Flowering in bamboo is gregarious and unpredictable (The Wealth of India, 1948) and may take anywhere from 25 to 60 years. After seeding the whole forests die. Moreover viability of bamboo seeds (DOGRA, 1981) persists for a short period, but can be extended if stored at lower temperatures. Because of these major drawbacks, any vegetative method of propagation even from seedlings would be very important if very high multiplication rates can be achieved. This would bypass the unpredictable flowering and seeding problems associated with many bamboo plantations. Furthermore by this method seedlings would always be available for planting. The method we have developed for *D. strictus* seedlings by which over 10,000 viable plantlets can be obtained from one seedling in a year could be an asset for plantation and social forestry programmes. To our knowledge, this is the first report on the rapid micropropagation of *D. strictus* where high rates of multiplication and survival of plants in the field have been achieved by tissue culture of seedlings.

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Results of 5- to 6-Year-Old Provenance Trials of Pinus oocarpa Schiede on Eight Sites in Puerto Rico

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Summary

Four of fifteen *Pinus oocarpa* provenances, three from Nicaragua and one from Mt. Pine Ridge, Belize, outperformed all others in Puerto Rico at five and six years from planting. Mean annual height and diameter increments for the four were respectively 2.0 m and 2.7 cm, compared to 2.0 m and 2.6 cm for a fast-growing Alamicamba, Nicaragua *Pinus caribaea* var. *hondurensis* tester provenance. Survival averaged 70% for the top *P. oocarpa* provenances and 76% for the *P. caribaea* tester. Detailed form and volume assessments at one site showed that, compared to *P. caribaea* provenances in adjacent, similar-age trials, *P. oocarpa* provenances had finer branching, flatter branch angles, greater forking, higher overbark volumes, and less foxtailing.

All *P. oocarpa* provenances suffered wind or rain damage from two tropical storms in 1979. Highest blow-down mortality averaged 16 to 20% and included two of the top *P. oocarpa* performers. The *P. caribaea* tester had only 3% blow-down and the least non-mortality damage, 17%. All *P. oocarpa* provenances had inferior wind resistance to the *P. caribaea* tester, indicating potential problems in reforesting large wind-prone areas with *P. oocarpa*.

Key words: Provenance test, *Pinus oocarpa, Pinus caribaea* var. *hondurensis*, hurricane damage.

Zusammenfassung

Vier von fünfzehn *Pinus oocarpa* Herkünften, drei aus Nicaragua und eine vom Mt. Pine Ridge in Belize, übertrafen in Puerto Rico 5 und 6 Jahre nach der Pflanzung alle anderen. Der mittlere jährliche Höhen- und Durchmesserzuwachs der vier Herkünfte betrug 2,00 m und 2,7 cm im Vergleich zu 2,00 m und 2,6 cm bei einer schnellwachsenden *Pinus caribaea* var. *hondurensis* Kontrollherkunft aus Alamicamba, Nicaragua. Das durchschnittliche Überlebensprozent betrug für die Spitzenherkünfte von *Pinus oocarpa* 70% und für die *Pinus caribaea* Kontrolle 76%. Detaillierte Form- und Volumenerhebungen an einem Standort zeigten, daß, verglichen mit *Pinus caribaea* Provenienzen, in benachbarten gleichaltrigen Versuchsflächen, *Pinus oocarpa* feinere Äste, flachere Astwinkel, eine größere Gabelung, ein höheres Stammvolumen mit Rinde und weniger Foxtails aufwies.

Alle *Pinus oocarpa* Provenienzen erlitten Sturm- oder Regenschäden durch tropische Stürme im Jahre 1979. Die höchsten Windwurf-Schäden reichten durchschnittlich von 16 bis 20% und schlossen 2 der *Pinus oocarpa* Spitzenherkünfte mit ein. Die *Pinus caribaea* Kontrolle hatte nur 3% Windwurfschaden und zeigte nur 17% an sonstigen Schäden. Alle *Pinus oocarpa* Herkünfte hatten eine geringere Windresistenz als die *Pinus caribaea* Kontrolle und zeigen an, daß es für größere Aufforstungen in windwurfgefährdeten Gebieten mit *Pinus oocarpa* große Probleme gibt.

Introduction

Pinus oocarpa Schiede has a wide range between Mexico and Nicaragua. It occurs in large or small continuous stands, discontinuous stands, or in mixed stands with *Pinus caribaea* Morelet var. *hondurensis* Barr. and Golf. and *Pinus maximinoi*. There is disagreement taxonimically about the number of *P. oocarpa* varieties; natural hybridization of *P. oocarpa* × *P. caribaea* or *P. caribaea* × *P. oocarpa* does exist (Styles *et al.*, 1982).

