EFFECTS OF SOME SOIL PHYSICAL PROPERTIES ON GROWTH OF *PINUS CARIBAEA* VAR. *HONDURENSIS* IN NORTHERN GUINEA SAVANNA AREA OF NIGERIA

Effets de différentes caractéristiques physiques du sol sur la croissance de *Pinus caribaea* var. *hondurensis* dans le secteur de savane de North Guinea (Nigéria).

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RESUME

Les effets de différents caractères du sol (profondeur, teneur en cailloux, capacité de rétention et densité apparente) sur la croissance d'une plantation de Pinus caribaea *de sept ans ont été étudiés dans la région d'Afaka (Kaduna State, Nigeria). Le résultat montre que hauteurs et aires basales des arbres sont corrélées avec la profondeur, et négativement avec la teneur en cailloux. Il a également été observé que les sols peu profonds avaient une capacité de rétention inférieure. Le choix des sites, des espèces et des aménagements sont discutés en fonction de ces observations.*

ABSTRACT

The effects of soil depth, percentage gravel content, water capacity and bulk density of soils on growth of seven-year old Pinus caribaea *stands were studied at Afaka in Kaduna State of Nigeria. The result shows that effective soil depths significantly correlated with tree heights and basal areas. On the other hand, mean percentage gravel contents correlated negatively with both tree heights and basal areas. It was also observed that shallow soils had lower water capacity than deeper soils. The implications of these findings as regards site selection, choice of species and proper forest management are discussed.*

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INTRODUCTION

The Nigerian Savanna vegetation is incapable of meeting local requirements of wood products and reliance must be placed on plantations of introduced tree species.

A large species trials programme was started about 1960 in seven areas of Nigeria with the objective of finding the suitable tree species for large scale forest plantations on the many varied savanna sites. Over 90 species including 18 pines, have so far been tried ; and four of the most promising 23 species are pines (KEMP, 1969). These are *Pinus caribaea* Morelet, *P. oocarpa* Schiede, *P. kesiya* Royle ex Gordon, and *P. merkusii* Jungh & de Vriese. Of the four pine species, *P. caribaea* had proved the obvious first choice for large scale planting (EGUNJOBI & BADA, 1979), with *P. oocarpa* as a good second choice in the Northern Guinea Savanna area of Nigeria.

Determination of site quality is a prerequisite for intensive forest management. The quality and quantity of timber that may be produced on a particular site depends upon the quality of forest lands and the environmental factors prevailing there. The growth of a forest stand is an integrated expression of all the biological and environmental variables that have influenced it (SHRIVASTAVA & ULRICH, 1978). However, obtaining an accurate estimate of the potential productive capacity of bare land, or land in immature trees is one of the most difficult problems confronting forest managers. Most successful studies evaluating forest site quality have involved the correlation of various soil properties with tree growth. On areas with similar climates, soil profile characteristics and topography appear to be the most feasible guides to tree growth prediction. AUTEN (1945), COILE (1948), EINSPAHR & McCOMB (1951) CARMEAN (1965) and BROADFOOT (1969) are just a few of the many authors who in recent years have made studies in various areas in which soil properties have been correlated with forest tree growth. Physical soil properties rather than level of soil nutrients have generally been found to be more important in the prediction of forest tree growth, although physical and chemical properties are closely interrelated and their effects cannot be separated (EINSPAHR & Mc COMB, 1951).

The objective of this study is to determine the effects of some soil physical properties such as soil depth, percentage gravel content, bulk

density and water capacity of soils on the growth of *Pinus caribaea* at Afaka in Kaduna State.

