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PROVENANCE - SITE INTERACTION IN *PINUS CARIBAEA* AND ITS IMPLICATIONS FOR GENETIC IMPROVEMENT AND AFFORESTATION PROGRAMMES IN THE NIGERIAN SAVANNA

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OTEGBEYE, G.O. 1995. Provenance-site interaction in *Pinus caribaea* and its implications for genetic improvement and afforestation programmes in the Nigerian savanna. Provenance x site interaction was estimated for tree height and girth at breast height of 12-y-old *Pinus caribaea* grown at three Nigerian savanna sites, namely Afaka, Nimbia and Miango. The provenances examined were Mt. Pine Ridge (Belize), commercial lot (Belize), New Providence (Bahamas), Great Abaco (Bahamas) and Pinar del Rio (West of Cuba). There was no significant provenance x site interaction in any of the two growth characteristics examined. The provenances maintained their relative performance at the three sites, with the two Belize sources emerging as the most suited. There were highly significant between-site differences in tree height of the *Pinus caribaea* provenances grown while no such differences existed for their girth growth. The fastest growth was measured at Miango while the slowest at Afaka. Both tree height and girth growth of the *Pinus caribaea* provenances examined had high provenance heritability. This shows that the expression of the characteristics was not mediated differentially by the three test environments.

Key words: *Pinus caribaea* - provenance x site interaction - tree height - girth at breast height - afforestation - improvement

OTEGBEYE, G.O. 1995. Saling tindakan tapak kawasan dan provenan dalam *Pinus caribaea* dan implikasinya ke atas pembaikan genetik dan program-program penghutanan di savana Nigeria. Saling tindakan provenan x tapak kawasan telah dianggar untuk ketinggian pokok dan ukurlilit pada aras dada *Pinus caribaea* yang berumur 12 tahun di tiga tapak savana Nigeria iaitu Afaka, Nimbia and Miango. Provenan yang dikaji adalah Gunung Pine Ridge (Belize), lot dagangan (Belize), New Providence (Bahamas), Great Abaco (Bahamas) dan Pinar del Rio (Cuba Barat). Tidak terdapat saling tindakan provenan x tapak kawasan yang ketara dalam kedua-dua ciri tumbesaran yang dikaji. Provenan-provenan mengekalkan prestasi relatif mereka di ketiga-tiga tapak kawasan dengan kedua-dua sumber Belize didapati paling sesuai. Terdapat perbezaan yang sangat ketara di antara tapak kawasan dalam ketinggian bagi provenan-provenan *Pinus caribaea* tetapi tidak untuk pertumbuhan ukurlilit. Pertumbuhan yang paling cepat telah disukat di Miango manakala yang terendah di Afaka. Ketinggian pokok dan pertumbuhan ukurlilit provenan *Pinus caribaea* yang dikaji mempunyai keturunan provenan yang tinggi. Ini menunjukkan bahawa ekspresi ciri-ciri tersebut tidak melalui cara yang sama di ketiga-tiga kawasan ujian.

Introduction

The term provenance x site interaction is used to detect any inconsistency in the relative performance of provenances in different environments. It occurs when different environments do not have the same effect on different genotypes (Falconer 1960). Although the interaction can take many forms, it only becomes important in practice if the best population for one site is not necessarily the best for others (Barnes *et al.* 1984).

Literature reviews by Squillace (1970) and Wright (1973) have shown the existence of strong provenance x site interaction in forest tree species, especially for growth rate. However, the absence of such interaction has been reported in other studies (e.g. Harris 1969, Butcher 1974, Matziris 1982, Otegbeye 1990, 1992). Thus, according to Barnes *et al.* (1984), the level at which interaction occurs varies with species and characteristics. Interaction depends also on the genetic make-up of the investigated material. Strongest effects may be expected on clonal material which provenances will buffer interactions more effectively (Matyas, pers. comm.).

Pinus caribaea Morelet provenance trials were established at three different Nigerian savanna sites in 1968. Growth data at ages 3 y (Ojo & Shado 1973) and 12 y (Otegbeye & Shado 1984) have shown the variation patterns among the provenances at each of the test sites. Although no attempt has been made to estimate provenance x site interaction in the species in the Nigeria savanna region, many other studies have shown that such interaction can be quite low. The aims of this paper are therefore to use the 12-y growth data to: (1) estimate provenance x site interaction for height and girth at breast height (GBH) of the species, and (2) identify the most suitable provenance of the species for the three sites.

