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EDAPHIC FACTORS AFFECTING THE GROWTH OF *TECTONA GRANDIS* ON BASALTIC SOILS IN THE DERIVED SAVANNA AREA OF NIGERIA

Les facteurs édaphiques de la croissance de *Tectona grandis* sur les sols basaltiques dans une région anciennement de savane.

M.I.S. EZENWA*

RESUME

La relation qui existe entre certaines propriétés du sol et la croissance de spécimens de Tectona grandis *(teck) âgés de 12 ans, a été étudiée dans quinze parcelles de la réserve de Nimbia (Kaduna State). Profondeur du sol, pH, teneur en azote et en ions Ca et K échangeables ont une corrélation positive avec la hauteur et la surface basale des arbres et une corrélation négative avec le phosphore disponible, la teneur moyenne en cailloux du profil entier ainsi que la teneur en particules fines (argiles et limon) de l'horizon A.*

Une régression multiple montre que cette teneur en particules fines associée à la profondeur du sol, expliquent respectivement 93,8 et 89,7 % des variations de la croissance de la hauteur des arbres et de la surface basale.

L'impact que peut avoir ce résultat sur la sélection des sites et sur l'aménagement de la forêt est ensuite discuté pour le cas d'une région de savane du Nigéria.

ABSTRACT

The relationship between some soil properties and growth of 11-year old Tectona grandis *L.f. (teak) was studied on 15 sample plots at Nimbia in Kaduna State of Nigeria. It was observed that effective soil depth, soil pH, total nitrogen, exchangeable Ca and K and total exchangeable bases are positively correlated with tree heights and basal areas. Conversely, there were significant negative correlations between tree growth and available phosphorus, mean profile gravel content and silt-plus-clay content of the A horizon. Results of multiple regression analyses showed that silt-plus-clay contents of A horizons and effective soil depths accounted for 93.8 and 89.7 percent of variability in tree height and basal area growth respectively. The implications of the finding as regards site selection and proper forest management in the Derived Savanna area of Nigeria are discussed.*

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* Savanna Forestry Research Station, F.R.I.N. - Samaru - Zaria

INTRODUCTION

The Nigerian savanna vegetation has been adversely affected by human activities. Consequently, the residual natural vegetation is incapable of meeting, both in quality and quantity, the rapidly increasing requirements of wood and wood products. Apart from human interferences, the growth of the indigenous tree species in the reserved areas is very poor. Reliance must therefore be placed on plantations of introduced tree species.

Various trials of exotic species therefore began and the results led to early establishment of plantations of *Tectona grandis* L.f,, Eucalypts, Pines, *Azadirachta indica* A. Juss. and *Dalbergia sissoo* Roxb. in the Nigerian savannas. Following favourable reports of the outstanding wood quality of *Tectona grandis*, its high demand fot its beautiful texture in furniture and cabinet making (ANON, 1950), considerable attention is now being given to the establishment of large scale plantations of the species in the Derived Savanna area of Nigeria.

The determination of site quality is a perequisite for intensive forest management. The quantity and quality of timber that may be produced on a particular site depends on the quality of forest lands and the environmental factors prevailing in the area. The growth of a forest stand is an integrated expression of all the biological and environmental variables that have influenced it (SHRIVASTAVA and ULRICH, 1978). To obtain an accurate estimate of the potential productive capacity of a bare land, or land in immature tree is however, one of the most difficult problems facing forest managers. Most successful studies evaluating forest site quality have involved the correlation of various soil properties with tree growth. Soil profile characteristics and topography appear to be the most feasible guides to tree growth prediction on areas with similar climates. ENSPAHR and McCOMB (1951), CARMEAN (1965) and EZENWA (1988) are just a few of the many authors who in recent years have made studies in various areas in which soil properties have correlated with tree growth. ENSPAHR and McCOMB (1951) observed that 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 connot be separated.

The objective of this study is to determine the effects of some selected soil physical and chemical properties such as the effective soil depth, percentage gravel content, soil reaction, total nitrogen, available P, exchangeable Ca, Mg and K on growth of 11-year old *Tectona gandis* at Nimbia in Kaduna State of Nigeria.

