VARIATION IN VOLUME OVERBARK, STEM STRAIGHTNESS AND LONGEST INTERNODE LENGTH AT FIVE YEARS OF AGE BETWEEN TEN PROVENANCES OF *Pinus caribaea* MORELET AND TWO PROVENANCES OF *Pinus oocarpa* SCHEIDE IN COSTA RICA.

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SUMMARY

This paper details the variation of volume overbark, stem straightness and longest internode length, observed after five years growth, between ten provenances of *Pinus caribaea* Morelet and two provenances of *Pinus oocarpa* Scheide in a provenance trial replicated over four sites in Costa Rica, Central América.

The variable survival and the lack of adequate protection against cattle and fire damage has placed considerable constraints on the interpretation of the data.

A test was made to assess the consistency of the measurements taken in the field. This was not found to be a statistically significant source of error.

The two provenances of *P. oocarpa* exhibited superior volume growth compared to both varieties of *P. caribaea* and in addition the Yucul origen showed excellent stability in its branching habit.

A combined analysis failed to show a significant provenance x environment interaction for any of the three traits examined.

The Yucul origen, which may belong to a new taxon, *Pinus patula* subsp *tecumumanii* (Schwerdft). Styles, would appear to have considerable potential as plantation material on those sites where growth was assessed.

1. Introduction

The absence of any fast growing indigenous conifers in Costa Rica has prompted the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) into carrying out species trials with a wide variety of exotic conifers.

Pinus caribaea Morelet, since its introduction around 1960, has shown an ability to grow well in several parts of the country and this has generated interest in examining further the potential of this highly variable species, through the establishment of a series of provenance trials.

This paper details the variation in three traits, namely volume over-bark, stem straightness and longest internode length, observed after five years growth, between ten provenances of P. caribaea and two provenances of Pinus oocarpa Scheide (see table 1) in a provenance trial replicated over four sites (see table 2).

2. Experimental Methods

The experimental design chosen for each site was the randomized complete block design, with five replicates at sites 1, 2 and 4 and four replicates at site 3. A seven tree line plot was the chosen plot size at all sites, with no surround trees planted within the experiment, separating adjacent plots. At sites 3 and 4 no external surrounds are present either, although at sites 1 and 2 guard rows were planted. Unfortunately in both cases survival within the guard rows is now very variable.

Site 1 is the only site not to have been affected by external agencies since planting. Fire damage has occurred at sites 3 and 4, having a more severe effect at the latter due to it occurring at an earlier stage in the life of the experiment. The result of the fire damage at site 4 has been the complete loss of block 2 at that site.

At site 3 fire damage took place in February 1982 and although all the trees over the entire site suffered from scorch few trees were killed. Survival at site 2 was affected by cattle damage during the early years

TABLE 1. Provenance Source Information

CATIE trial No.	Supplier	Supplier's Site and Collection No.	Source: Country	Source: Site	Latitude	Longitude	Elevation (m)
1		PC3C	Nicaragua	Alamicamba	13°34'N	84°17'W	20 - 30
2		PC5A	"	Río Coco	14°45'N	83°55'W	50 - 100
3		PC8A	Honduras	Guanaja	16°27'N	85°54'W	50 - 100
4	Commonwealth	PC6B	Guatemala	Poptum	16°21'N	89°25'W	500
5	Forestry	PC14A	Honduras	Culmi	15°06'N	85°37'W	500 - 600
6	Institute,	PC7B	"	Brus Lagoon	15°45'N	84°40'W	10
7	Oxford,	PC13C	"	Los Limones	14°03'N	86°42'W	700
8	England	PC20H	Belize	Mountain Pine Ridge	17°00'N	88°55'W	400[1]
9		PC23B	"	Melinda	17°01'N	88°20'W	10 - 15
10		PC36A	Cuba	Pinar del Río	22°49'N	82°57'W	N/A[2]
11		PO18A	Nicaragua	Yucul	12°55'N	85°47'W	900
12		PO26C	Belice	Mountain Pine Ridge	17°00'N	88°55'W	700[1]

