limones	16	14.05	700	663	22.2
	Mountain Pine Ridge	16	17.00	400	1 558	23.9
	Queensland	8*				
	Rio Twas	1	15.80	10	-	-
P. oocarpa	Angeles	16	14.12	1 300	920	20.2
	Bucaral	18	15.02	1 150	900	21.6
	Bonete	15	12.83	950	922	21.4
	Dipilto	4	13.72	1 100	1 143	21.4
	Mal Paso	16	15.18	1 000	1 800	22.4
	Siguatepeque	16	14.53	1 100	1 247	19.9
	Commercial Mal Paso, Guatemala	-				
P. tecunumanii	Rafael	6	13.23	1 200	1 366	20.8
	Yucul	16	12.92	900	1 394	22.4
P. kesiya	Commercial Phillipines	-				
P. merkusii	-	1	-			

*The Queensland source of *P. caribaea* var. *hondurensis* is derived from Mountain Pine Ridge, Belize.

Due to the number of families available within a species, the trials were planted so that no more than 50 families were present in any one trial. Thus, there are two trials for each of *P. caribaea* var. *hondurensis* and *P. oocarpa* and *P. tecunumanii* at La Suiza. In Aguaclara, all of the available families of *P. caribaea* var. *hondurensis* were included, though the family representation differs from that at La Suiza (Table 2).

The statistical model was mixed with provenances fixed and families random in agreement with Crockford *et al.* (3) and Kanowski and Nikles (10). The data were analyzed for height(H) and diameter outside bark at 1.4 m above ground(D) and volume inside bark(V). Individual tree volumes were derived from the formulas of Lopez (13), as follows:

— Volume with bark (VB) = H x (0.0002 + 0.01364 x D + 0.30593 x D x D).

— Percentage bark (B) = 70.83 - 93.51 x Square root (VB) + 41.12 x VB.

— Volume inside bark (V) = VB x (1-B/100).

Increment cores of 8 mm diameter were removed at breast height from two trees of average diameter in each replication for all of the *P. tecunumanii* families

Table 3. Mean square values (MS) and percentage variance accounted for (VC%) for height, diameter outside bark at eight years and volume inside bark at age eight years for provenances and families of *P. oocarpa* and *P. tecunumanii* at La Suiza.

Trial 1.

Source	df	Height(m) MS	Height(m) VC%	Diameter(cm) MS	Diameter(cm) VC%	Volume (m^3) MS	Volume (m^3) VC%
Replication	8	81***	3.0	69***	1.0	0.029**	0.8
Provenance	5	252***	6.4	174***	2.0	0.144***	3.0
RepxProv	39	20***	3.2	23 NS	0.4	0.012 NS	0.6
Family(Prov)	43	42***	6.8	63***	4.2	0.042***	5.6
RepxFam(Prov)	343	7***	0.2	19 NS	0.6	0.009 NS	7.8
Residual	1 677	8	80.4	18	91.8	0.009	82.2
Total	2 115						

Trial 2.

Source	df	Height(m) MS	Height(m) VC%	Diameter(cm) MS	Diameter(cm) VC%	Volume (m^3) MS	Volume (m^3) VC%
Replication	8	69***	1.2	57**	0.4	0.027*	0.2
Provenance	5	545***	10.6	958***	9.4	0.995***	14.3
RepxProv	40	32***	4.2	19	0.0	0.015	0.2
Family(Prov)	44	28***	2.3	69***	3.5	0.043***	3.0
RepxFam(Prov)	343	13***	6.0	22	0.8	0.014	0.1
Residual	1 624	9	75.7	21	85.9	0.014	82.2
Total	2 073						

Table 4. Mean square values (MS) and percentage variance accounted for (VC%) for height, diameter outside bark and volume inside bark at age eight years for provenances and families of *P. caribaea* var. *hondurensis* at La Suiza.

Trial 1.

Source	df	Height(m) MS	Height(m) VC%	Diameter(cm) MS	Diameter(cm) VC%	Volume (m^3) MS	Volume (m^3) VC%
Replication	5	139***	4.4	39***	0.2	0.048**	1.7
Provenance	6	253***	7.2	446***	7.2	0.182***	7.4
RepxProv	30	67***	13.8	69***	4.7	0.030***	6.8
Family(Prov)	39	28***	3.5	58***	3.2	0.023***	2.8
RepxFam(Prov)	190	12 NS	6.9	23 NS	0.7	0.009*	3.4
Residual	1 036	7	64.2	22	84.0	0.007	77.9
Total	1 306						