THE STUDY AREA

Nimbia Forest Reserve is located in the Derived Savanna Zone of Nigeria and it is situated at about 65 kilometres south of Jos along the Jos - Jema'a road. It lies within latitudes 9°26' and 9°31' North and longitudes 7°12' and 7°26' East, having an area of about 10,792 hectares. Most of the reserve is underlain by the Newer Basalt. A small portion of the Northern part, excluded in this study, is underlain by the Basement Complex consisting mainly of metamorphic rocks. Rainfall averages 1650 mm spread over seven months. The yearly maximum and minimum temperatures average 18.2° C and 31.5° C respectively and the relative humidities range from 38 to 84 percent. The topography varies from flat to a gentle slope. The soils of Nimbia Forest Reserve are classified as plinthic/chromic luvisols and plinthic acrisols (FAO/UNESCO, 1974). The principal difference among many soils of the area other than drainage is the depth of the soil above the plinthite layer. BARRERA (1968) has carried out semi-detailed soil survey of the area and has classified the soils into seven series.

The old vegetation has been cut over by the Kaduna State Government and planted up with mainly *Tectona grandis* and a few *Gmelina arborea* Roxb. stands at a spacing of 3 m x 3 m. Forestry Research Institute of Nigeria has a few pines, teak, *Gmelina arborea* and *Chlorophora* sp. experimental plots in the reserve. The remnants of the original vegetation are found along the banks of the rivers and in patches all over the reserve.

MATERIALS AND METHODS

Three soil series namely, Nimbia, Jenta and Nimbia variant were chosen for the study. For each soil series covered by 11-year old teak, five sample plots of 16th trees each were laid. Height and girth measurements of the 16 trees were made in each plot and five soil auger holes were made in each plot to determine effective soil depth. Soil samples were taken at only four depth levels namely : 0 - 15 cm, 15 - 25 cm, 25 - 50 cm and 125 - 150 cm. Five soil samples were taken from each depth level and composited into one. Particle size distribution analyses were carried out by the

P lot N°	Effective Soil Depth	Mean Gravel Content A hor.	Silt + Clay	pH (C_aCl2)	Tot. N	Avail. P	Ca	Mg	K	TEB	Mean Tree Ht.	Mean Basal Area/ha
	cm	%	----		%	ppm	----	meq/100 g		----	m	m^2
							NIMBIA SERIES					
1	150	3.0		4.3	0.07	1.0	1.58	0.80	0.14	2.57	16.7	24.4
2	140	1.5		4.2	0.07	1.3	1.52	0.66	0.26	2.50	16.3	20.8
3	139	1.8		4.6	0.09	2.0	1.68	0.72	0.21	2.85	15.8	20.7
44	150	1.7		4.5	0.08	1.5	1.55	1.05	0.25	2.89	16.0	21.4
5	145	0.3		4.5	0.09	1.8	1.57	1.07	0.36	2.99	16.8	24.0
Total	724	8.5		22.1	0.40	7.5	8.10	4.30	1.16	13.80	81.6	110.7
Mean	144	1.7	36.0*	4.4	0.08	1.5	1.60	0.86	0.23	2.76	16.3	22.1
							NIMBIA VARIANT					
1	57	1.7		4.2	0.07	5.5	1.67	0.66	0.29	2.64	16.2	15.8
2	84	3.5		4.3	0.08	5.2	1.48	0.89	0.24	2.62	15.5	14.2
3	85	5.1		4.4	0.07	4.9	1.45	0.79	0.24	2.50	14.3	11.2
4	74	1.8		4.3	0.06	5.6	1.84	0.55	0.26	2.68	13.0	11.2
5	58	1.7		4.2	0.08	5.0	1.44	0.92	0.27	2.64	12.6	9.6
Total	358	13.8		21.4	0.36	26.2	7.88	3.81	1.30	13.08	71.6	62.0
Mean	71.6	2.8	39.8*	4.3	0.07	5.2	1.58	0.71	0.26	2.62	14.3	12.4
							JENTA SERIES					
1	40	8.1		4.0	0.07	2.8	1.50	0.77	0.13	2.44	8.1	7.6
2	40	7.2		3.7	0.06	3.0	1.20	0.66	0.16	2.09	7.2	6.8
3	30	7.9		3.5	0.06	3.7	1.10	0.83	0.16	2.15	7.9	8.3
4	44	9.1		3.7	0.06	3.8	1.20	0.77	0.20	2.26	9.1	8.5
5	45	7.3		4.0	0.06	3.5	1.30	1.06	0.16	2.56	7.3	6.0
Total	199	39.6		18.9	0.31	16.8	6.30	4.09	0.81	11.50	39.6	37.2
Mean	39.8	7.9	36.0*	3.8	0.06	3.4	1.30	0.82	0.16	2.30	7.9	7.4

* Mean values of three plots.

