VARIATION AMONG OPEN-POLLINATED FAMILIES OF *PINUS CARIBAEA* VAR *HONDURENSIS* FROM GUANAJA ISLAND, HONDURAS, GROWN IN BRAZIL.

Vicente Pongitory Gifoni Moura[1]
W. S. Dvorak[2]

Abstract: Pinus caribaea var. *hondurensis* (Sénécl) Barr. & Golf. is a tropical pine that naturally occurs in lowland areas of Belize, El Salvador, Guatemala, Honduras Nicaragua and eastern Mexico. Over the last 20 years it has been one of the most studied tropical pines and the one with the most commercial importance in central and northern Brazil. One of the most productive *P. caribaea* provenances in Brazil is Guanaja Island that is located 60 km off the northern coast of Honduras. Thirty-nine open-pollinated families from Guanaja Island were grown in a progeny test in the Brazilian "Cerrado" (tropical savanna) at 15° 35' S latitude and 1000 m altitude, and assessed at ten years of age. The traits of height, diameter (dbh), volume, branch diameter, stem straightness and multistem appeared to be under moderate additive genetic control with individual tree heritability of 0.28, 0.30, 0.31, 0.10, 0.24 and 0.13 respectively. If the best 20 trees for volume are selected in the trial regardless of quality, the estimated genetic gain in the next generation would be approximately 30%. Because the tree stem form and branching patterns of unimproved *P. caribaea* from Central America and Mexico are often poor, selection criteria for quality traits may need to be relaxed in the first generation of breeding in order to make large genetic gains in productivity.

Keyword: pine, breeding, genetic gain, heritability

INTRODUCTION

Pinus caribaea var. *hondurensis* (Sénécl) Barr. & Golf. is a tropical pine that occurs in lowland areas of Belize, El Salvador, Guatemala, Honduras, Nicaragua and in one location in the state of Quintana Roo, Mexico. The species has great commercial importance in places like Queensland, Australia, central and northern Brazil, the Fiji Islands, and Venezuela. The largest plantation area of *P. caribaea* is in Venezuela where

[1] Centro de Pesquisa Agropecuária dos Cerrados, Caixa Postal 08223, Planaltina, DF, Brazil.
E-mail: vmoura@cpaceembrapa.br.
[2] CAMCORE Cooperative, North Carolina State University, College of Forest Resources - Box 7626, Grinnells Laboratories, Raleigh, North Carolina 27695-7626, USA.
E-mail: dvorak@cfrecfr.ncsu.edu

approximately 600,000 hectares have been established and 30,000 hectares are planted annually.

In the 1970s, a number of *Pe caribaea* provenances were tested throughout the tropics under the auspices of the Oxford Forestry Instiute (OFI). One of the most promising *Pe caribaea* populations was Guanaja Island, Honduras, located approximately 60 km north of the mainland of the country. The stands on the island are phenotypically poor having been high graded by the local populace for several decades and are subjected to annual fires set by cattle ranchers. However, trees from Guanaja Island demonstrated good growth and high wood density relative to some other Caribbean pine populations in the international provenance trials.

Provenance/progeny tests of *Pinus caribaea* were subsequentely established in a second phase seed collection program by both the OFI and the Central America and Mexico Coniferous Resources Cooperative (CAMCORE), North Carolina State University in the early 1980s (Dvorak and Donahue 1992). The objectives for the second set of trials were to better determine family and within family variation and establish *ex situ* conservation plantings. CAMCORE made collections in 24 provenances and sampled well over 1000 mother trees in Mexico and Central America, including 75 trees from Guanaja Island (Dvorak and Donahue 1992). The Guanaja Island collections were planted across multiple sites in Brazil, Colombia, and Venezuela.

One trial of the CAMCORE Guanaja material was established at Planaltina, Brazil, located at 15° 35'S and 1000 m altitude in the "Cerrado" region of the country. This paper reports on the growth, heritability, and expected genetic gain from selection in the Guanaja material at Planaltina and discusses the performance of similar material planted in other countries in northern South America.