Trial 2

Source	df	Height(m) MS	Height(m) VC%	Diameter(cm) MS	Diameter(cm) VC%	Volume (m^3) MS	Volume (m^3) VC%
Replication	7	359***	13.8	102***	1.6	0.162**	5.1
Provenance	5	163***	3.4	209***	2.4	0.117***	2.2
RepxProv	34	31***	8.5	21 NS	0.2	0.014*	14.9
Family(Prov)	39	19**	1.4	69***	3.9	0.029***	2.7
RepxFam(Prov)	271	11***	5.9	22 NS	1.7	0.011*	2.3
Residual	1 347	7	67.0	20	90.2	0.009	72.8
Total	1 703						

Table 5. Mean square values (MS) and percentage variance accounted for (VC%) for height, diameter outside bark and volume inside bark at age eight years of age for provenances and families of *P. caribaea* var. *hondurensis* at Aguaclara.

Source	df	Height(m) MS	VC%	Diameter(cm) MS	VC%	Volume (m^3) MS	VC%
Replication	2	148***	33.1	225***	13.4	0.059***	23.4
Provenance	9	45***	0.3	150***	2.6	0.014***	1.3
RepxProv1	6	9***	3.9	12 NS	0.0	0.004*	2.2
Family(Prov)	27	21***	12.7	65***	7.7	0.007***	5.6
RepxFam(Prov)	35	2	1.2	20 NS	3.1	0.002	0.8
Residual	338	3	48.8	14	73.2	0.002	66.7
Total	418						

Table 6. Mean values for survival percentage (S), height (H), diameter outside bark (D), volume per tree (V) and gravimetric density (G) at eight years of age for provenances of *P. oocarpa*, *P. tecunumanii* and *P. kesiya* at La Suiza.

	Trial 1				Trial 2				
Provenance	S	H	D	V	S	H	D	V	G
	(%)	(m)	(cm)	(m^3)	(%)	(m)	(cm)	(m^3)	(kg/m^3)
P. oocarpa	80	16.7	19.3	0.164	87	17.1	20.0	0.183	397
Angeles					74	17.0	19.5	0.184	
Bucaral					76	16.4	18.9	0.164	
Bonete	80	15.6	19.6	0.172	74	16.1	18.9	0.167	
Dipilto	79	18.3	21.1	0.235					
Mal Paso	79	16.8	18.9	0.165					
Siguatepeque	80	17.3	19.3	0.180					
P. tecunumanii									
Rafael					80	17.8	21.9	0.245	372
Yucul					79	19.2	22.4	0.281	379
P. kesiya	81	15.5	21.4	0.204					315
Trial Mean	84	16.8	19.4	0.178	79	17.7	20.6	0.219	-
Standard Error	-	0.7	0.7	0.015	-	0.8	0.6	0.017	

and for the commercial controls of *P. kesiya* and *P. oocarpa*. The increment cores were measured for length to calculate green volume; following extraction, the dry weight of each core was used to calculate gravimetric density.

RESULTS AND DISCUSSION

Results for the analysis of variance are given in Tables 3 to 5. The level of statistical significance is indicated by *, ** or ***, for the levels of 0.05, 0.01 or 0.001, respectively. The mean survival for provenances in each trial is given in Tables 6 to 8, along with provenance mean values for height, diameter, volume and gravimetric density, but no statistical comparison was undertaken on survival or gravimetric density data.

Provenances and families were significantly different ($p<0.01$) for height, diameter and volume in all the trials. However, the residual term accounted for most of the variance in these trials. This would indicate a large amount of variation within plots, which is to be expected for the traits reported (3). The interaction between replication and family was significant for volume ($p<0.05$) in *P. caribaea* var. *hondurensis* at La Suiza, but not for the other trials.

The provenances Yucul and Rafael from *P. tecunumanii* produced, respectively, 54% and 34% more volume per tree, than the commercial control of *P. oocarpa* from Mal Paso, Gua. The only provenance of *P. oocarpa* to approach the volume production of Yucul and Rafael was Dipilto. Crockford *et al.* (3) also found the Dipilto provenance to perform well. None of the provenances of *P. caribaea* var. *hondurensis* approached the volume per tree of the control of *P. oocarpa* from Mal Paso, Guatemala. The *P. merkusii* Jungh. and de Vriese included in these trials had very poor survival, although there is no record of the exact seed source. The *P. kesiya* source grew well in the trials at La Suiza, where its volume exceeded that of *P. oocarpa*. This species was not planted in the trial at Aguaclara but a large trial of *P. kesiya* has since been established in that area.

Table 7. Mean values for survival percentage (S), height (H), diameter outside bark (D) and volume per tree (V) at eight years of age for provenances of *P. caribaea* var. *hondurensis*, *P. oocarpa* and *P. kesiya* in La Suiza.