Table I : The distribution of individual plot physical and chemical properties and tree growth data for each soil series at Nimbia.

hydrometer method. Soil pH was determined potentiometrically using 1 : 25 soil/$CaCl_2$ solution ratio. The laboratory methods used in the analyses of the soil samples were those described by the U.S.D.A. Soil Survey Investigation Staff (1967). Correlation coefficient and multiple regression were used in the analyses of the data.

RESULTS

Average tree height of 14.3 m, 16.3 m and 7.9 m and mean basal areas per ha of 12.5 m^2, 22.1 m^2 and 7.4 m^2 respectively were obtained on soils with mean physical and chemical values as shown in Table I. The matrix of coefficients of cxorrelation (r: Table II) shows significant positive correlations between tree growth and soil pH, total nitrogen, exchangeable K, Ca and effective soil depth. Conversely, there were significant negative correlations between tree growth and available phosphorus, mean profile gravel content and silt-plus-clay content in the A horizon. Results of multiple regression analyses of the soil properties and tree growth (Table III) show that silt-plus-clay content of A horizon and effective soil depth accounted for 93.8 and 89.7 percent of the variability in tree height and basal area growth respectively.

DISCUSSION

Table I shows marked gradation in nutrient contents and some physical properties of the soils in Nimbia. This gradation is also reflected in the growth of *Tectonia grandis* in the area. Nimbia series gave the highest mean values of nutrient except available P. These nutrient levels are still regarded as low to very low. Similarly, the tree height and basal area growth on this soil series were the highest (16.3 m and 22.1 m^2 respectively). The Jenta series gave the lowest mean values of the above soil chemical properties except available P. The effective soil depth of Jenta series was the shallowest while the mean gravel content was the highest. PRITCHETT (1979) observed that the volume of soil available to tree roots as indicated by soil depth influences tree growth to the extent that it affects nutrient and moisture supplies and root development and also anchorage against wind-throw. This undoubtedly shows why shallower Jenta series supported lower tree growth than the deeper Nimbia series and its variant. The tree roots in Jenta series were restricted by plinthite layer which was associated with high sesquioxide gravel contents as can be seen in table I. These findings supported EZENWA's (1988) findings on soil formed on Basement Complex

Soil property/tree growth	Correlation coefficients
Soil depth (cm) Vs Tree height (m)	0.832**
Soil depth (cm) Vs Basal area/ha (m^2)	0.947**
Gravel content (%) Vs Tree height (m)	-0.931**
Gravel content (%) Vs Basal area/ha (m^2)	-0.751**
Silt + clay (%) Vs Tree height (m)	-0.969**
Silt + caly (%) Vs Basal area/ha (m^2)	-0.844**
pH ($CaCl_2$)Vs Tree height (m)	0.838**
pH ($CaCl_2$) Vs Basal area/ha (m^2)	0.712**
Total Nitrogen (%) Vs Tree height (m)	0.687**
Total Nitrogen (%) Vs Basal area/ha (m^2)	0.663**
Available Phosphorus (ppm) Vs Tree height (m)	-0.199
Available Phosphorus (ppm) Vs Basal area/ha (m^2)	-0.599*
Ca meq/100g Vs Tree Height (m)	0.703**
Ca meq/100 g Vs Basal area/ha (m^2)	0.580*
Mg meq/100 g Vs Tree height (m)	0.032
Mg meq/100 g Vs Basal area/ha (m^2)	0.149
K meq/100 g Vs Tree height (m)	0.648**
K meq/100 g Vs Basal area/ha (m^2)	0.453
Total exch. Bases meq/100 g Vs Tree height (m)	0.742**
Total Exch. Basas meq/100 g Vs Basal area/ha (m^2)	0.682**

* significant at 5 % level ; ** Significant at 1 % level

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

Variable n°	Equation	(R^2 %) *
1	Tree height growth (Y)	
	Y = 33.28 - 0.47 (S + C)	93.8
	(0.04)	
1	Tree basal area growth (Y)	
	Y = 2.50 + 0.14 (E.D.)	89.7
	(0.01)	

S + C = Silt-plus-clay percent of A horizon; E.D. = Effective soil depth (cm);

* only significant R^2 values are presented in the table.