1. Mean altitude - Seed obtained from wide-ranging commercial collections.
2. Not available.

TABLE 2. Site Information Summary

	Site	Latitude	Longitude	Altitude (m.a.s.l.)	Mean Annual Rainfall (mm.)	Soil Type[1]	Previous Land Use	Ecological Life Zone[2]
1:	Celulosa	83° 37' W	9° 56' N	720	3665	Andic Humitropept	Cut-over Secondary Forest	Tropical Wet Forest, Premontane Belt Transition
2:	Florencia Norte	83° 41' W	9° 53' N	650	2639	Andic Humitropept	Mixed Forest Plantation	Tropical Moist Forest, Premontane Belt Transition
3:	Volcán	83° 28' W	9° 12' N	420	3666	Ustic Tropohumult	Open Pasture	Tropical Moist Forest
4:	San Isidro	83° 41 W	9° 21' N	670	3054	Orthoxic Palehumult	Coffee Plantation	Tropical Moist Forest, Premontane Belt Transition

1. Terminology under US soil classification system.
2. After the Holdridge Life Zone system (Holdridge et al., 1971).

of the trial particularly over block 5 which was therefore excluded from the statistical analases. One additional factor complicating the interpretation of the results was the presence of other tree species within the experiment at sites 2 and 4.

3. Data Colection and Analyses

The author, aided by two field workers followed the field assessment procedure that has been developed by Barnes and Gibson (in press) specificaly for the International Provenance Trials of P. caribaea and P. oocarpa. On becoming familiar with the procedure the number of trees assessed rose to approximately sixty/day.

One possible source of error in any assessment procedure is the inconsistency of the observer in assessing each trait. In order to examine the magnitude of the error the author chose to re-measure two plots, selected at random, at each of the four sites. The t test for paired comparisons was then employed to evaluate the consistency of the measurements taken.

At each of the four sites the results obtained for the three traits under examination were interpreted by the comparison of plot means using the analysis of variance (anova). However as the within plot survival was variable an approximate method had to be employed, namely the unweighted analysis of all means, where the analysis is carried out paying no attention to the number of trees per plot (Scheffé, 1959).

The Newman-Keuls method was that used to examine the difference between provenance means whenever the initial F test was found to be significant at the 5% probability level. This test provides a conservative estimate of the minimum significant difference between ranked provenance means.

In order to assess the importance of the provenance x environment interaction a combined analysis was carried out. Due to the unequal replication and variable survival over the four sites it was decided to utilize an experimental approach, employing the BMDP 3V programme (Jennrich and Sampson, 1982). This programme uses the maximum likelihood approach, testing the significance of each effect in the model sequentially.

Site 3 was excluded from the combined analyses of volume overbark and stem straightness as the site had been planted six months after the other three. However, it was included in the analysis of the longest internode length as it was felt that the difference in age had affected the expression of this trait to a far lesser degree.

4. Results and Discussion

4.1. Introduction

At all four sites the performance of P. caribaea var. caribaea in terms of volume growth was apreciably poorer than both P. caribaea var hondurensis and P. oocarpa. Therefore it was decided to exclude this variety from the various statistical analyses on the basis that its inclusion might mask differences in performance between the various provenances of P. caribaea var. hondurensis.

The analyses of variance for the three traits at each site were conducted twice. The first analysis included the two provenances of P. oocarpa, whilst the second was conducted only on the data from the nine provenances of P. caribaea var. hondurensis.

4.2. Consistency Checks

The following results, all based upon 48 degrees of freedom, were obtained:

Tree height	$t = -0.2141$	NS
Dbh	$t = -0.4603$	NS
Stem straightness	$t = 0.5057$	NS
Longest internode length	$t = -0.4674$	NS

As none of these results approaches anywhere near the 5% probability level, which for 50 d.f. = 2.009, no evidence exists to suggest that inconsistency of measurement was an appreciable source of error.

I believe that this exercise was of paramount importance. The short time spent on re-measurement and the ease of the analysis should allow consistency checks to become an integral part of any final assessment. The fact that the evaluation of this source of error appears to be frequently overlooked is a major drawback to any subsequent interpretation of such data.

4.3. Individual traits

The results of the simple anova at each site, in terms of the significance of the f test, are given in table 3, with the results of the Newman-Keuls test given in table 4. Table 5 presents the results of the combined analyses.