	Trial 1				Trail 2			
Provenance	S (%)	H (m)	D (cm)	V (m^3)	S (%)	H (m)	D (cm)	V (m^3)
P. caribaea var *hondurensis*								
Alamicamba					85	12.0	19.5	0.124
Araslaya	82	7.7	16.1	0.055				
Culmi					81	14.1	22.4	0.194
Guanaja	75	10.5	20.6	0.127				
Karawala	80	10.3	19.6	0.107				
Limones	83	11.3	21.2	0.140	80	12.5	21.3	0.160
Mountain					77	13.1	21.5	0.170
Pine Ridge								
Queensland	83	11.9	21.7	0.160				
Rio Twas	78	10.2	18.8	0.104				
P. oocarpa	81	13.92	3.7	0.208	83	14.8	20.3	0.161
P. merkusii					38	13.5	18.9	0.123
Trial Mean	80	10.6	20.2	0.123	79	13.0	21.3	0.166
Standard Error	-	1.3	1.3	0.027	-	0.8	0.7	0.017

Table 8. Mean values for survival percentage (S), height (H), diameter outside bark (D) and volume per tree (V) at eight years of age for provenances of *P. caribaea* var. *hondurensis*, *P. oocarpa* and *P. merkusii* in Aguaclara.

Provenance	S (%)	H (m)	D (cm)	V (m^3)
P. caribaea var *hondurensis*				
Alamicamba	98	9.91	6.9	0.071
Araslaya	89	6.91	2.0	0.031
Culmi	91	10.9	19.1	0.099
Guanaja	83	9.5	15.9	0.062
Karawala	89	10.0	17.6	0.079
Limones	91	9.9	17.1	0.074
Mountain	71	10.2	18.7	0.089
Pine Ridge				
Queensland	93	10.3	17.9	0.088
P. oocarpa	78	11.8	19.0	0.103
P. merkusii	11	9.5	18.0	0.067
Trial Mean	83	9.9	17.3	0.078
Standard Error	-	0.5	0.6	0.011

Ladrach (11, 12) also found the Yucul provenance to be among the best for volume production per tree when evaluated at age eight years. In the department of Cauca, Yucul was among the best provenances for height growth at age three years (9). The trials analyzed in the present study provide new material for inclusion in grafted seed orchards and give an indication of volume productivity on sites previously untested. Numerous trials of families within provenance of *P. tecunumanii* have now been established with seed from CAMCORE. These trials will provide a wide genetic base from which to develop a tree breeding program for *P. tecunumanii*.

The average volume per tree in the La Suiza trial of *P. caribaea* var. *hondurensis* was almost twice that from Aguaclara. As management and overall genetic composition of the two trials were similar, it appears that the climatic and/or edaphic conditions are better at La Suiza.

The mean gravimetric density (Table 6) of *P. kesiya* was 20.6% less than that of *P. oocarpa* and confirms previous findings in Colombia (12). The Rafael and Yucul provenances of *P. tecunumanii* were respectively 6.8% and 4.5% lower in gravimetric density than the *P. oocarpa* commercial control. The superior volume growth of *P. tecunumanii* would result in considerably more dry tons of wood produced per hectare when compared with *P. oocarpa*, as has been observed in other OFI trials (19).

CONCLUSION

No further work is anticipated with *P. caribaea* var. *hondurensis* at these altitudes, though the species does grow well in the Llanos region of Colombia. Selections have been made in the best families of *P. tecunumanii* and these will be included in grafted seed orchards. Seed of *P. tecunumanii* is presently imported from several provenances in Central America for operational plantations. Smurfit Carton de Colombia no longer operationally plants *P. oocarpa*, although a breeding base in trials and seed orchards is maintained.

LITERATURE CITED

1. BARNES, R.D.; BURLEY, J. 1990. Tropical forest genetics at the Oxford Forestry Institute: Exploration, evaluation, utilization and conservation of genetic resources. Forest Ecology and Management 35:159-170.

2. BARNES, R.D.; STYLES, B.T. 1983. The closed-cone pines of Mexico and Central America. Commonwealth Forestry Review 62:81-84.

3. CROCKFORD, K.J.; DUNSDON, A.J.; BAYLIS, W.B.H; BIRKS, J.S.; BARNES, R.D. 1990. Evaluation of tropical pine provenance and progeny tests: Final Report. Oxford Forestry Institute. 136 p.

4. DVORAK, W.S.; BALOCCHI, C.E.; RAYMOND, R.H. 1989. Performance and stability of provenances and families of *Pinus tecunumanii* in the tropics and subtropics. In IUFRO Conference Breeding Tropical Trees: Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry (1988, Pattaya, Thailand) Proceedings. G.L. Gibson, A.R. Griffin, A.C. Matheson (Eds.). Oxford Forestry Institute, Oxford, UK; Winrock International, Arlington, Virginia, USA. p. 187-196.

