Provenance Variation in Stem Volume and Wood Density of *Pinus caribaea*, *P. oocarpa* and *P. patula* spp. *tecunumanii* in Puerto Rico[1]

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ABSTRACT

Provenance trials of *Pinus caribaea* Morelet and *P. oocarpa* Schiede/*P. patula* Schiede and Deppe ssp. *tecunumanii* (Eguiluz and Perry) styles of the International Series coordinated by the Oxford Forestry Institute, University of Oxford, were established at Anasco, Puerto Rico, in 1973. The trials were assessed in 1979 for volume under bark (VUB) and wood density (DEN), and these two traits plus the derived indices of within-sample density variation (VAR) and dry matter index (DMI) were analyzed. There were significant statistical differences ($P < 0.1$) between provenances in the *P. caribaea* trial for VAR, VUB and DMI and in the *P. oocarpa/P. patula* ssp. *tecunumanii* trial for VUB and DMI. Provenances of *P. patula* spp. *tecunumanii* were superior in terms of VUB and DMI to provenances of *P. caribaea* and *P. oocarpa*

COMPENDIO

Se presentan los resultados de más pruebas de procedencias de *Pinus caribaea* Morelet y *P. oocarpa* Schiede, *P. patula* Schiede y Deppe ssp. *tecunumanii* (Eguiluz y Perry) Styles, correspondientes a la serie internacional que está siendo coordinada por el Instituto Forestal de Oxford de la Universidad de Oxford. Las pruebas fueron establecidas en Anasco, Puerto Rico en 1973 y analizadas en 1979, considerando el volumen sin corteza (VUB), densidad de la madera (DEN); además, se consideraron índices derivados de la variación de la densidad dentro de la muestra (VAR) y el índice de materia seca (DMI). Se encontraron diferencias estadísticamente significativas ($P < 0.01$) entre procedencias de *P. caribaea* para VAR, VUB y DMI; en *P. oocarpa/ P. patula* ssp. *tecunumanii* se observaron diferencias para VUB y DMI. Las procedencias de *P. patula* y *tecunumanii* fueron superiores en términos de VUB y DMI con respecto a las procedencias de *P. caribaea* y *P. oocarpa*.

INTRODUCTION

The annual cost of forest products imported into Puerto Rico totals almost 500 million dollars and constitutes 90% of the construction, pulp and paper materials used in the country (15). While much of the arable land of Puerto Rico is needed for agricultural crops, there are extensive areas that could be afforested to reduce the need for imported wood products. The Institute of Tropical Forestry began to identify fast-growing exotic species in 1939 (13). Since then, numerous trials have indicated that *Pinus caribaea* Morelet and *P. oocarpa* Schiede have good survival and rapid growth over a variety of sites (4, 5). This paper concerns adjacent provenance trials of *P. caribaea* and *P. oocarpa* at Anasco, Puerto Rico, as part of the International Series coordinated by the Oxford Forestry Institute (OFI), University of Oxford, England

MATERIALS AND METHODS

Two trials of *P. caribaea* and one trial of *P. oocarpa* were established in 1973, using five blocks of seven-tree row plots at a spacing of 2.7 x 2.7 m. The Anasco site is at 18°20'N of latitude with an elevation of 175 m and the mean annual precipitation and temperature are respectively 2090 mm and 25.3°C. Provenance details for *P. caribaea* are summarized in Greaves (8) and for *P. oocarpa* in Greaves (9). Four of the *P. oocarpa* provenances represented in this trial have subsequently been identified as *P. patula* Schiede and Deppe ssp. *tecunumanii* (Eguiluz and Perry) Styles (15). Details of provenances, country of origin and abbreviations used for these trials are summarized in Table 1.

The trials were measured in 1979, at age 5.7 years, and results for a range of traits in *P. caribaea* were reported in Gibson (6) and in *P. caribaea* and *P. oocarpa* in Liegel *et al* (13). At the time of measure-

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Seeds for the international provenance trials of *P. caribaea* and *P. oocarpa/P. patula* ssp. *tecunumanii* were collected and distributed under Research Schemes at the Oxford Forestry Institute (OFI), University of Oxford, England, funded by the Overseas Development Administration of the British Government and with the cooperation of the forest authorities in various countries of Central America and the Caribbean where the species are indigenous. The trials were established and maintained by the Institute of Tropical Forestry, United States Forest Service and their help with these assessments and permission to publish the results are gratefully acknowledged. We would also like to thank Mr. Tony Quilter of the OFI for his assistance in preparing the wood samples for densitometry.