4.3.1. Volume Overbark

The same trend was observed at all four sites. No significant block effects were obtained at any site, whilst the significant provenance effects were almost enterely attributable to the superior growth of the two provenances of P. oocarpa. Their removal from the analyses generally led to the provenance effect becoming non significant.

The combined analysis did not produce any evidence of a significant site x provenance interaction. However it did bring out the very large influence of site upon this trait.

Unfortunately the considerable intra-provenance variation in tree volume may have masked differences in performance between the provenances of P. caribaea var. hondurensis. This is one important reason for not employing such a small plot size in this type of provenance trial, particularly if the supervision of the experimental site is low and survival may be expected to be less than the optimum.

4.3.2. Stem Straightness

No significant differences between blocks were detected at any site, whilst significant provenance effects were a feature at only one, site 4.

Whilst site uniformity may partially explain the lack of significant differences between blocks, the large standard errors for this trait (especially at site 2), reflecting the large amount of variation between individual trees within provenances, is thought to have been a major factor in obscuring differences between provenances.

However it is of some interest that the one provenance distinguished for its superior stem form at site 4 was Alamicamba, as it has previously been found to be the best provenance of P. caribaea var. hondurensis for this trait in a number of provenance trials located in several countries (Gibson, 1982).

As with volume overbark the site x provenance interaction was found to be not significant in the combined analysis. The site effect was also not significant which, as first noted by Barnes, Gibson and Bardy (1980) suggests that stem straightness is a trait that is under strong genetic control in the exotic environment.

4.3.3. Longest Internode Length

Significant differences between blocks were a feature at site 1 only, which being the only site with variable topography might be an indication that microsite conditions are important for the expression of this trait. On the other hand significant provenance differences were found at all sites with the exception of site 2. At both this site and site 3 growth was slow and few foxtails were recorded, although the slightly smaller standard error at site 3 resulted in the difference between the extreme means being statistically significant. At sites 1 and 4, where growth was distinctly better, foxtails were more prevalent, which is reflected in the higher provenance mean values at these two sites.

At all four sites Brus Lagoon occupied the highest ranking for this trait whilst Alamicamba was always in the top three rankings. This result is consistent with other trials containing provenances of P. caribaea var hondurensis where these two southern coastal provenances have generally been found to produce the longest internodes (Greaves, 1980).

TABLE 3. Simple ANOVA: Significance of the F test

Volume Overbark

Site	1: Celulosa		2: Florencia		3: Volcán		4: San Isidro	
No. of Prov.	11	9	11	9	11	9	11	9
Block effect	NS	NS	NS	NS	NS	NS	NS	NS
Prov. effect	**	NS	*	NS	***	*	NS	NS

Stem Straightness

Site	1: Celulosa		2: Florencia		3: Volcán		4: San Isidro	
No. of Prov.	11	9	11	9	11	9	11	9
Block effect	NS	NS	NS	NS	NS	NS	NS	NS
Prov. effect	NS	NS	NS	NS	NS	NS	***	**

Longest Internode

Site	1: Celulosa		2: Florencia		3: Volcán		4: San Isidro	
No. of Prov.	11	9	11	9	11	9	11	9
Block effect	NS	*	NS	NS	NS	NS	NS	NS
Prov. effect	***	**	NS	NS	**	**	***	**

<u>Notes</u>:

$P > 0.05$: NS
$0.05 \geq P > 0.01$: *
$0.01 \geq P > 0.001$: **
$P \leq 0.001$: ***

TABLE 4. Combined Analysis: Significance of the Likelihood ratio test

Traits	Volume Overbark	Stem Straightness	Longest Internode
No. of Prov.	11	11	11
No. of Sites	3	3	4
Site x Block effect	*	NS	NS
Block x Provenance effect	NS	NS	NS
Site x Provenance effect	NS	NS	NS
Block effect	NS	NS	NS
Site effect	***	NS	***
Provenance effect	***	*	***

TABLE 5. Newman-Keuls Test (excluding Prov. 10)