5. EASLEY, D.F.; LAMBETH, C.C. 1989. Five-year results of forty-five eucalyptus species growing in the Andean region of Colombia. Cali: Smurfit Carton de Colombia Research Report no. 123. 9 p.

6. EGUILUZ, P.I.; PERRY, J.P. 1982. *Pinus tecunumanii*. Una nueva especie de Guatemala. Ciencia Forestal 8(41):3-22.

7. GREAVES, A. 1978. Descriptions of seed sources and collections for provenances of *Pinus caribaea*. Commonwealth Forestry Institute, Oxford. Tropical Forestry Papers no. 12. 89 p.

8. GREAVES, A. 1979. Descriptions of seed sources and collections for provenances of *Pinus oocarpa*. Commonwealth Forestry Institute, Oxford. Tropical Forestry Papers no. 13. 144 p.

9. JARA N., L.F. 1981. Provenance trials of *Pinus oocarpa* Schiede in the southwestern region of Colombia, South America. In IUFRO World Congress, (37, 1981, Kyoto, Japan).

10. KANOWSKI, P.J.; NIKLES, D.G. 1989. Family structure in provenance trials, conservation stands and genetic base populations. In Breeding Tropical Trees: Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry. IUFRO Conference (1988, Pattaya, Thailand) Proceedings. G.L. Gibson, G.L., A.R. Griffin, A.C. Matheson (Eds.). Oxford Forestry Institute, Oxford, UK; Winrock International, Arlington, Virginia, USA. p. 68-78.

11. LADRACH, W.E. 1985. Comparison between provenances and sources of fourteen conifers in the Colombian Andes after five years. Cali: Smurfit Carton de Colombia Research Report no. 102. 13 p.

12. LADRACH, W.E. 1986. Comparison between provenances of seven conifers in the Andean region after eight years. Cali: Smurfit Carton de Colombia Research Report no. 105. 8 p.

13. LOPEZ C., B.R. 1986. Indices de sitio y funciones de produccion de *Pinus oocarpa* y *Pinus kesiya* en los departamentos del Valle y Cauca, Colombia: Contract Report. Medellin. 99 p.

14. McCARTER, P.S.; BIRKS, J.S. 1985. *Pinus patula* subspecies *tecunumanii*: The application of numerical techniques to some problems of its taxonomy. Commonwealth Forestry Review 64:117-132.

15. URREGO, J.B. 1989. Fifth year results of San Jose, Salinas and Guachicona arboretums. Cali, Smurfit Carton de Colombia Research Report no. 124. 8 p.

16. WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1986. Variation of stem volume and wood density of *Pinus caribaea*, *P.*

oocarpa and *P. patula* spp. *tecunumanii* in Zambia. Commonwealth Forestry Review 65:33-40. 1986.

17. WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1986. Variation of stem volume and wood density of *Pinus oocarpa* and *P. patula* spp. *tecunumanii* at Agudos, Sao Paulo, Brazil. IPEF 32:21-23.

18. WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1987. Provenance variation in stem volume and wood density of *Pinus oocarpa* and *P. patula* spp. *tecunumanii* growing at two elevations in South Africa. South African Forestry Journal 143:46-48.

19. WRIGHT, J.A. 1987. Provenance variation in wood characteristics of *Pinus caribaea* Morelet and *P. oocarpa* Schiede. Ph D. Thesis. University of Oxford. 153 p.

20. WRIGHT, J.A. 1987. Results of micropulping wood samples of *Pinus caribaea, P. elliottii, P. oocarpa* and *P. patula* spp. *tecunumanii* in the Eastern Transvaal and Zululand. IV. In Simposio sobre Silvicultura y Mejoramiento Genético de Especies Forestales. (1987, Buenos Aires, Arg.). Buenos Aires, Centro de Investigaciones y Experiencias Forestales. p. 247-256.

21. WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1988. Provenance variation in stem volume and wood density of *Pinus caribaea, P. oocarpa* and *P. patula* spp. *tecunumanii* in Puerto Rico. Turrialba 38:123-126.

22. WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1989. Variación en volumen y densidad de la madera de ocho procedencias de *Pinus oocarpa* y *P. patula* spp. *tecunumanii* en Conocoto, Ec. IPEF 41-42:5-7.

23. WRIGHT, J.A. 1990. Variation in wood properties of *Pinus oocarpa* and *P. patula* spp. *tecunumanii* provenances at six sites. Silvae Genetica 39(1):1-4.