MATERIAL AND METHODS

Seed were collected from 75 mother trees of *P. caribaea* var. *hondurensis* on Guanaja Island in 1983 by the CAMCORE Cooperative and the National School of Forest Science (ESNACIFOR) in Siguatepeque, Honduras. The selected trees were of average to excellent phenotypic quality and were separated by a distance of 100 m whenever possible following CAMCORE guidelines (Balocchi 1990). The island of Guanaja has gently rolling to hilly topography and trees were sampled at altitudes between 65 and 165 m. The phenotypically best trees were found in valleys that were protected against seasonally strong winds and where the soils were most fertile. The average annual rainfall on Guanaja is approximately 2500 mm, most of which occurs from October to January.

RESULTS

The study at Planaltina, Brazil

Survival of Caribbean pine trees at Planaltina was 95% after 10 years of age. Family differences were significant for all traits analyzed (Table 1)e The average height growth for the Guanaja material was 16.1 m and the mean difference between the best and the worst family in the test was 3.5 m at ten years of age. The individual tree volume of the best family was 59% greater than the worst familye Individual tree heritability for growth traits ranged from 0.28 to 0.31 and family heritability varied from 0.68 to 0.71 (Table 1).

The stem form of the Guanaja trees at Planaltina was poor and had an average score of 1.2. The best family for stem form in the trial had 14% of its trees classified as "3", *i.e.,* perfectly straight. There were several families that had mostly small, thin branches (Table 3). Individual tree heritability for stem form and branch diameter was 0.24 and 0.10, respectively (Table 1).

The frequency of forking (11%), foxtails (2%), and broken tops (1%) was low in this trial. Cone production at 10 years of age was also low with only 0.1% of the trees having cones. However the frequency of multistem trees in the test was high (24.8 %) with some family means as high as 40% (Table 3).

Ninety percent of the trees in the tests had some kind of defect (poor stem form, branchness, multistem etce). When all the defected trees were removed from the analysis and the best remaining 20 selected, the estimated genetic gain for volume was 12%.

Performance of Guanaja material in other locations

Three other tests of Guanaja material were established at El Hierro, Venezuela (lat. 9° 10'N, and altitude 150 m), El Amparo, Colombia (lat. 9° 45'N, and altitude 100 m) and Jari, Brazil (lat. 0° 54' S, and altitude 200 m) with as many as 28 open-pollinated families in common to the ones planted at Planaltina. Growth rates varied considerably in these trials depending on the planting site as did forking and foxtail percents (Table 2). For example, the growth rate at El Amparo, Colombia, was substantially poorer than the other three sites; foxtail percents at Jari and El Hierro were 20% and 40%, respectively, versus 2% at Planaltina. Furthermore, family ranks for volume changed considerably across location and genotype x site interactions appeared to be of practical significance (Table 4).

DISCUSSION

The Guanaja material at Planaltina has proven to have excellent growth and vigor; not only has this provenance grown well compared to other *Pe caribaea* var. *hondurensis* populations but is also superior to *P. oocarpa* and *P. tecunumanii*. Heights of Guanaja Island trees at 10 years of age are slightly less than the ones reported for provenances of Mountain Pine Ridge, Belize; Poptun, Guatemala and Culmi, Honduras at 12 years of age grown in central Brazil (Moura *et ale* 1991). Average height growth of Guanaja *Pe caribaea* at Planaltina was also superior to Guanaja material growing in New Caledonia after 14 years (Cremiere 1989). At Cardwell, Queensland, Australia, Guanaja was significantly more productive than all the other Caribbean pine provenances tested (Kanowski *et al.* 1989) and also was the case at Jocón Honduras. However the Guanaja Island source performed less well at Carta and poorly at Culmi, Honduras (Cornelius and Ponce 1989). The poor stem form of the Guanaja material has also been reported elsewhere. In New Caledonia, the insular material of Guanaja had good vigor but poor stem form making selection difficult, when compared to other coastal provenances (Cremiere 1989). However at Cardwell, Australia, Guanaja and Alamikamba were the straightest provenances (Kanowski *et al.* 1989). Environment apparently has great effect on stem form.

The environmental conditions in the Brazilian cerrados are not only favorable to vigor of Caribbean pine but also to low rate of mortality, foxtail and forking, in contrast to other sites in Brazil, Venezuela and Colombia. (Dvorak & Donahue, 1992; Vasquez & Dvorak 1996). Cremiere (1989) reported that Guanaja had poorer resistance to wind than the coastal provenances of *Pinus caribaea* var. *hondurensis* in New Caledonia. At Planaltina, wind damage has not been of any importance.