Materials and methods

Five *Pinus caribaea* provenances grown at three Nigerian savanna sites in 1968 were involved in the study. The provenances are commercial lot (Belize), Mt. Pine Ridge (Belize), New Providence (Bahamas), Great Abaco (Bahamas) and Pinar del Rio (West of Cuba). The description of the three sites, namely Afaka, Nimbia and Miango, is presented on Table 1.

The experimental design followed at each of the trial sites was randomised complete block design with three replications. There were 36 trees in each plot, planted in a 6×6 configuration with spacing of 2.7×2.7 m at Nimbia and Afaka, where the plots were mechanically weeded, and 1.8×1.8 m at Miango, where weeding was done manually.

Because of the mortality of some of the trees, only 10 inner trees per plot were selected at random for assessment of tree height and girth at breast height (GBH) when they were 12 y old in the field. The data collected were subjected to combined analyses of variance over sites using plot means.

Table 1. Description of the three Nigerian savanna sites where some *Pinus caribaea* provenances were tested*

	Site		
	Afaka	Nimbia	Miango
Latitude	10°37'N	8°30'N	9°50'N
Longitude	7°17'E	9°30'E	8°40'E
Altitude (m)	600	600	1130
Rainfall (mm)	1290	1750	1570
Length of rainy season (days)	180	220	180
Mean annual temperature (°C)	25	25	22
Mean minimum temperature of coldest month (°C)	14	15	13
Mean maximum temperature of hottest month (°C)	35	36	31
Soil	Ferrugineous tropical sandy loam to sandy clay loam, over plinthite; pH 5.3-6.2	Eutrophic brown, loam to clay loam, derived from basalt, pH 6.0-6.8	Eutrophic brown derived from basalt clay loam, pH 5.2-5.6

* Source: Ojo & Shado 1973.

Table 2. Combined analysis of variance on height and girth at breast height of 12-y-old *Pinus caribaea* provenances tested at the three Nigerian savanna sites

Source of variance	df	Mean square[1]	Expected mean square
Site	2	H 28.426** G 97.038	$\sigma_e^2 + 5\sigma_{r(s)}^2 + 15\sigma_s^2$
Replication	6	H 1.192* G 27.421	$\sigma_e^2 + 5\sigma_{r(s)}^2$
Provenance	4	H 2.827 G 229.820**	$\sigma_e^2 + 3\sigma_{ps}^2 + 9\sigma_p^2$
Provenance x site	8	H 0.754 G 11.818	$\sigma_e^2 + 3\sigma_{ps}^2$
Error	24	H 0.387 G 58.632	σ_e^2

[1] The upper and lower figures in each cell under mean square show the mean square values for tree height and girth at breast height respectively.
Significance levels: *, 0.05; **, 0.01.

The relevant components of variance were estimated from the analysis of variance (Table 2):

$$\sigma_p^2 = \frac{MS_b - MS_{ps}}{9}$$

$$\sigma_{ps}^2 = \frac{MS_{ps} - MS_e}{9}$$

$$\sigma_e^2 = MS_e$$

Where

σ_p^2 = genetic variance among provenance means

σ_{ps}^2 = provenance x site interaction variance

σ_e^2 = error variance

MS = mean square of appropriate subscripted source of variance

Heritability of provenance means (h_p^2) were estimated for each of the two growth characteristics according to Otegbeye and Samarawira (1992):

$$h_p^2 = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_{ps/r}^2 + \sigma_{e/rs}^2}$$

where

r = number of replications
s = number of sites

Results and discussion

The analyses of variance by site showed that there were significant differences among the *Pinus caribaea* provenances examined at each of the three test sites for tree height and GBH except for tree height at Miango (Otegbeye & Shado 1984).

However, the combined analyses of variance presented here show that while there was no significant variation in tree height among the provenances, there were highly significant differences in their GBH (Table 2). The two Belize sources were similar in growth (Table 3). Although not significant, height growth of the two Belize sources also had an edge over the other sources. Moreover, none of the provenances has been observed to be susceptible to windthrow and diseases in the region. Therefore, the Belize sources, representing var. *hondurensis*, are better suited to these Nigerian savanna environments. Hence, because of their plasticity, they can be used more broadly than the other provenances.