Most stands occur between 700 and 1500 m elevation, in areas receiving from 800 to 1500 mm of rainfall annually. Recently, several low elevation provenances have been found (Greaves, 1979). Ecologically, *P. oocarpa* is better adapted to areas with less rainfall and longer dry seasons than most other Central American pines. It grows well on steep mountain slopes where runoff is rapid and soils are shallow.

The Commonwealth Forestry Institute (CFI), Oxford University, Great Britain, initiated provenance trials of *P. oocarpa* in the late 1960's. By 1978, CFI staff had collected and distributed 50 *P. oocarpa* seed sources to 35 countries (Greaves, 1980). About a decade before CFI trials began, the Institute of Tropical Forestry (ITF) in Puerto Rico had included *P. oocarpa* in island-wide adaptability trials. The *P. oocarpa* seed for these trials came from unknown sources in Guatemala and Mexico (Geary and Briscoe, 1972). Growth and survival were good. Mean annual height increments at about 7 years from field planting ranged from 1.0 to 1.7 m on sandy loam and from 0.4 to 0.9 m on shallow loam and deep mountain clay soils (Venator, 1974). Based on these findings, ITF obtained 15 *P. oocarpa* provenances from CFI and outplanted them at eight sites *(Figure 1)* between 1973 and 1975. This report summarizes mean annual height and diameter growth and survival data for these provenances as well as assessments of form and hurricane damage.

Planting Sites

Mean annual rainfall at the eight sites ranges from 1760 to about 2500 mm; two Holdridge-defined (1967) life zones are represented. Local site elevations are classified as lowland (< 100 m), upland (> 300 to 800 m), and intermediate (150 to 300 m) *(Table 1)*. All sites have elevations that are substantially lower and annual rainfall that is much higher than conditions at the *P. oocarpa* provenance seed origins *(Table 2)*. Also, true dry periods are absent in Puerto Rico, with all sites receiving at least 50 mm of rain each month of the year.

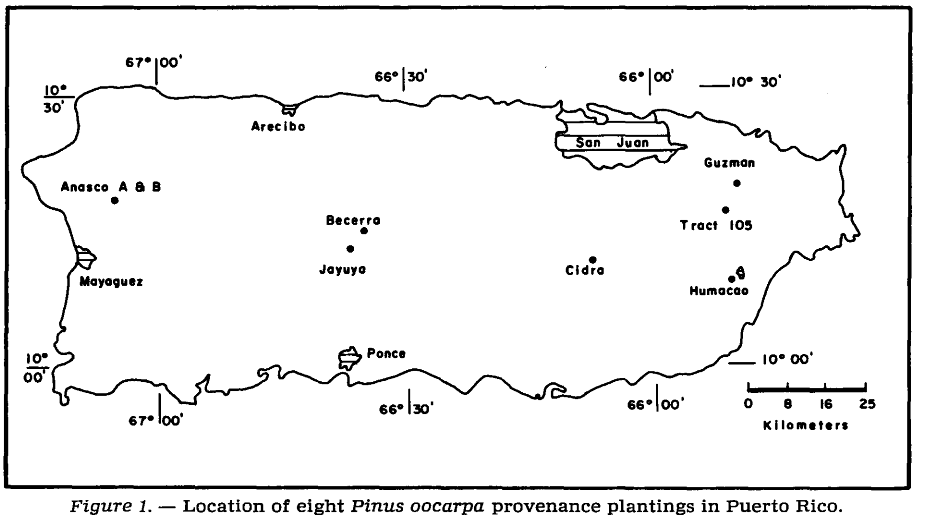

Figure 1. — Location of eight *Pinus oocarpa* provenance plantings in Puerto Rico.

Table 1. — Site data for 5- to 6-year-old *Pinus oocarpa* provenance trials in Puerto Rico.

Site Name	Age (yrs.)	Elevation (m)	Rainfall (mm)	Life Zone[1]	Soils: Parent Material	pH	Drainage
Guzman	6.1	320–350	2500	Subtropical wet	Volcanic rocks	4.5–5.0	Moderately well
Añasco A	5.7			Subtropical wet	Basic volcanic rocks		Moderately well
Añasco B	5.6	150–200	2090			4.5–5.0	Well drained
Tract 105	5.1	400–450	1800	Subtropical moist	Basic volcanic rocks	6.1–6.5	Well drained
Humacao	5.0	25	2170	Subtropical moist	Basic volcanic rocks	4.5–5.0	Poorly drained
Jayuya	4.8	470–500	1760	Subtropical moist	Plutonic rocks	4.5–5.5	Well drained
Cidra	4.9	450–500	1860	Subtropical moist	Volcanic rocks	4.5–5.5	Well drained
Becerra	4.8	830–850	2280	Subtropical wet	Volcanic rocks	4.5–5.5	Moderately well

[1] Using Holdridge (1967) system.