Pinus caribaea does not produce good cone crops in the region of the cerrados compared to other pine species like *P. oocarpa* (Moura *et al.* 1996). Under other environmental conditions *P. caribaea* var. *hondurensis* starts fruiting at four to five years in Vietnam (Kha *et al.* 1989). Survival is thought to be better at Planaltina than in the western Ilanos of Venezuela and eastern Colombia because the soils are deep, have high clay contents and are not compacted. High variability was found in all growth and quality characteristics. Family, and individual h^2 was high indicating that good gains can be achieved in the selection process (Table 1).

Selecting the best 20 individuals for height, dbh and volume regardless of quality, would result in expected genetic gains in the order of 6.1%, 30.9% and 31.1%, respectively, at Planaltina. However, when stem form, branching and other defected

characteristics are considered these gains for height, dbh and volume are reduced to 3.7, 4.2 and 11.9%. If the defected trees are excluded from the selection process, only 73 out of 804 would be available in the breeding population. In populations of *Pe caribaea* var. *hondurensis* at other sites, a high proportion of defected trees was also observed. Even moderate selection for quality would eliminate most of the trees considered as good candidates for volume in the next cycle of breeding. To maintain a reasonable selection differential for the volume, the selection criteria should be relaxed for quality traits, during the first cycle of selection.

The selection and use of this important material of *P. caribaea* from Guanaja is extremely important for the development of pine forestry in the cerrado region of Brazil. The cerrados has an area of 204 millions ha and less than 2% are occupied by forest plantations. Because the use of the native trees species are restricted and the high demand for sawn timber in the region both pine and eucalypt plantations will be extremely important in the future.

LITERATURE CITED

Balocchi,C.E. 1990. CAMCORE tree Improvement Program. CAMCORE Bulletin on Tropical Forestry Nr. 7. College of Forest Resources, North Carolina State University. Raleigh, NC. USAe

Cornelius, J. P., Ponce,E.G. 1989. Provenances trials of *Pinus caribaea* Morelet var. Hondurensis (Sencl.) Barr. & Golfari and *Pe oocarpa* Schiede in the Republic of Honduras. Commone For. Rev. 69(3): 227-246.

Cremiere,L. 1989. Resultats a 14 ans des Essai dese Provenances de *Pinus caribaea* et de *Pinus oocarpa* en Nouvelle Caledonie P.368-369 In: Breeding Tropical Trees - Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry. Proc. IUFRO Conference, Pataya, Thailand, November, 1988. G.L. Gibson, A.R. Griffin and A.C. Matheson eds. Oxford Forestry Institute, Oxford, United Kingdom and Winrock International, Arlington, Virginia, USA,.

Crockford,K.J., Birks,J.S. and Barnes, R.D. 1989. Family within provenances trials of Pinus caribaea, Pinus oocarpa and P. patula ssp. tecunumanii - early results and implications for breeding strategy. P.176-186 In: Breeding Tropical Trees - Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry. Proc. IUFRO Conference, Pataya, Thailand, November, 1988. G.L. Gibson, A.R. Griffin and A.C. Matheson eds. Oxford Forestry Institute, Oxford, United Kingdom and Winrock International, Arlington, Virginia, USA,.

Dvorak,W.S. and Donahue,J.K. 1992.CAMCORE Research Review 1980-1992. Department of Forestry, College of Forest Resources, North Carolina State University. Raleigh, NC, USA, 93p.

Dvorak,D.W., Ross,K.D. and Liu,Y. 1993. Performance of *Pinus caribaea* var. *hondurensis* in Brazil, Colombia and Venezuela., Bulletin on Tropical Forestry, CAMCORE, North Carolina State University, 11:1-46.

Kha,L.D., Dien.P.Q. and Nhung,DeV. 1989. Growth of *Pinus caribaea* in Vietnam. P.376 In: Breeding Tropical Trees - Population Structure and Genetic Improvement Strategies in Clonal and Seedling Forestry. Proc. IUFRO Conference, Pataya, Thailand, November, 1988. G.L. Gibson, A.R. Griffin and A.C. Matheson eds. Oxford Forestry Institute, Oxford, United Kingdom and Winrock International, Arlington, Virginia, USA,.

