Variation in Wood Properties of Pinus oocarpa and P. patula ssp. tecunumanii Provenances at Six Sites

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Summary

Sub-sets of four *Pinus oocarpa* Schiede and five *P. patula* Schiede and Deppe ssp. *tecunumanii* (Eguiluz and Perry) Styles provenances at six sites were assessed for densitometric density (DEN) and within sample density variation (VAR). There were significant differences for DEN and VAR between sites ($p < 0.001$) and provenances ($p < 0.05$). The site by provenance interaction term was not significant for either DEN or VAR. The two taxa had higher DEN and lower VAR than that reported for *P. caribaea* var. *hondurensis* Barrett and Golfari.

Key words: Pinus oocarpa, P. patula ssp. tecunumanii, provenance variation, wood densiity, genotype by environment interaction.

Introduction

The Internationtl Provenance Trials (IPT) of *Pinus oocarpa* Schiede coordinated by the Oxford Forestry Institute (OFI) have increased the awareness of the afforestation potential of this species across a range of sites. In particular, four of the provenances in those trials have now been reclassified as *P. patula* Schiede and Deppe ssp. *tecunumanii* (Eguiluz and Perry) Styles (McCarter and Birks, 1985; Barnes and Styles, 1983) and have been observed to have fast growth under a range of environmental conditions. It should be noted that some authorities refer to this species as *P. tecunumanii* (Eguiluz and Perry, 1982),

Multivariate analysis of variance for production traits from subsets of up to 26 provenances at 10 locations of the *P. oocarpa* IPT have been reported (Birks and Barnes, 1985). Variation in provenance productivity at certain individual sites has also been reviewed (Wright, 1987 a and b; Wright, Gibson and Barnes, 1988, 1987, 1986 a, b and c; Chagala and Gibson, 1984; mullin and Quaile, 1984; Liegel, 1984 a, b; and van Wyk, 1978).

Geographic variation for certain wood properties within the natural range of *P. patula* ssp. *tecunumanii* have been reported (Eguiluz and zobel, 1986). Variation in wood properties of species and provenances across sites is a critical factor in determining the most suitable seed source for plantation establishment. Some of the previously cited references discuss variation in wood properties of these taxa and results at other sites have also been reported (Ladrach, 1986; Palmer and Ganguli, 1985; Bucci, Deschamps and Rubial, 1984; and Foelkel *et al.*, 1975). The present study details the variation in wood properties of sub-sets of five *P. oocarpa* and four *P. patula* ssp. *tecunumanii* provenances at six sites.

Materials and Methods

The experimental details of the trials are listed in *table 1* and environmental details are summarized in *table 2*. Greaves (1979) has described the site and stand conditions of the seed collection areas and the most pertinent information from his study is contained in *table 3*. The trials included in the analysis were selected to represent a range of environments. Provenances were selected so that the most orthogonal set of provenances across sites would be included in the analysis. All of the provenances, however, are not represented at all sites.

The trials were evaluated in 1979, 1980 or 1981. The number of trees sampled for density varied from two to three per measured plot. This sub-sample is likely to contain the final crop trees and those most likely to be included in any future breeding population. At the time of measurement, increment cores of 8mm diameter were removed bark to bark at breast height (1.3 m) from the largest diameter trees in the measured plot. Following shipment to the OFI, the cores were oven-dried to 12 percent moisture content, weighed and the gravimetric density determined using dry weight and wet volume calculated from a nominal 8 mm increment core diameter and fresh core length (Barnes, Gibson and Bardey, 1983). The cores were then machined to 5 mm thickness in both axial and radial planes and the resin was extracted.

Hughes and Sardinha (1975) and Kanowski (1985) have described in detail the equipment and procedures used at the OFI with respect to densitometry. The machined increment cores were X-rayed and the resulting radiographs were scanned using the Joyce-Loebl MDM6 optical densitometer. The resulting data were used to calculate the mean densitometric density (DEN) as well as the within sample density variation (VAR). The VAR term is derived identically to the standard deviation but does not have its statistical connotations (Kanowski, 1985). A lower value of VAR implies greater wood uniformity. High VAR is likely the result of an increased amount of wood with higher density (Wright, 1987 b; Echols, 1972).