Table 2. — Seed source data for 15 *Pinus oocarpa* and 1 *P. caribaea* var. *hondurensis* tester* provenance planted at eight sites in Puerto Rico between 1973 and 1975.

CFI No.	Store No.	- - Provenance	Origin[1] - -	Latitude[2] (° ′)	Longitude[3] (° ′)	Elevation (m)	Rainfall (mm)	- - Parent Material[4] - -
-	31/71	Jitotil	Mexico	17 05	92 30	1650		
K49	30/71	Mt. Pine Ridge	Belize	17 00	88 55	700	1600	Granite over shale
K48	29/71	Malacatancito	Guatemala	15 13	91 32	1700	1000	Granite and gneiss
K44	27/71	Rafael	Nicaragua	13 14	86 08	1200	1400	Andesite/other rocks
K47	10/71	San Jose	Guatemala	14 28	89 28	1000	950	Schist/volcanic ash/tuff
K43	8/71	Lagunilla	Guatemala	14 42	89 57	1600	930	Cemented volcanic ash/tuff
K45	7/71	Siguatepeque	Honduras	14 32	87 50	1100	1250	Rhyolitic tuffs
K42	6/71	Yucul	Nicaragua	12 55	85 47	900	1400	Basalt/andesite
K36	5/71	Zamorano	Honduras	13 58	86 59	1100	1100	Rhyolitic tuffs
K34	3/71	Bucaral	Guatemala	15 01	90 09	1100	900	Micaceous schist
K31	1/71	Junquillo	Honduras	13 42	86 35	1000	900	Granite
K20	22/70*	Alamicamba	Nicaragua	13 34	84 17	25	2900	Alluvium
K16	16/70	Agua Fria	Honduras	15 16	87 06	1100	1100	Schist
K11	11/70	Conacaste	Guatemala	15 10	89 21	650	1900	Micaceous schist
K6	6/70	Zapotillo	Honduras	14 37	87 02	1000	1270	Rhyolitic tuffs
K1	1/70	Camelias	Nicaragua	13 46	86 18	900	1500	Granite

[1] In other tables, provenance origin names are abbreviated to a 3- or 4-letter code shown by underlining.
[2] All are North latitudes.
[3] All are West longitudes.
[4] From information in Greaves (1978, 1979).

Soils at the eight sites are Ultisols and Inceptisols, derived from volcanic rocks. Clay textures predominate except at Jayuya where there are clay loams or sandy loams. Profiles are usually deep (40 to 170 cm) and soil reaction is acid to very acid (pH 4.5 to 6.0). Drainage varies from well to poorly drained, being somewhat dependent on topographic position as well as annual rainfall *(Table 1)*.

Methods

All seed lots arriving at ITF from CFI in 1971 were stored at 0° C. Between 1973 and 1974, seeds were germinated in trays filled with vermiculite and transplanted into containers 4 to 5 days following germination. The 1973 germinates were transplanted into 10 × 23 cm vented polyethylene bags filled with sandy loam soil; the 1974 germinates were transplanted into styroblock 8[1] containers filled with a Jiffy-7[1] peatmoss:vermiculite mixture and in polyethylene bags. Growth media in bags and styroblocks were inoculated with mycorrhizal fungi (Briscoe, 1959), using mineral soil and duff collected under 10-year-old *P. caribaea* var. *hondurensis* trees growing near the nursery.

Field layout was randomized complete blocks with 7-tree row plots of each provenance replicated five times. Fifteen *P. oocarpa* and one *P. caribaea* var. *hondurensis* tester, from Alamicamba, Nicaragua were used *(Table 2)*. Seedlings were approximately 7 months old and ranged from 20 to 30 cm when outplanted. Field spacing was 2.7 × 2.7 m with no border rows. No thinning was done prior to the field assessments.

Site preparation included the use of machetes, bow saws, and chain saws to remove grass, brush, and trees. At Añasco A, where profuse shrubby secondary growth predominated on highly eroded, infertile soils, a bulldozer was used for ground clearing. The Añasco B site was hand-cleared and burned because steep ravines precluded using a bulldozer. Debris at other sites was accumulated outside plot perimeters. After outplanting, plots were cleaned periodically by use of machetes.