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ment, increment cores of 8 mm diameter were taken bark to bark at breast height from the two largest trees in each provenance in each block of the *P. oocarpa/P. patula* ssp. *tecunumanii* trial. In *P. caribaea,* increment cores of 8 mm diameter were taken at breast height from the largest diameter tree per provenance per block in the first trial and from the two largest diameter trees per provenance per block in the second trial. The increment cores were prepared for densitometry using the methods described by Wright *et al.* (16). Kanowski (10) has described the procedures used at OFI with respect to densitometry. In addition to mean density (DEN), data from the densitometer can also be used to calculate within-sample density variation (VAR). Volume under bark (VUB) was determined for each tree sampled for DEN using under-bark diameter at breast height, total height and a form quotient based on the outside bark diameter at breast height and at 6 mm (7). The dry matter index is the product of DEN and VUB.

Table 1. Details of provenances, country of origin and abbreviations used for *P. caribaea* and *P. oocarpa/P. patula* ssp. *tecunumanii* at Anasco, Puerto Rico.

Species	Provenance	Country	Abbreviation
P. caribaea var. *caribaea*	Buren	Cuba	BUR
	Palacios	Cuba	PCC
P. caribaea var. *hondurensis*	Alamicamba	Nicaragua	ALA
	Briones	Honduras	BRI
	Brus Lagoon	Honduras	BRU
	Byfield	Australia	BYF
	Culmi	Honduras	CUL
	Guanaja	Honduras	GUA
	Karawala	Nicaragua	KAR
	Melinda	Belize	MEL
	Mountain Pine Ridge	Belize	MPR
	Poptun	Guatemala	POP
	Potosi	Honduras	POT
	Rio Coco	Nicaragua	RIO
	Santa Clara	Nicaragua	STA
P. oocarpa	Agua Fria	Honduras	FRI
	Bucaral	Guatemala	BUC
	Conacaste	Guatemala	CON
	Huehuetenango	Guatemala	HUE
	Jitotol	Mexico	JIT
	Junquillo	Nicaragua	JUN
	Lagunilla	Guatemala	LAG
	San Jose	Guatemala	JOS
	Siguatepeque	Honduras	SIG
	Zamorano	Honduras	ZAM
	Zapotillo	Honduras	ZAP
P. patula ssp. *tecunumanii*	Camelias	Nicaragua	CAM
	Mountain Pine Ridge	Belize	MPO
	Rafael	Nicaragua	RAF
	Yucul	Nicaragua	YUC

The *P. oocarpa* trial was analyzed as a randomized complete block design. Since the *P. caribaea* trials are contiguous, data from them were analyzed together using a completely randomized design with 15 observations per provenance. The results should be interpreted with caution, however, because one trial was twice as intensively sampled as the other and the common environment of two trees per plot in one trial could have influenced differences between provenances. The analysis of variance was applied to data for DEN, VAR, VUB and DMI. Differences between provenances within trials were tested at the 5% level using the Q statistic as described by Chew (3).

RESULTS AND DISCUSSION

The results of the analysis of variance are summarized in Fig. 1 for *P. caribaea* and in Fig. 2 for *P. oocarpa/P. patula* ssp. *tecunumanii*. Provenances were significantly different ($P < 0.01$) for VAR, VUB and DMI in the *P. caribaea* trial and for BUB and DMI in the *P. oocarpa/P. patula* ssp. *tecunumanii* trial. The Q statistic exceeded the range for DEN and VAR in the *P. oocarpa/P. patula* ssp. *tecunumanii* trial and has not been presented for these traits.

In the *P. caribaea* trial, the *P. caribaea* var. *hondurensis* provenances Mountain Pine Ridge, Poptun,

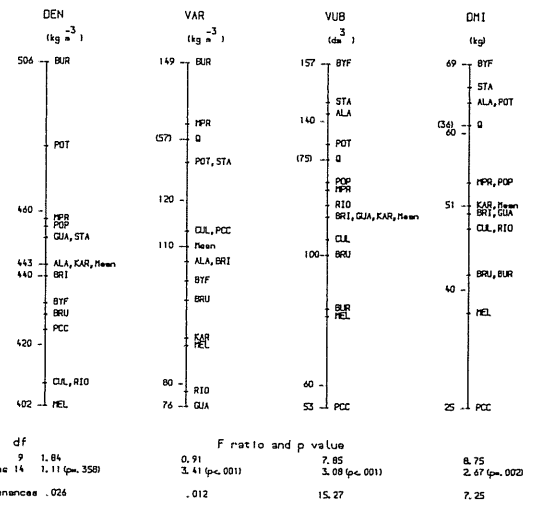

Fig. 1. Analysis of variance and ranked means for densitometric density (DEN), within sample variation (VAR), volume under bark (VUB) and dry matter Index (DMI) of *P. caribaea* provenances at Anasco, Puerto Rico.