Bartlett's Test (Snedecor and Cochran, 1980) was used before the genotype by environment interaction (GEI) analysis to determine if the residual variances of the individual trials were sufficiently homogeneous. If the residual variances are heterogeneous, significant treatment effects could occur with greater frequency than would be expected. Gibson (1982) found in a GEI analysis of *P. caribaea* var. *hondurensis* Barrett and Golfari that "Virtually all traits analysed show significant differences in error variance between experiments". The Bartlett's Test on the residual variances of DEN and VAR indicated that these variances were significantly different (*Table 4*). This indicates that treatment effects tested against the pooled residual variance in the F test may be in doubt if they are slightly above the tabular statistical levels (Cochran and Cox, 1957).

For the selected provenances and sites, provenance block means for DEN and VAR were analyzed using the analysis of variance (ANOVA). The model used was:

Table 1. — Details of experimental design of *P. oocarpa* provenance trials.

Location	No. of blocks	Overall plot size	Measured plot size	Trees sampled /measured plot	Spacing (m)
Anasco, Puerto Rico	5	7x1	7x1	2	2.7x2.7
Conocoto, Ecuador	5	7x7	4x4	3	2.0x2.0
Agudos, Brazil	4	5x5	4x4	3	3.0x3.0
Ndola East, Zambia	2	10x6	8x2	3	3.1x3.1
Wilgeboom, South Africa	5	6x6	4x4	3	2.7x2.7
Nzoia, Kenya	4	5x5	4x4	3	2.5x2.5

Table 2. — Details of environmental condition of *P. oocarpa* provenance trials.

Location	Lat. (o)	Alt. (m)	Mean Annual Precip. (mm)	Mean Annual Temp. (oC)	Age (months)
Anasco, Puerto Rico	18.33 N	175	2090	25.3	69
Conocoto, Ecuador	0.26 N	2510	1386	15.2	72
Agudos, Brazil	22.37 S	550	1300	21.2	84
Ndola East, Zambia	13.00 S	1300	1174	19.6	75
Wilgeboom, South Africa	24.97 S	945	1348	18.2	91
Nzoia, Kenya	0.93 N	1700	1250	18.9	91

Table 3. — Details of *P. oocarpa* and *P. patula* ssp. *tecunumanii* provenances (Greaves, 1979).

Species	Provenance	Code	Lat. (o)	Alt. (m)	Mean Annual Precip. (mm)	Mean Annual Temp. (oC)
P. oocarpa	Huehuetenango	HUE	15.32 N	1700	1037	16.9
	Lagunilla	LAG	14.70 N	1600	936	19.5
	Siguatepeque	SIG	14.53 N	1100	1247	19.9
	Zamorano	ZAM	14.03 N	1100	1117	20.2
	Zapotillo	ZAP	14.62 N	1000	1272	21.8
P. patula ssp. tecunumanii	Camelias	CAM	13.77 N	900	1500	22.4
	Mountain Pine Ridge	MPO	16.97 N	700	1558	23.9
	Rafael	RAF	13.23 N	1200	1366	20.8
	Yucul	YUC	12.92 N	900	1394	22.4

$$DENsp \text{ or } VARsp = \mu + Bb(s) + Ss + Pp + SPsp + Esp$$

where DENsp or VARsp is the trial value at the sth site and the pth provenance, μ is the population mean, Bb(s) is the effect of the bth block in the sth site, Ss is the effect of the sth site, Pp is the effect of the pth provenance, SPsp is the interaction of the sth site and the pth provenance and Esp is the residual. The Scheffés test was used to determine if there were significant differences between *P. oocarpa* and *P. patula* ssp. *tecunumanii* for DEN and VAR.

Results

The ANOVA revealed significant differences between sites and provenances (*Table 5*). The site by provenance interaction term was not significant and accounted for none of the variance. The low F ratio of the site by provenance interaction term indicates that the use of the pooled residual variances was acceptable for testing this source. In DEN, the residual term accounted for most of the variance (69.4%) whereas for VAR most of the variance was accounted for by sites (56.6%). This was similar to the pattern observed in *P. caribaea* var. *hondurensis* (Wright, in press). The low variance accounted for by provenance is most likely due to large differences in DEN and VAR within provenances. These large differences in DEN and VAR may have resulted because the three trees sampled per measured plot were not a sufficiently large sample to give a reliable provenance mean.