[1]) Mention of a registered trademark product does not imply endorsement, but is given for information only.

Field data were taken between June and December 1979, slightly before and after Hurricane David and Tropical Storm Frederic affected field sites from August 30 through September 4. Tree form data were taken only at the Añasco A site, using CFI worldwide uniform assessment criteria (Liegel *et al.*, 1980). Total heights to the nearest 0.5 m were measured with a range pole or altimeter, while overbark breast height diameters were measured with metal tape to the nearest 0.1 cm. Within provenances, heights of individual trees with broken tops were estimated with the following regression:

$$Y = b_0 + b_1X \quad \text{where} \quad Y = \frac{1}{\text{total height of sound trees}}$$

$$\text{and} \quad X = \frac{1}{\text{overbark breast height diameter of all sound trees}}$$

and b_0 and b_1 are regression coefficients.

Estimated total heights were obtained after calculating regression coefficients for each provenance, then substituting known diameters for trees with broken tops. Correlation coefficients, r, were usually higher than 0.8.

Mean annual heights and diameters were obtained by dividing total heights and diameters by age (years) since outplanting *(Table 1)*. Analysis of variance (ANOVA) was used to detect provenance performance differences in mean annual height and diameter growth rates and survivals. The significance level was $\alpha = 0.05$ for data at individual sites and combined data for all sites. Multiple comparison tests using Studentized range ($\alpha = 0.05$) were used for ranking provenance and site means. Plot means were used for both ANOVA and range tests.

Table 3. — Multiple comparisons of mean annual height increment for 15 *P. oocarpa* and 1 *P. caribaea* var. *hondurensis* tester* provenance planted at eight sites in Puerto Rico. Studentized Range Levels at $\alpha = 0.05$; provenance means joined by the same bar are not statistically different.

Provenances	Height Increment (m)	Provenances	Height Increment (m)	Provenances	Height Increment (m)
Guzmań (6.1 yrs.)		**Añasco B (5.6 yrs.)**		**Añasco A (5.7 yrs.)**	
Yuc	2.2	Yuc	2.2	MtPR	2.0
Raf	2.0	MtPR	2.2	Yuc	1.9
Ala*	2.0	Ala*	2.0	Ala*	1.9
MtPR	2.0	Raf	2.0	Cam	1.8
Jun	1.7	Cam	1.9	Raf	1.8
Zap	1.6	Zam	1.9	Zam	1.7
Buc	1.6	Sig	1.9	Jun	1.6
Jun	1.6	Zap	1.8	San	1.6
Sig	1.5	Jun	1.8	Con	1.6
Lag	1.5	San	1.8	Lag	1.5
San	1.4	Jit	1.8	Sig	1.5
Con	1.4	Con	1.8	Buc	1.4
Jit	1.4	Agua	1.7	Zap	1.4
Zam	1.4	Buc	1.7	Jit	1.4
Agua	1.3	Lag	1.7	Agua	1.4
Mal	1.0	Mal	1.4	Mal	1.3
$\bar{X}$	1.6		1.8		1.6
Tract 105 (5.1 yrs.)		**Humacao (5.0 yrs.)**		**Jayuya 4.8 yrs.)**	
Yuc	2.4	Yuc	1.9	Jun	2.3
Cam	2.1	Ala*	1.8	Yuc	2.3
Ala*	2.0	MtPR	1.8	Cam	2.3
Raf	2.0	Cam	1.8	Raf	2.3
MtPR	2.0	Raf	1.5	Ala*	2.2
Zap	1.7	Lag	1.5	Agua	2.1
Lag	1.7	Mal	1.5	Sig	2.1
Agua	1.7	Con	1.5	San	2.1
Jun	1.6	Agua	1.5	MtPR	2.0
Cam	1.6	Jun	1.4	Zap	2.0
Sig	1.5	Buc	1.4	Buc	1.9
San	1.4	Zam	1.4	Con	1.9
Zam	1.4	San	1.4	Jit	1.8
Buc	1.4	Sig	1.3	Mal	1.6
Mal	1.3	Jit	1.2	Zam	1.6
Jit	1.0	Zap	1.1	Lag	1.6
$\bar{X}$	1.7		1.5		2.0
Cidra (4.9 yrs.)		**Becerra (4.8 yrs.)**			
MtPR	2.0	Yuc	2.1		
Ala*	1.9	MtPR	2.0		
Yuc	1.9	Ala*	1.8		
Con	1.8	Cam	1.8		
Raf	1.8	Lag	1.8		
Cam	1.7	Raf	1.7		
Jun	1.6	Zam	1.6		
Lag	1.6	Con	1.6		
San	1.5	Jit	1.6		
Sig	1.5	Sig	1.6	Note: Site means include the 15 P. oocarpa provenances only.	
Zap	1.4	Jun	1.5		
Buc	1.4	Buc	1.5		
Agua	1.4	San	1.5		
Zam	1.2	Zap	1.4		
Mal	1.2	Agua	1.4		
Jit	1.0	Mal	1.3		
$\bar{X}$	1.5		1.6		