Kanowski,P.J., Woolaston and Nikles.D.G. 1989. Preliminary Results of the OFI Second Stages provenance Trial of *Pinus caribaea* var. *hondurensis* in Queensland.. P. 373-375 In: Breeding Tropical Trees - Population Structure and Genetic lmprovement Strategies in Clonal and Seedling Forestry. Proc. IUFRO Conference, Pataya, Thailand, November, 1988. G.L. Gibson, A.R. Griffin and A.C. Matheson eds. Oxford Forestry Institute, Oxford, United Kingdom and Winrock International, Arlington, Virginia, USA..

Ladrach,W.E. 1986. Comparaciones entre procedências de siete coniferas en la Zona Andina al finalizar los ochos Informe de Investigacion 105: 8p. Smurfit de Colombia,

Moura,V.P.G., Parca,M.L.S. and Silva,M.A. 1991.Variação da Densidade da Madeira de Espécies e procedência de Pinus Centro-Americanos em Tres Locais na Região dos Cerrados. 22/23:29-44. Colombo: EMBRAPA-CNPF. Boletim de Pesquisa Florestal.

Moura,V.P.G., Oliveira,J.B. and Rezer Junior,J. 1996. Variabilidade e Ganho Genético em Progenies de Meio-irmãos de *Pinus patula* ssp. *tecunumanii,* em Planaltina-DF. P.230-234 In: Forest'96, Belo Horizonte, MG, Brasil, Sociedade Brasileira para a Valorização do Meio-Ambiente - BIOSFERA, 1996.

SAS. 1990. SAS/STAT User's guide, Version 6, Fourth Edition, Volume 2. SAS Institute Inc., Cary, NC. USA.

Satterthwaite,F.E. 1946. An approximate Distribution of Estimates of Variance Components. **Biometrics Bulletin,** 2:110-114.

Vásquez,J. and Dvorak,W.S. 1996. Trends in Variances and Heritabilities with Stand Development of Tropical Pines. Canadian Journal Forest Research, 26.: 1473-1480.

Table 1. Heritabilities for *Pinus caribaea* var. *hondurensis* provenance of Guanaja Island, in Planaltina-DF, Brazil at 10 years.

Characteristic	Mean	CV(%)	Heritability	
			112 f	h2 i
Height	16.0 m	10.7	0.70	0.28
dbh	0.18 m	18.3	0.71	0..30
volume	0.26 m3	43.3	0.68	0.31
Branch diameter	1.9	39.0	0.42	0.10
Stem form	1.2	32.4	0.65	0.24
multistem	24.9%	43.6	0.49	0.13

Table 2. Means of different traits at age five years for families of *Pinus caribaea* var. *hondurensis* from Guanaja Island, grown at Planaltina and Jan, Brazil; El Hierro, Venezuela and El Amparo, Colombia.

Characteristic	Planaltina Brazil	El Hierro Venezuela	El Amparo Colombia	Jan Brazil
Height (m)	7.8	7.1	4.8	7.4
dbh (m)	0.13	0.13	0.09	0.12
volume (m3)	0.04	.0.04	0.02	0.04
fox tail	1.31	41.6	-	21.8
forking	2.8	27.8	-	26.6
survival (%)	96.7	70.9	82.0	96.0

Table 3. Family means and percentage of height (H), dbh, volume (vol.), stem form (ST), multistem (MS), forking (FK), foxtail (FX), fruiting (FR) and broken-top (BT) of the Guanaja Island provenance of *P. caribaea* var. *hondurensis* at Planaltina-DF, Brazil.