Differences in site means for DEN (*Figure 1*) and VAR (*Figure 2*) could be due to different ages, rainfall or temperature patterns. The Conocoto and Agudos sites had the highest values of DEN. For VAR, the Wilgeboom and Agudos sites had the highest values. The lowest values for VAR were observed at Nzoia and Conocoto and these two trials were at the lowest latitude and highest altitude of those assessed.

Table 4. — Bartlett's Test for homogeneity of the residual variance for DEN and VAR of trials and provenances selected for GEI analysis.

Trait	df	Chi square	Probability
DEN	5	53.5	$p<0.001$
VAR	5	62.7	$p<0.001$

Table 5. — Analysis of variance of plot means from five provenances of *P. oocarpa* and four provenances of *P. patula* ssp. *tecunumanii* at six sites for DEN and VAR.

Source	df	MS		VC (%)		F	
		DEN	VAR	DEN	VAR	DEN	VAR
Site	5	0.0171	0.0103	24.5	56.6	6.3***	174***
Blocks in sites	19	0.0027	0.00006	2.0	0.0	2.5**	0.3
Provenance	8	0.0026	0.0005	4.1	2.5	2.4*	2.5*
Sitexprovenance	35(5)	0.0011	0.0002	0.0	0.0	1.0	1.0
Residual	130(22)	0.0011	0.0002	69.4	40.9		
Total	197						

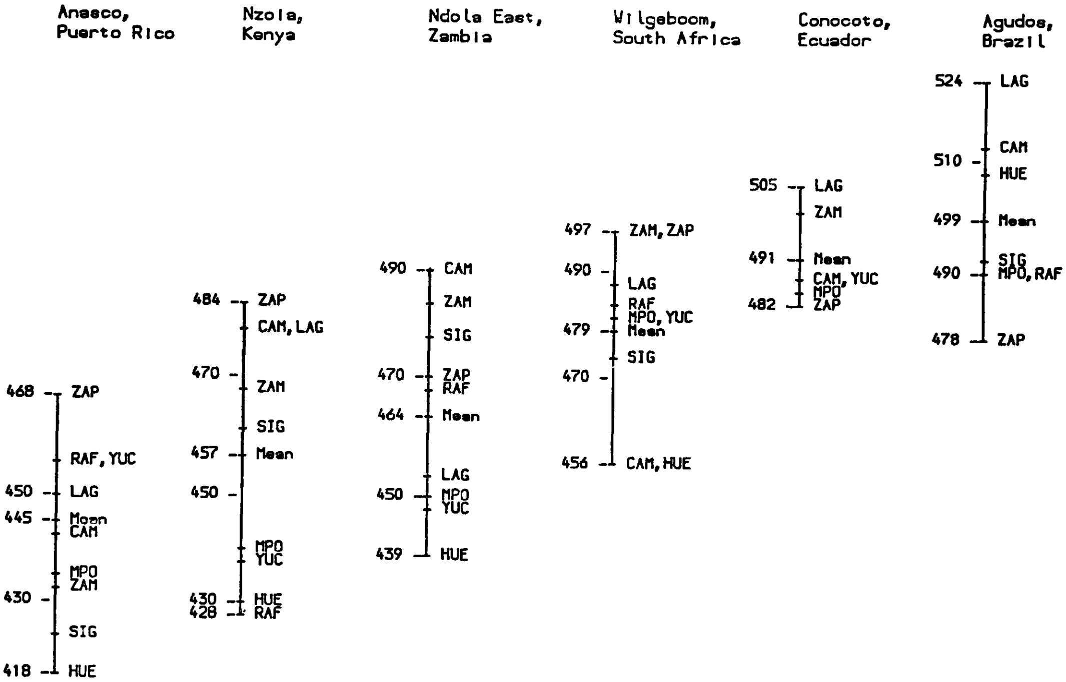

Figure 1. — Density (kgm⁻³) of five provenances of *Pinus oocarpa* and four provenances of *P. patula* ssp. *tecunumanii* at six sites.