The hurricane damage assessment identified three damage classes: 1) blow-down or windthrow mortality; 2) non-mortality damage which included trees with broken tops (upper and lower stem) and lean from 5° to over 45°, and 3) total damage, the sum of damage percent from classes 1 and 2. Both storms were of low intensity and short duration. Wind velocities averaged 40 to 85 km hr^{-1}, with gusts over 100 km hr^{-1} in mountainous areas (LIEGEL, 1984).

Results

Height Growth

Provenance differences in mean annual heights were significant at all sites except Añasco B. The top-ranked

P. oocarpa performers at any one site usually included the three Nicaraguan and Mt. Pine Ridge, Belize sources and the *P. caribaea* tester, also from Nicaragua. For these five provenances, mean annual height increments ranged from 1.5 to 2.4 m; differences were not significant except at Becerra *(Table 3)*. Consistently poor performers were those from Malacatancito, Guatemala; Zamorano, Honduras; and Jitotil, Mexico.

Using combined data, mean annual height increments at Jayuya and Añasco B, respectively 2.0 and 1.8 m *(Table 4)*, were superior to those at remaining sites. Best overall mean annual height growth occurred on the drier, well drained upland sites; poorest growth was at Humacao, a wet, poorly drained lowland site. Microsite effects on height growth were evident at Añasco. Although plot boundaries of Añasco A and Añasco B are almost adjacent, mean annual height growth at Añasco B, 1.9 m, was significantly greater than at Añasco A, 1.6 m.

Diameter Growth

Provenance differences in mean annual diameter growth paralleled those for mean annual height growth: the three Nicaraguan, Mt. Pine Ridge, and the *P. caribaea* tester were the five top-ranked performers *(Table 5)*. However, for these top performers, differences at any site were not significant except at Becerra where the Mt. Pine Ridge source was superior to 12 other *P. oocarpa* sources but not to the *P. caribaea* tester and Yucul source. For the top five provenances, mean annual diameter increments ranged from 2.1 to 3.3 cm. The three poor performers for mean annual diameter growth also had inferior mean annual height growth.

Using combined data, mean annual diameter increments for the best four sites were 2.2 to 2.3 cm; site differences were not significant *(Table 4)*. Except for Jayuya, wetter upland and lowland sites with annual rainfall over 2000 mm had best diameter growth. At Tract 105, the site with lowest mean annual diameter increment, the rate was still a respectable 2.0 cm.

Table 4. — Multiple comparisons of combined data on mean annual height and diameter increments and pre- and post-hurricane survivals for 15 *P. oocarpa* and 1 *P. caribaea* var. *hondurensis* tester* provenance planted at eight sites in Puerto Rico.[1]

Site	Mean Annual Height Increment (m)	Site	Mean Annual Diameter Increment (cm)
Jayuya	2.0	Becerra	2.3
Añasco B	1.8	Jayuya	2.3
Tract 105	1.7	Humacao	2.2
Becerra	1.6	Guzman	2.2
Añasco A	1.6	Añasco B	2.1
Guzman	1.6	Añasco A	2.1
Cidra	1.6	Cidra	2.1
Humacao	1.5	Tract 105	2.0

Site	Pre-Hurricane Survival (%)	Post-Hurricane Survival (%)
Añasco B	87	84
Añasco A	86	85
Becerra	73	65
Tract 105	73	60
Cidra	72	67
Jayuya	56	54
Guzman	53	34
Humacao	39	25

[1] Studentized range levels at $\alpha = 0.05$; site means joined by the same bar are not statistically different. For post-hurricane survival percentages, multiple comparisons were not made.