THE STUDY AREA

Afaka Forest Reserve is located in Kaduna State about 10 km. from Kaduna along Kaduna-Lagos Road. Rainfall averages 1275 mm spread over six to seven months. The mean monthly temperatures range from 17° C to 32° C and relative humidities from 29 to 87 percent. The topography varies from flat to a gentle slope. The soils of Afaka Forest Reserve are classified under Ferrugenous Tropical Soils derived from the Basement Compex rocks. The principal difference among many soils of the area, other than drainage, is the depth of soil above the plinthite layer (BARRERA & AMUJO, 1971). ALEXANDER and CADY (1962) defined plinthite layer as consisting of highly weathered materials rich in secondary oxides of iron and aluminium or both, and containing very small quantities of bases and primary silicates but large amounts of quartz and kaolinite. Plinthite has a high bulk density and tends to harden when dry. Upon wetting, it will soften, but under certain conditions it becomes indurated or permanently hard (ALEXANDER & CADY, 1962).

BARRERA and AMUJO (1971) have carried out semi-detailed soil survey of the area and have classified the soils into 20 soil mapping units.

Part of the forest reserve has been planted with exotic species such as eucalyptus and pines. Part is still under savanna woodland. The pine stands were planted between 1969 and 1978 by Savanna Forestry Research Station and Kaduna State Forestry Division at a spacing of 3 m x 3 m with mycorrhiza innoculated seedling. KADEBA and ADUAYI (1986) have reported on dry matter production and nutrient distribution in these pine stands.

MATERIALS AND METHODS

Five sample plots of 16 trees each were laid on each of three different soil units namely Anara sandy loam, Afaka sandy loam Dandadi sandy loam, covered by seven-year old stands of *Pinus caribaea* Morelet var. *hondurensis* Barret & Golfari. The demarcation of sample plots was done with the aid of soil augering to make sure that each plot was uniform in soil type. Height and girth measurements of 16 trees were made

in each plot to determine soil effective depths. The effective soil depth was taken as the soil depth to hard plinthite layer. Soil samples were taken at only three depth levels namely 0 - 15 , 15 - 25 and 25 - 50 cm. Five soil samples were taken from each depth level and composited into one. Undisturbed soil cores were also collected from profile pits of two soil units for bulk density and water capacity determination of percentage gravel contents. Simple correlation coefficient tests were used in the analysis of the data.

RESULTS

Plot n°	Mean % gravel content	Effective depth (cm)	Mean tree ht. (m)	Basal area (cm^2)
		Anara Soil Unit		
1	11.6	40	5.7	51.7
2	23.2	25	4.9	42.4
3	12.0	26	5.0	55.4
4	16.1	40	4.7	44.3
5	12.9	26	4.6	34.6
Total	75.8	157	24.9	228.4
Mean	15.2	31.4	5.0	45.7
		Afaka Soil Unit		
1	1.9	58	7.8	82.4
2	3.0	65	7.9	81.4
3	1.3	75	7.5	75.5
4	2.8	75	7.2	72.0
5	2.7	55	7.2	74.0
Total	11.7	328	37.6	385.3
Mean	2.3	65.6	7.5	77.1
		Dandadi Soil Unit		
1	0.3	150	7.8	84.5
2	0.4	150	7.5	79.9
3	0.2	150	6.4	122.8
4	0.5	150	8.1	95.2
5	0.4	150	7.8	84.5
Total	1.8	750	37.6	466.9
Mean	0.4	150	7.5	93.4

Table I : The distribution of individual plot values of effective soil depths, mean percentage gravel contents and tree growth data for each mapping unit.

Soil Property/Tree Growth	Correlation Coefficient with P = 0,01
Mean effective depth vs tree height	0.72
Mean effective depth vs basal area	0.91
Mean percentage gravel content vs tree height	-0.97
Mean percentage gravel content vs basal area	-0.99

Table II : Correlation Coefficient associating soil characteristics with tree growth.