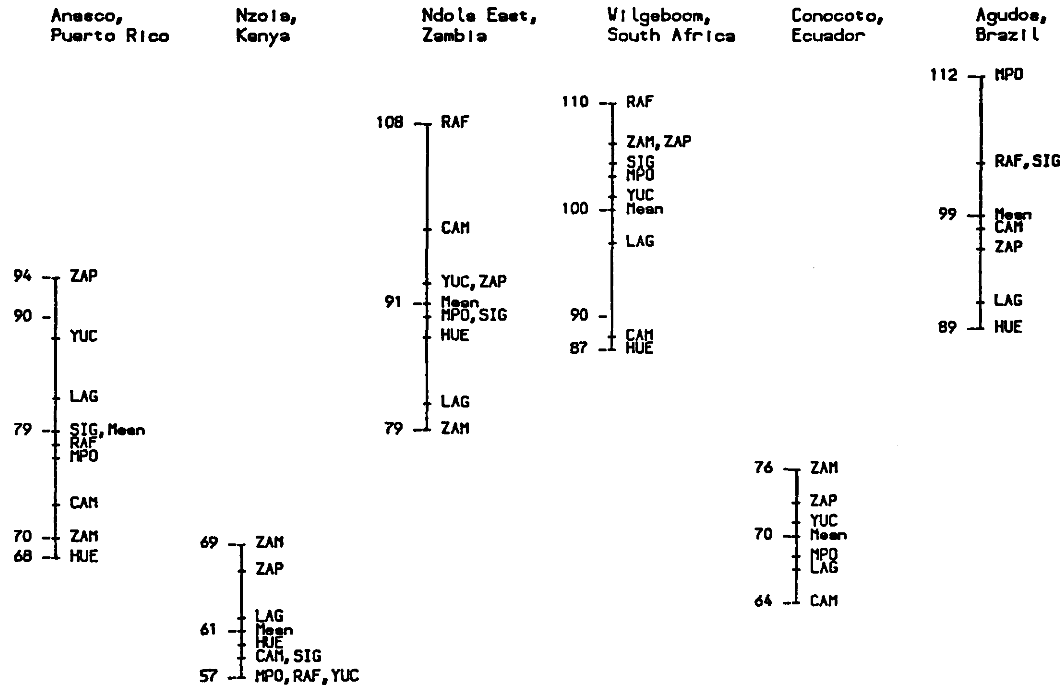

Figure 2. — Within sample density variation (kg m⁻³) of five provenances of *P. oocarpa* and four provenances of *P. patula* ssp. *tecunumanii* at six sites.

The Scheffés test revealed no significant differences in DEN and VAR between *P. oocarpa* and *P. patula* ssp. *tecunumanii*. However, the Huehuetenango provenance of P. oocarpa was ranked consistently low for DEN and VAR. Birks and Barnes (1985) also observed the Huehuetenango provenance to be "unique amongst this set of provenances".

Conclusion

The mean value for DEN at the six sites exceeded the generally accepted minimum value of 450 kg m-3 for kraft linerboard production (van Buijtenen, 1987) and DEN is likely to increase as the trees become older. This indicates that sites similar to those tested here should produce trees with acceptable wood properties for a number of end uses. This is in contrast to certain tropical pines with low density such as *P.caribaea* var. *hondurensis* and *P. chiapensis* Martinez that are generally less desirable for kraft paper production as well as for certain structural uses. The VAR of *P. oocarpa* and *P. patula* ssp. *tecunumanii* was lower than that reported for *P. caribaea* var. *hondurensis* (Wright, 1987 b). Low VAR is desirable for structural timber and veneer (Plumptre, 1979) as well as for certain pulping processes such as chemi-thermomechanical pulp (C. Davies, Sappi Research, pers. comm.). Across a range of sites, the high DEN and low VAR of *P. oocarpa* and *P. patula* ssp *tecunumanii* provenances indicate their wood utilization and hence afforestation potential.

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