Trait	Site	No. of Prov.	Residual Mean Square	$S\bar{X}$	Q0.05	D
Volume Overbark (m3)	Celulosa	11	0.00063	0.01122	4.82	0.0541
		9	0.00071	0.01192	4.70	0.0560
	Florencia	11	0.00062	0.01245	4.92	0.0613
		9	0.00054	0.01162	4.81	0.0559
	Volcán	11	0.00013	0.00570	4.92	0.0280
		9	0.00012	0.00548	4.81	0.0264
	San Isidro	11	0.00101	0.01589	4.96	0.0788
		9	0.00134	0.01830	4.84	0.0886
Stem Straightness (score)	Celulosa	11	895.85116	13.38545	4.82	64.5
		9	835.57375	12.92729	4.70	60.8
	Florencia	11	1342.75815	18.32183	4.92	90.1
		9	1534.46497	19.58612	4.81	94.2
	Volcán	11	636.66265	12.61609	4.92	62.1
		9	603.81250	12.28630	4.81	59.1
	San Isidro	11	515.07403	11.34762	4.96	56.3
		9	570.92577	11.94703	4.86	58.1
Longest Internode (m)	Celulosa	11	0.92250	0.42953	4.82	2.1
		9	0.99974	0.44716	4.70	2.1
	Florencia	11	0.22814	0.23882	4.92	1.2
		9	0.25306	0.25152	4.81	1.2
	Volcán	11	0.16129	0.20080	4.92	1.0
		9	0.16769	0.20475	4.81	1.0
	San Isidro	11	0.61919	0.39344	4.96	2.0
		9	0.73636	0.42906	4.86	2.1

Notes:

$$S\bar{X} = \sqrt{\frac{\text{Residual Mean Square}}{b}}$$ where b = nos. of blocks

Initial determination of Q0.05:

Site	k,v values	Q values, P = 0.05
1: Celulosa	11,40	4.82
	9,32	4.70
2 + 3: Florencia and Volcán	11,30	4.92
	9,24	4.81
4: San Isidro	11,27	4.96
	9,22	4.86

TABLE 5A. Newman-Keuls Test (excluding Prov. 10)

Volume Overbark (m^3)

1: Celulosa

Prov.	Value	Prov.	Value
12	0.1572	5	0.1387
11	0.1434	6	0.1290
5	0.1387	4	0.1285
6	0.1290	2	0.1197
4	0.1285	9	0.1196
2	0.1197	8	0.1130
9	0.1196	1	0.1012
8	0.1130	3	0.1070
1	0.1012	7	0.0793 *
3	0.1070		
7	0.0793		

2: Florencia

Prov.	Value	Prov.	Value
12	0.1156	5	0.0651
5	0.0651	8	0.0634
8	0.0634	4	0.0602
4	0.0602	1	0.0588
1	0.0588	7	0.0536
7	0.0536	2	0.0499
11	0.0536	6	0.0455
2	0.0499	9	0.0423
6	0.0455	3	0.0418
9	0.0423		
3	0.0418		

* Rounding error = NS

3: Volcán

Prov.	Value	Prov.	Value
12	0.1010	7	0.0640
11	0.0978	4	0.0591
7	0.0640	1	0.0570
4	0.0591	8	0.0567
1	0.0570	5	0.0555
8	0.0567	9	0.0530
5	0.0555	6	0.0491
9	0.0530	3	0.0392
6	0.0491	2	0.0371
3	0.0392		
2	0.0371		

4: San Isidro

Prov.	Value
11	0.1392
12	0.1319
1	0.1261
5	0.1256
4	0.1224
9	0.1106
8	0.1072
6	0.1044
2	0.1043
3	0.0894
7	0.0882

TABLE 5B. NEWMAN-KEULS TEST (excluding Prov. 10)

Stem Straightness (score)

1. Celulosa

Prov.	Value
3	98.3
1	96.6
8	94.4
6	87.0
12	79.4
9	75.4
2	71.0
5	68.1
11	67.1
4	54.3
7	54.1

2: Florencia

Prov.	Value
8	112.1
12	97.3
9	89.8
4	87.1
2	86.4
11	86.3
1	71.0
7	60.9
6	48.6
5	44.1
3	42.5

3: Volcán

Prov.	Value
1	68.0
7	60.7
4	60.5
2	52.0
6	51.3
8	47.9
11	45.6
9	44.9
12	37.2
5	33.6
3	22.8

4: San Isidro

Prov.	Value	Prov.	Value
1	104.9	1	104.9
11	79.2	6	69.5
6	69.5	3	62.2
3	62.2	2	53.3
2	53.3	9	51.0
9	51.0	7	42.8
7	42.8	8	41.1
8	41.1	5	36.8
5	36.8	4	31.3
12	35.0		
4	31.3		

Note: Stem straightness improves with increasing score.