Soil depth (cm)	Bulk density (gm/cc)	1/3 Bar	15 Bar	Available moisture (% wt)
		Afaka sandy loam		
0.15	1.29	12.01	5.41	6.54
15-20	1.51	9.69	4.85	4.84
20-33	1.72	16.24	10.52	5.72
Total	4.52		17.10	17.10
Mean	1.5			5.7
		Anara Sandy loam		
0-15	1.60	6.50	3.37	3.13
15-25	1.50	8.27	5.29	2.98
25-83	1.62	20.21	15.17	5.04
Total	4.78			11.15
Mean	1.6			3.7

Table III : Bulk density and available moisture of two soil mapping units.

Table I shows the distribution of individual plot values of effective soil depths, mean percentage gravel contents and tree growth data for each soil mapping unit. Average tree heights of 5.0 , 7.5 and 7.5 m and mean basal areas of 45.7 , 77.1 and 93.4 cm^2 respectively were obtained on soils with mean effective depths of 31.4 , 65.6 and 150 cm, and mean gravel contents of 15.2 , 2.3 and 0.4 percent respectively.

Table II shows that effective soil depths significantly correlated with tree heights and basal areas. On the other hand, mean percentage gravel contents correlated negatively with both tree heights and basal areas.

Table III shows the bulk density and available moisture of Anara sandy loam and Afaka sandy loam. Anara sandy loam (shallow soil) indicated a lower water capacity than Afaka sandy loam (deep soil). There is no much difference in bulk densities of the two soil units.

DISCUSSION

The volume of soil available to tree roots as indicated by soil depth, influences tree growth to the extent that it effects nutrient and moisture supplies, root development and of course, the anchorage against windthrow (PRITCHETT, 1979). There is therefore no doubt that shallower Anara Soil Series supported lower tree growth than the deeper Dandadi and Afaka Soil Series. PRITCHETT (1979) indicates that when soil dept is such that it defines the volume of growing space for tree roots above some restricting layer, such as a clay pan, siltpan, bedrock or other horizon of low permeability, depth measurement can be used with some precision to predict growth patterns in well drained soils. He also states that growth normally follows a trend that can be expressed as a reciprocal function of soil depth with greatest decline in growth found on soil with less than 25 cm of effective depth. As indicated earlier, the principal difference among many soils of Afaka Forest Reserve, other than drainage, is the depth of soil above the plinthite layer. Plinthite layers are also associated with high sesquioxidic gravel contents. There is therefore no doubt that tree growth correlated negatively with percentage gravel contents as show in Table II.

The above results supported the finding of some authors such as HANNA (1968), BARNES and RALSON (1955) and JACKSON (1965) who reported that site productivity increased with effective soil depth.

It appears from these results that effective soil depths, percentage gravels and water capacities could be used among other factors for prediction of growth of *Pinus caribaea* in well drained soils formed on the Basement Complex on the Northern Guinea Savanna area of Nigeria. However, it should be noted that some difficulties in using soil depth to estimate productivity may be encountered where drought, erosion or poor drainage are products of surface soil thickness or depth of soil above some restricting layer. There may be soil fertility interactions important to tree growth that cannot be determined from depth measurement alone in each of these cases. It should also be noted that through out this report, soil considerations have been spot-lighted ; this is intentional and does not preclude other considerations. The fact that soil is a medium for growth of crops does not mean that growth depends on it entirely. One thing however is clear, some of the variations in the growth of *Pinus caribaea* at Afaka Forest Reserve are directly attributed to the soil physical characteristics mentioned. As long as these soil characteristics are considered in the delineation of soil unit boundaries, preference should be given to deeper soils in the choice of sites for *Pinus caribaea* as tree species for afforestation. It is suggested that other species such as eucalyptus which have roots more capable of penetrating through the plinthite layer be used for afforestation of areas with shallower soils.

CONCLUSION

The study on the effects of soil depth, percentage gravel content and water capacity of soils on growth of seven year old *Pinus caribaea* shows significant correlations between tree growth and soil effective depth and between tree growth and percentage gravel content. It was found that water capacity of deep Afaka sandy loam that supported higher tree growth was higher than that of shallow Anara Sandy loam.

The implication of these finding as regards site selection, choice of species and forest management have been discussed.

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