Table 3. Height and girth at breast height (GBH) of five 12-y-old *Pinus caribaea* provenances tested at the three Nigerian savanna sites

Provenance	Height (m)				GBH(cm)			
	Afaka	Nimbia	Miango	Mean	Afaka	Nimbia	Miango	Mean
Commercial seeds (Belize)	9.21(1.27)[a]	10.33(1.60)	12.96(1.45)	10.84(2.48)	47.41(11.69)	54.19(14.13)	57.13(9.13)	52.91(8.98)
Mt. Pine Ridge (Belize)	10.08(0.98)	10.79(1.22)	12.68(1.83)	11.18(1.99)	51.48(7.55)	51.83(8.24)	54.25(13.22)	52.25(6.18)
New Providence (Bahamas)	8.95(1.09)	9.12(1.25)	11.01(2.07)	9.70(1.85)	39.90(10.56)	39.63(9.87)	42.17(13.15)	40.83(6.18)
Pinar del Rio (West of Cuba)	9.69(1.01)	9.91(1.22)	11.36(1.67)	10.32(1.29)	45.90(10.94)	47.33(13.18)	47.74(11.06)	46.99(4.78)
Great Abaco (Bahamas)	9.49(1.07)	9.07(1.02)	12.12(1.61)	10.22(2.11)	42.18(11.49)	44.69(10.99)	50.16(12.48)	45.68(6.70)
Mean	9.48(0.39)	9.84 (0.67)	12.03(0.75)		45.37(4.05)	47.53(5.16)	50.29(5.19)	

[a]Standard deviation in parenthesis.

There were highly significant (p = 0.01) site differences for tree height but no such differences existed for GBH. The site mean tree heights recorded were 9.48, 9.84 and 12.03 m for Afaka, Nimbia and Miango respectively. Although there were no significant differences in the GBH of the species, the highest site mean value (50.29 cm) was recorded for Miango while Afaka and Nimbia had mean values of 45.37 and 49.53 cm respectively. Therefore, greater *Pinus caribaea* wood volume production should be obtained at Miango than at either of the other two sites. A slightly different picture has been reported for *Pinus oocarpa* grown at these sites (Otegbeye 1990). In that study, Miango was reported to have supported the highest *P. oocarpa* height growth while Nimbia supported the highest GBH of the species, with Nimbia having an edge over Miango in the species's wood volume production.

There was no significant provenance x site interaction in any of the two growth characteristics. This shows that the provenances maintained their relative performance in all the test sites. Similar results have been obtained for *Pinus oocarpa* tested at these same sites (Otegbeye 1990) and for other tree species (Harris 1969, Butcher 1974, Matziris 1982, Otegbeye 1992).

Since none of the growth characteristics of the *Pinus caribaea* provenances examined displayed provenance x site interaction, it is possible to identify the best provenance out of the five for afforestation and genetic improvement programmes in the Nigerian savanna region. Moreover, seeds of the species can readily be exchanged in the region without the fear of deleterious effects. Since it will be possible to develop a genetic improvement programme for a single provenance, the breeder's ability to develop the desired trees of superior genetic constitution in a shorter period of time and at reduced cost will be greatly enhanced. This will be possible because the breeder will not have to maintain different breeding populations for the different environments.

Partitioning the total phenotypic variance of each characteristic into components helps in determining the proportion of heritable variation that can be exploited for the selection of outstanding genetic resources. It is the estimate of heritability that is required for this purpose. It indicates the proportion of observed variation that is due to genetic effects.

The relevant variance components and provenance heritability estimate (h_p^2) for each of the two growth characteristics are presented in Table 4. In estimating h_p^2 for GBH, the interaction component of variance was assumed to be zero since a negative value (-15.6046) was actually obtained. Both tree height and GBH of the *Pinus caribaea* provenances examined were under strong genetic control. Tree height had h_p^2 estimate of 0.73 while GBH had a value of 0.79. The high h_p^2 recorded for the two characteristics is an indication that the expression of the characteristics was not influenced differentially by the three test environments.

Table 4. Variance components and provenance heritability (h_p^2) estimates for height and girth at breast height (GBH) of 12-y-old *Pinus caribaea* provenances grown at the three Nigerian savanna sites

Components of variance	Height	GBH
Provenance	0.2303	24.2224
Provenance x site	0.1223	-15.6046
Error	0.387	58.632
h_p^2	0.73	0.79

Conclusion

The relative growth performances of *Pinus caribaea* provenances tested in the Nigerian savanna region are stable over different environmental conditions. It is possible, therefore, to use one best provenance for afforestation and genetic improvement programmes for all the environments. This has economic implications for breeding and propagation of the species in the region.

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