TABLE 5C. NEWMAN-KEULS TEST (excluding Prov. 10)

Longest Internode (m)

1: Celulosa

Prov.	Value	Prov.	Value
6	3.5	6	3.5
1	3.3	1	3.3
2	2.8	2	2.8
9	2.4	9	2.4
8	2.3	8	2.3
4	1.8	4	1.8
5	1.7	5	1.7
12	1.4	7	1.3
7	1.3	3	1.3
3	1.3		
11	0.7		

2: Florencia

Prov.	Value
6	1.5
5	1.4
1	1.2
2	1.2
12	1.2
3	0.9
4	0.8
7	0.8
8	0.8
9	0.6
11	0.5

3: Volcán

Prov.	Value	Prov.	Value
6	1.7	6	1.7
4	1.5	4	1.5
1	1.4	1	1.4
9	1.4	9	1.4
12	1.2	7	1.0
7	1.0	8	0.9
8	0.9	2	0.8
2	0.8	5	0.8
5	0.8	3	0.6
11	0.6		
3	0.6		

4: San Isidro

Prov.	Value	Prov.	Value
6	3.5	6	3.5
8	3.5	8	3.5
1	2.2	1	2.2
2	2.0	2	2.0
4	1.5	4	1.5
9	1.5	9	1.5
3	1.4	3	1.4
5	1.4	5	1.4
7	1.2	7	1.2
12	0.9		
11	0.8		

T The only other provenance that retained the same ranking across all four sites was Yucul, one of the two P. oocarpa provenances. This provenance consistently occupied the lowest ranking, which was confirmed by examination of the field data which showed that this was the only provenance analyzed for which no foxtails were recorded at any of the four sites.

In the combined analyses the site x provenance term was again found to be not significant.

5. Conclusion

The results obtained from any assessment must be evaluated in the light of the present condition of the experiment under investigation.

Two aspects of the original experimental design are considered to warrant criticism, namely the chosen plot size and the absence of surround rows separating adjacent plots within the experiment. With regard to the former, the small plot size, confounded by the variable survival, is thought to have led to poor estimates of the provenance mean values, with the occasional exceptional individual inflating some means, leading to a high standard error for the trait in question. For this type of provenance trial Gibson (1982) recommends the use of 36 tree plots with the assessment confined to the central 4 x 4 trees.

In addition to these two weaknesses in the experimental design, the standard of maintenance of this experiment has not been as high as one would hope. The failure to replace early losses, the retention of other tree species within two of the experimental sites and the lack of adequate protection against cattle and fire damage are all factors which make subsequent evaluations of provenance performance less precise.

However, one of the most important findings of this study was the superior growth rate of the two provenances of P. oocarpa. Yucul and Mountain Pine Ridge, compared to both varaties of P. caribaea present in the experiment. Although this concerns growth over only the first five years this result does question the long held assumption that P. caribaea var. hondurensis would be the most important pine species for lowland tropical sites (Lamb, 1973).

In addition the stability of the Yucul origen of P. oocarpa in producing regular branch whorls under conditions of rapid growth is noteworthy, as the combination of these two characteristics is clearly desirable.

As to the failure to detect a significant provenance x environment interaction, this suggests that the rankings obtained for the provenances represented in this trial will not be dramatically altered on other sites suitable for these two species of pine throughout Costa Rica.

Finally, mention should be made of recent taxonomic studies (Barnes and Styles, 1983) which indicate that part of the Central American population of P. oocarpa, including the Yucul provenance, may in fact be a subspecies of P. patula, P. patula subsp. tecumumanii (Schwerdft). Styles. As Barnes and Styles report "this new taxon may provide some excellent plantation material for very extensive areas in the tropics and sub-tropics".

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