Pre-Hurricane Survival

Within-site provenance differences were usually not significant except at Becerra, Cidra, and Tract 105. Of these three, only at Becerra was survival of the *P. caribaea* tester, 66%, significantly inferior to the top *P. oocarpa* provenances, 71 to 97%. At four other sites, the tester was the top-ranked provenance with survivals of 66 to 100%. For individual sites, the only *P. oocarpa* source with 100% survival was Bucaral, Guatemala at Añasco B.

Using combined data, highest survivals were 74, 73, and 71% respectively for Lagunilla, Guatemala; Yucul; and Mt. Pine Ridge sources. Lowest survivals were 57% each for Malacatancito and Jitotil sources. Best overall survivals of 86 to 87% were on moist, intermediate elevation sites. Worst survival, 39%, was on the wet, poorly drained, lowland Humacao site. Other sites had survival percentages intermediate to these extremes *(Table 4)*.

Post-Hurricane Damage and Survivals

There were substantial storm damage differences for provenances and species *(Figure 2)*. The *P. caribaea* tester had less blow-down and non-mortality damage than did any of the 15 *P. oocarpa* provenances *(Table 6)*. Of the four top-ranked *P. oocarpa* provenances in mean annual height and diameter growth, only the Mt. Pine Ridge source had less than 10% blow-down mortality. However, Mt. Pine Ridge along with the equally fast-growing Camelias, Nicaragua source had highest overall non-mortality damage, 37 and 40% respectively. Least susceptible to non-mortality damage, 24%, was the Rafael, Nicaragua source, another of the fastest growers.

Least blow-down and non-mortality damage occurred at drier sites of low and intermediate elevation; worst damage was usually at wetter and higher elevation sites *(Table 6)*. The Humacao site had the second highest blow-down damage, 22%, but the lowest non-mortality damage, 13%. The Cidra site had low blow-down damage, 5%, but the second highest non-mortality damage, 53%. After the storms, the Añasco sites had best overall survivals of 84 and 85% *(Table 4)*.

Form, Volume, Insects and Disease

Form and volume assessment results were reported elsewhere (Liegel *et al.*, 1980). The three Nicaraguan and Mt. Pine Ridge *P. oocarpa* sources had highest overbark form factors, greatest crown depth, and high stem straightness ratings--except for Mt. Pine Ridge. Differences in these traits for the four provenances were not significant. Total overbark volumes for the top-ranked *P.oocarpa* provenances averaged 134 to 212 m^3 ha^{-1}. These values were two to four times greater than those for lower-ranked provenances and represented mean annual increments of 23 to 37 m^3 ha^{-1} for 6-year-old trees.

The *P. oocarpa* sources had finer branching and slightly flatter branch angles than did the *P. caribaea* tester. For both species, fastest growing provenances had coarser branches and more acute branch angles. Fastest growing *P. oocarpa* sources had significantly less whorls from 1 to 6 m than did slower growers; yet, they had significantly more branches per whorl (3.3 to 3.9) than did other *P. oocarpa* sources (2.7 to 3.2) or the *P. caribaea* tester (2.9). Forking frequency ranged from 0 to 42% for *P. oocarpa* provenances with the Siguatepeque, Honduras source

Table 5. — Multiple comparisons of mean annual diameter increments for 15 *P. oocarpa* and 1 *P. caribaea* var. *hondurensis* tester* provenance planted at eight sites in Puerto Rico. Studentized Range Levels at α = 0.05; provenance means joined by the same bar are not statistically different.