FAM	H (m)	dbh (cm)	vole (m')	ST	BD	MS (%)	FK (%)	FX (%)	FR (%)	BT (%)
326	16.54	20e11	0.30	1.09	1.70	11.1	3.7	0.0	0.0	0.0
327	16.06	17e73	0.25	1.09	1.66	37e2	2.9	0e0	0.0	2e9
332	15.16	17e77	0.19	1e17	1.95	42e9	9.5	0e0	0e0	0e0
336	14e58	18e33	0.26	1e00	1.50	16e7	0.0	16.7	0e0	0e0
337	16.38	18e52	0.31	1e12	1.88	22.3	5.6	0.0	0e0	0.0
338	15.33	16.83	0e20	1.18	1.74	28.6	4.8	9.5	0.0	0.0
339	16.03	17.48	0.22	1.04	1e04	17.2	0.0	3.4	0.0	0.0
341	16.32	19.00	0.31	1.02	1.57	7.1	0e0	0.0	0.0	0.0
343	13.68	16.72	0.22	1.21	1.93	7e6	0.0	0e0	0.0	0e0
345	15.55	19.13	0.26	1.22	1.75	34.7	0.0	0e0	0.0	0.0
347	16.40	17e65	0.24	1e24	1.52	14.3	4.8	4.8	0e0	0.0
348	16.50	19.61	0e32	1e10	1.85	35	0.0	0.0	0.0	0.0
350	15.37	16.38	0e17	1.20	1.77	5.9	5.9	5.9	0.0	0.0
351	16.90	19.68	0.29	1.33	1.93	0.0	0.0	0e0	0.0	0.0
352	16.75	19.45	0.30	1.15	1.84	16.7	5.6	11.1	0.0	0.0
353	16.50	19.28	0e29	1.09	1.59	20.6	3e4	3.4	0.0	0.0
354	15.96	17.53	0.23	1.36	2.07	71.4	0e0	0.0	0.0	0.0
355	16.61	18.43	0.28	1.23	2.02	29.6	0e0	3.7	0.0	0.0
356	17.11	19.37	0e29	1.08	1.85	7.7	0e0	7.7	0e0	0.0
358	15.34	18.03	0.25	1.62	1.81	12e5	0e0	0e0	0.0	0.0
359	16.34	18.35	0.26	1.05	1.79	31.6	0.0	0.0	0.0	0.0
360	16.00	17e38	0.24	1.32	2.04	32.8	4.6	0.0	0.0	4.5
363	16.06	18.18	0.27	1.06	2.17	27.8	5.6	0	0.0	0.0
365	15.76	18.03	0e26	1.05	1.90	14.3	9.5	0e0	0e0	0.0
366	16e45	19.07	0e26	1.42	2.00	31.6	5.3	0.0	0.0	5.3
370	15.58	18e69	0.24	1.17	1.78	50.0	11.1	0e0	0.0	0.0
373	16.15	18.10	0.22	1.23	1.69	11.5	3.8	11.5	0.0	7.7
378	17.00	17.79	0.27	1.20	2.20	40.0	0.0	10.0	0.0	0.0
379	16.16	17.75	0.23	1e05	2.10	31.6	0.0	0.0	0.0	0.0
381	15.77	18.53	0.26	1.08	2.08	23.8	0.0	0.0	0.0	0.0
382	16.09	17.70	0e24	1.19	2.19	43.7	0e0	0.0	0.0	0.0
383	16.29	18.94	0.32	1.08	1.38	12e5	0.0	6.3	0.0	6.3
384	17.05	18.69	0e28	1.37	2.17	37.5	6.3	0.0	0.0	0.0
387	16.15	17.42	0.23	1e05	1.85	25.9	7.4	7.4	0.0	0e0
388	14.63	13.90	0.19	1.40	2.40	22e2	0.0	5.6	0e0	5.6
390	16.09	16.91	0.21	1.13	1.90	17.2	6.9	3.4	0.0	0.0
391	16.80	22.31	0.41	1.40	1.55	17.9	3.6	0e0	0e0	0.0
397	16.25	18.79	0.28	1.41	2e05	19.2	0e0	0.0	3.8	0e0
398	15.91	17.46	0.24	1..43	2.24	39.4	0e0	0.0	0.0	0.0
mean	16e04	18.23	0.26	1.19	1.86	24.9	2e8	2.8	0e1	0.8

Table 4 Family volume means (m^3) of *P. caribaea* var. *hondurensis* from Guanaja Island, growing at different sites and with different ages.

Family	Planaltina (10 years)	El Amparo (5 years)	El Hierro (8 years)
391	.412		172
383	.322	.014	167
338	.199	.015	
353	.290	.015	
351	.295	-	.205
352	.304	.015	
373	.219	.011	
347	.239	.016	
348	.324	.020	
359	.262	.028	
397	.284	-	.162
384	.284	-	.157
366	.257	.017	.174
354	.233	.016	
360	.236	.013	.167
337	.310	.012	.187
387	.226	.020	.170
345	.262	-	.179
363	.271	.019	
365	.261	.013	
356	.295	.019	
358	.248	.012	
327	.248	.020	
339	.225	.018	
378	.271	.016	.164
381	.262	.022	.161
390	.208	.010	
355	.281	.017	.172
370	.243	.011	
350	.172	.013	
379	.235	.013	.174
382	.242	013	
398	.240		.161
388	.187	.013	.172