Potosi and Santa Clara were ranked above the trial mean for DEN, VUB and DMI. By contrast, the *P. caribaea* var. *hondurensis* provenance Melinda was ranked below the trial mean for DEN, VUB and DMI. This indicates that slow growth is not necessarily accompanied by higher wood density. Based on assessments of *P. caribaea* provenance trials at age 10 years, Liegel (11) concluded that the provenances Alamicamba, Byfield, Karawala, Mountain Pine Ridge, Poptun, Potosi and Santa Clara were superior for height and/or diameter at breast height and these provenances exceeded the trial mean for VUB in this assessment with the exception of Karawala. However, the coastal provenances Alamicamba, Karawala and the Queensland source, Byfield, had a DEN equal to or below the trial mean as did the other coastal provenances of *P caribaea,* Brus Lagoon, Melinda and Rio Coco, which is in accordance with Barnes *et al.* (2). The *P. caribaea* var. *hondurensis* provenance Guanaja had the lowest value for VAR in the *P. caribaea* trial and this confirms the findings in other trials of this series (16).

The *P. patula* ssp. *tecunumanii* provenances Camelias, Mountain Pine Ridge, Rafael and Yucul were clearly superior to provenances of *P. oocarpa* in terms of VUB and DMI and these findings are similar to previous reports in Puerto Rico (12), Zambia (16), Brazil (17), Kenya (19) and Ecuador (18). The *P. patula* ssp. *tecunumanii* provenances Rafael and Yucul were also ranked above the trial mean for DEN. The trial mean values for DEN of 443 kg m-3 in *P. caribaea* and 446 kg m-3 in *P. oocarpa/P. patula* ssp. *tecunumanii* were almost equal. However, the range of provenance mean values for DEN was higher in *P caribaea* (402-506 kg m-3) than in *P. oocarpa/ P. patula* ssp. *tecunumanii* (418-485 kg m-3). The trial mean for VAR was considerably higher for *P. caribaea* than for *P oocarpa/P. patula* ssp. *tecunumanii.*

Comparisons between the two trials indicate that the *P. patula* ssp. *tecunumanii* provenances Camelias, Mountain Pine Ridge, Rafael and Yucul were superior to *P. caribaea* provenances for VUB and DMI. These results were unexpected because the coastal climate at Anasco is more similar to that of the most tropical of the *P caribaea* provenances Liegel (12) has observed that fast growing provenances of *P. patula* ssp. *tecunumanii* are highly susceptible to damage in cyclonic storms. Further, *P. patula* itself is known to have an outstanding early performance when grown in climates that are more tropical than that where it occurs naturally, but this is not maintained for the full rotation (1), and the subspecies may perform in a similar manner. Assessments taken closer to rotation age should be evaluated before large-scale planting programmes are initiated with this species. The low DEN values of certain provenances such as Culmi, Melinda and Rio Coco of *P. caribaea* could limit their use for plantation establishment on sites similar to those at Anasco. Wood samples from these trials should be evaluated for their solid wood or pulp and paper-making properties before final decisions are made, since DEN influences end product uses and characteristics, but is not the sole determinant thereof.