Provenances	Diameter Increment (cm)	Provenances	Diameter Increment (cm)	Provenances	Diameter Increment (cm)
	Guzman (6.1 yrs.)		Añasco B (5.6 yrs.)		Añasco A (5.7 yrs.)
Yuc	3.3	Yuc	2.9	MtPR	2.8
MtPR	3.0	MtPR	2.7	Ala*	2.6
Raf	3.0	Cam	2.6	Yuc	2.6
Ala*	2.9	Ala*	2.6	Cam	2.4
Cam	2.7	Raf	2.4	Raf	2.4
Zap	2.4	Zam	2.0	Zam	2.3
Buc	2.3	Sig	2.0	Con	2.0
Jun	2.2	Agua	2.0	San	2.0
Sig	2.0	Con	2.0	Jit	2.0
Jit	1.9	Jit	1.9	Buc	1.9
Con	1.9	Buc	1.9	Jun	1.9
Lag	1.8	San	1.9	Mal	1.8
San	1.8	Jun	1.8	Agua	1.8
Agua	1.7	Lag	1.7	Lag	1.8
Zam	1.6	Zap	1.7	Sig	1.8
Mal	1.4	Mal	1.6	Zap	1.6
$\bar{X}$	2.2		2.1		2.1
	Tract 105 (5.1 yrs.)		Humacao (5.0 yrs.)		Jayuya (4.8 yrs.)
Yuc	2.8	Cam	3.0	Cam	2.8
Ala*	2.5	Yuc	2.9	Yuc	2.7
Cam	2.4	MtPR	2.9	Jun	2.6
Raf	2.3	Ala*	2.9	Raf	2.6
MtPR	2.1	Con	2.3	MtPR	2.5
Agua	2.0	Agua	2.2	Ala*	2.4
Con	2.0	Mal	2.2	Agua	2.4
Lag	1.9	Raf	2.2	Jit	2.3
Zap	1.9	Lag	2.1	Con	2.2
Sig	1.8	Buc	2.1	San	2.2
San	1.8	Sig	2.0	Zap	2.2
Jun	1.8	San	2.0	Sig	2.1
Buc	1.6	Jun	1.8	Buc	2.1
Mal	1.6	Zam	1.8	Mal	1.9
Zam	1.6	Jit	1.8	Lag	1.9
Jit	1.2	Zap	1.5	Zam	1.6
$\bar{X}$	1.9		2.2		2.3
	Cidra (4.9 yrs.)		Becerra (4.8 yrs.)		
MtPR	3.0	MtPR	3.2		
Yuc	2.6	Yuc	3.1		
Ala*	2.5	Ala*	2.7		
Raf	2.5	Raf	2.7		
Con	2.3	Cam	2.6		
Cam	2.2	Lag	2.3		
Agua	2.1	Zam	2.2		
Jun	2.0	Con	2.2		
Lag	2.0	Sig	2.1		
Buc	1.9	Jit	2.1		
Sig	1.9	San	2.1		
San	1.9	Zap	2.0		
Mal	1.6	Buc	2.0		
Zap	1.6	Mal	1.9		
Zam	1.4	Jun	1.9		
Jit	1.3	Agua	1.6		
$\bar{X}$	2.0		2.3		

Note: Site means include the 15 *P. oocarpa* provenances only.

having the maximum. Of the *P. oocarpa* provenances that foxtailed--trees with branchless internodes ≥ 1.2 m--only the Mt. Pine Ridge source had foxtail incidence over 9%. Foxtail percentage for the *P. caribaea* tester ranged from 17 to 63% across the eight sites. No major insect or disease damage existed in the *P. oocarpa* trials, although spider mites were seen in western Puerto Rico at Añasco on both *P. oocarpa* and *P. caribaea* CFI trials in 1980 (Barry and Anderson, 1981).

Discussion

In other trials less than five years old (Nikles *et al.*, 1978; Greaves, 1980), Yucul, Mt. Pine Ridge, Rafael, and Camelias sources usually had superior height growth over

Figure 2. — Blow-down and lean damage in Puerto Rican pine provenance trials in 1979 caused by Hurricane David and Tropical Storm Frederic. At the Guzman planting site, total damage in the *P. oocarpa* trial was 80% whereas an adjacent *P. caribaea* provenance trial suffered only 26% total damage.

most *P. oocarpa* provenances. In Puerto Rico these four provenances were almost always the top-ranked ones for mean annual height and diameter growth as well as survival percent. Growth of these four was similar to the commercially recognized, fast-growing Alamicamba, Nicaragua *P. caribaea* tester source to age 6 years. The worst

Table 6. — Summary of 1979 hurricane blow-down and non-mortality damage to 15 *P. oocarpa* and 1 *P. caribaea* var. *hondurensis* tester* provenance on eight sites in Puerto Rico.

Provenances	Blow-down Damage (%)	Provenances	Non-mortality damage (%)
- - - - - - - - -	Combined Provenance Means	- - - - - - - - -	
Jun	20	Cam	40
Cam	17	Lag	40
Zam	17	MtPR	37
Yuc	16	Mal	36
Zap	13	San	36
San	13	Jun	36
Raf	12	Buc	33
Buc	12	Jit	32
Lag	11	Sig	32
Jit	9	Con	32
Sig	9	Zap	32
Con	9	Yuc	31
Agua	8	Zam	31
Mal	6	Agua	30
MtPR	4	Raf	24
Ala*	3	Ala*	17
- - - - - - - - -	Combined Site Means	- - - - - - - - -	
Guzman	31	Tract 105	65
Humacao	22	Cidra	53
Tract 105	13	Guzman	49
Becerra	10	Becerra	30
Cidra	5	Jayuya	29
Añasco B	4	Añasco B	18
Jayuya	3	Añasco A	14
Añasco A	2	Humacao	13

performers in Greaves' summary, Jitotil and Malacatancito sources, were also the poorest performers in Puerto Rico, as were Zapotillo and Zamorano, Honduras sources.