Table III : Multiple-regression equations associating 11-year old *Tectona grandis* growth with soil properties at Nimbia.

where shallow Anara soil series restricted the growth of *Pinus caribaea* Morelet. There is therefore no doubt that tree growth correlated negatively with percentage gravel content.

The results of multiple regression analyses indicate that soil physical properties such as effective soil depth and percentage gravel content of the soils could be used among other factors for prediction of growth of *Tectona grandis* in well drained soils formed on the basaltic rocks in the Derived Savanna area of Nigeria. Soil nutrient levels in this area quite unlike those in soils formed on sandstone (EZENWA *et al.* 1987) contributed little in the regression equations indicating that siol physical properties are more important in the prediction of forest tree growth, especially teak in the area. Lack of significant correlation between tree growth and exchangeable Mg and the negative correlation between tree growth and available P indicate that the soil exchangeable Mg and available P are not much in demand by teak in the soils of the area. This is supported by the findings of CHIJIOKE (1980) who indicated that exchangeable Mg and available P were not much in demand by *Gmelina arborea* which belongs to the same family.

It should however be noted that the fact that soil is a medium for growth of tree crops does not mean that growth depends solely on it but as long as soil characteristics are considered in the delineation of soil unit boundaries, preference should be given to deeper soils in the choice of site for *Tectona grandis* as tree species for afforestration in the area. Use of fertilizers should also be critically examined.

CONCLUSION

The study of the effects of some edaphic factors on growth of 11-year old *Tectona grandis* showed significant positive correlations between the tree growth (height and basal area growth) and soil effective depth, soil pH, total nitrogen, exchangeable K and Ca. Conversely, there were significant negative correlations between tree growth and available P, mean profile gravel content and silt-plus-clay content of A horizon. The implications of these findings as regards site selection and forest management have been discussed.

REFERENCES

ANON, 1959. Yield and stand table for plantations of teak. *Ind. For. Records. Sil.* N° 9 (4), For. Res. Inst., Dehra Dun., India.

BARRERA, A.V., 1968. Soil survey of Nimbia forest reserve. Savanna For. res. Stn. Samaru, Zaria (Unpublished).

CHIJOKE, E.O., 1980. Soil-site factors in relation to growth and wood quality of *Gmelina arborea* (Linn.) in Western Nigeria. Ph.D. thesis, Dept. of Agronomy, Univ. Ibadan, Nigeria.

CARMEAN, W.H., 1965. Black oak site quality in relation to soil and topography in southern Ohio. *Soil Sci. Soc. Amer. Proc.* 29 : 308-312.

EZENWA, M.I.S., OKOROAFOR, C.N. & ESHALOMI, B., 1987. The effect of some soil physico-chemical properties on the growth of *Gmelina arborea* in the Southern Guinea Savanna. Proc. Annual Conf. of F.A.N., 47-52.

EZENWA, M.I.S., 1988. Effects of some soil physical properties on growth of *Pinus caribaea* var. *hondurensis* in Northern Guinea Savanna area of Nigeria. *Geo-Eco-Trop,* 10 (1-4), 49-56.

ENSPAHR, D. & McCOMB, A.L., 1951. Site index of oak in relation to soil and topography in northeastern Iowa. *Journ. For.* 49, 719-723.

F.A.O./UNESCO, 1974. Soil map of the world, 1:5,000,000. Vol. 1 - Legend sheet and memoir, Paris 59 p.

PRITCHETT, W.L., 1979. *Properties and management of forest soils.* John Wiley and Sons N.Y. 500 p.

SHRIVASTAVA, M.B. & ULRICH, B., 1978. Quantitative assessment of forest site productivity. *Ind. For.* 104 (2), 79-89.

SOIL SURVEY STAFF, 1967. Soil survey laboratory methods and procedure for collecting soil samples. U.S. Govnt. Pr. Office Washington D.C.