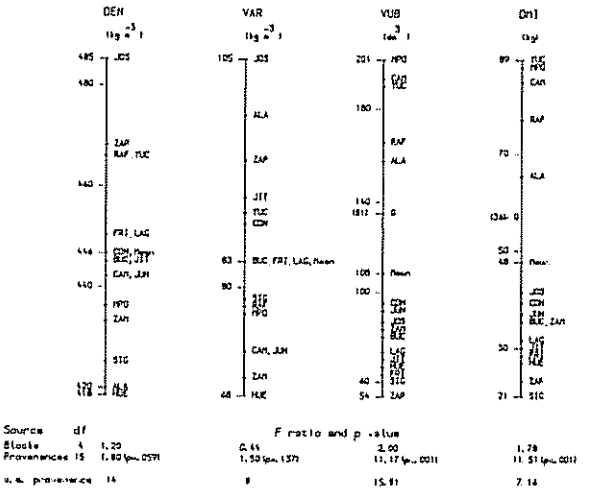

Fig. 2. Analysis of variance, ranked means and the critical difference, Q, at the 5% level for densitometric density (DEN), within sample variation (VAR), volume under bark (VUB) and dry matter index (DMI) of *P oocarpa* and *P patula* ssp. *tecunumanii* provenances at Anasco, Puerto Rico.

LITERATURE CITED

1 BARNES, R.D.; MULLIN, L.J. 1976. Selection of forest tree species in Rhodesia. South African Forestry Journal 98:16-20

2. BARNES, R.D.; GIBSON, G.L.; BARDEY, M.A. 1989. Variation and gentoype-environment interaction in international provenance trials of *Pinus caribaea* var. *hondurensis* and implications for population improvement strategy. Silvicultura 8:35-43.

3 CHEW, V. 1977. Comparisons among treatment means in an analysis of variance. Washington, D.C. Agricultural Research Service, United States Department of Agriculture. 64 p.

4. GEARY, T.F.; BRISCOE, C.B. 1972. Tree species for the granitic uplands of Puerto Rico. United States Forest Service Research. 8 p. (Paper ITF-14).

5. GEARY, T.F.; ZAMBRANA, J.A. 1972. Comparative adaptability of conifers in Puerto Rico. In Selection and breeding to improve some tropical conifers. Ed. by J. Burley; D.G. Nikles. Oxford. Commonwealth Forestry Institute. v. 1. p. 226-234.

6 GIBSON, G.L. 1982. Genotype-environment interaction in *Pinus caribaea*. Unit of Tropical Silviculture, Interim Report. Oxford. Commonwealth Forestry Institute. 89 p.

7 GIBSON, G.L.; BARNES, R.D.; BERRINGTON, J. 1983. Provenance productivity in *Pinus caribaea* and its interaction with environment. Commonwealth Forestry Review 62:93-106.

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

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

10 KANOWSKI, P.J. 1985. Densitometric analysis of a large number of wood samples. Journal of the Institute of Wood Science 10:145-151.

11 LIEGEL, L.H. 1984a. Ten-year growth results of *Pinus caribaea* and *Pinus oocarpa* provenance trials in Puerto Rico. In Provenance and genetic improvement strategies in tropical forest trees. Ed. by R.D. Barnes; G.L. Gibson. Oxford. Commonwealth Forestry Institute. p. 326-327.

12. LIEGEL, L.H. 1984b. Growth and performance in young *Pinus oocarpa* trials in Puerto Rico on eight sites. In Provenance and genetic improvement strategies in tropical forest trees. Ed. by R.D. Barnes, G.L. Gibson. Oxford. Commonwealth Forestry Institute. p. 324-325.

13 LIEGEL, L.H.; BARNES, R.D.; GIBSON, G.L. 1983. Growth and selected assessment traits of *Pinus caribaea* and *Pinus oocarpa* provenance trials in Puerto Rico. Silvicultura 8:107-111.

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

15. WADSWORTH, F.H.; BIRDSEY, R.A. 1985. A new look at the forests of Puerto Rico. Turrialba 35:11-17.

16 WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1986a. Provenance variation in stem volume and wood density of *Pinus caribaea*, P. oocarpa and *P. patula* ssp. *tecunumanii* in Zambia. Commonwealth Forestry Review 65:33-40.

17 WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. 1986b. Provenance variation in stem volume and wood density of provenances of *Pinus oocarpa* and *P. patula* ssp. *tecunumanii* at Agudos, São Paulo, Brazil. IPEF, Pircacicaba 32:21-23.

18 WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. s.f. Variación en volumen y densidad de la madera de ocho procedencias de *Pinus oocarpa* y *P. patula* ssp. *tecunumanii* en Conocoto, Ecuador. Quito. Dirección Nacional Forestal. Forestal Informativo no. 4.

19 WRIGHT, J.A.; GIBSON, G.L.; BARNES, R.D. s.f. Variation in stem volume and wood density in provenances of *Pinus oocarpa* and *P. patula* ssp. *tecunumanii* at Nzoia, Kenya.