Overall mean annual height and diameter growth for top-ranked provenances in Puerto Rico on relatively low elevation sites are quite high when compared with data from other countries. Individual provenances in some countries such as Nigeria (EGENTI, 1978) and East Africa (DYSON and GREAVES, 1976; GREAVES and DYSON, ND) or Brazil, South Africa, and Thailand (NIKLES *et al.*, 1978; GREAVES, 1980) have reached mean annual height increments of 1.8 to 2.2 m and mean annual diameter increments of 2.8 to 3.3 cm per year, over 3 to 5 years. More frequently, however, mean annual height and diameter growth rates of 1.5 m and 2.0 cm or less per year have been reported, especially for drier sites.

Although top-ranked performers grew well across all sites in Puerto Rico, the microsite growth anomaly at Añasco A and Añasco B is worth noting. Topography at Añasco B is steep and soils are well to excessively drained, conditions more like those of *P. oocarpa* natural ranges. By contrast, topography at Añasco A is flat to gently sloping so that soils are less well drained. Because site debris was burned at Añasco B before planting, outplanted seedlings could have quickly captured nutrients from the ash. Clearing by bulldozer could have removed surface nutrients and organic matter from the Añasco A site, already having infertile Ultisols.

The most disconcerting result thus far from the Puerto Rican trials is the high susceptibility of the fastest-growing *P. oocarpa* provenances to blowdown or other damage in relatively low intensity cyclonic storms. Across eight sites, no simple correlation existed between observed damage and sheltered or non-sheltered location of planting sites as was reported by GREAVES (1980). However, more complex correlations were found between increasing damage and several site factors like higher elevations, greater total storm rainfall, and greater pre-hurricane mortality (LIEGEL, 1984). Overall, damage was two to six times greater for *P. oocarpa* than for *P. caribaea* provenances on sites where both were planted together (LIEGEL, 1983).

Conclusions

Good growth and performance of known *P. oocarpa* sources in 5- to 6-year-old CFI trials in Puerto Rico paralleled similar performance for fewer but unknown provenances used in adaptability trials a decade earlier. Even the poorest provenances averaged 1.0 m or better in mean annual height growth on diverse soils ranging from deep clays to sandy clay loams. Genetic variability of tested provenances appears high because good growth occurred on sites in Puerto Rico that are much lower in elevation and have two to three times more annual rainfall than do the seed origin sites. However, generalizations or implications about this variation for reforestation or tree improvement programs, locally or elsewhere, seem premature until additional data are collected and analyzed. Data from the Ivory Coast and Sri Lanka (OJO, 1978) indicated changes in overall rankings for top *P. oocarpa* performers between 0.5 and 4.0 years.

Although the three Nicaraguan sources and that from Mt. Pine Ridge grew best, more extensive testing is needed before embarking on a reforestation program. Quantitative wind damage data must be obtained from other countries to determine *P. oocarpa*'s species and provenance damage susceptibility levels more accurately, and to ascertain under what conditions severe damage occurs. Wider assessments of form and wood quality traits, such as specific gravity and fiber lengths, are needed for local *P. oocarpa* trials, now 9- to 10-years-old. Using new and existing data, juvenile-to-mature correlations will be possible for all provenances regarding overall growth performance, growth traits and form, wood quality, and wind damage susceptibility.

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Seedling Growth Variation Among Rocky Mountain Populations of Lodgepole Pine

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Summary

One-hundred fifty-three lodgepole pine trees *(Pinus contorta* var. *latifolia)* from 34 natural populations representative of the latitudinal and elevational range of the species in Montana, Wyoming and Colorado supplied seedlings for a provenance test in Colorado. Growth models were developed for each population based on periodic height growth through the 1982 growing season. Results revealed clinal latitudinal effects of seed source on growth patterning, but the effect of elevational differences was unclear. Progeny from southern seed sources started growth earliest, had a gradual increase in growth rate, and then a gradual decrease in growth rate to the end of the season. Progeny from high latitude sources grew slowly at first, had a rapid increase in growth rate at mid season, and had the greatest overall incremental growth for the season. No sharp distinctions between the populations were evident from the growth models. Rather, the models described a gradual change in character along a latitudinal gradient.

Key words: geographic variation, lodgepole pine, phenology, seedling growth.