Geo-Eco-Trop, 1993, 17 (1-4) 59-65

A PRELIMINARY STUDY OF THE CORRELATION BETWEEN THE N, P AND K CONTENTS OF THE SOILS AND GROWTH OF *PINUS CARIBAEA* VAR. *HONDURENSIS* IN NORTHERN GUINEA SAVANNA AREA OF NIGERIA.

Etude préliminaire des corrélations entre les teneurs du sol en N, P et K et la croissance de *Pinus caribaea* var. *hondurensis* dans la zone de savane guinéenne au Nigéria.

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RESUME

Les effets des teneurs du sol en azote total, en phosphore disponible, et en potassium sur la croissance de P. caribaea ont été étudiées dans une plantation âgée de 7 ans, au sein de la réserve forestière d'Afaka dans l'Etat de Kaduna. Il existe, pour la zone étudiée, une corrélation significative entre la croissance des arbres et l'état du phosphore disponible. Ceci n'est pas le cas pour les teneurs en azote et en potassium. L'implication de ces résultats dans la sélection de sites et la création de plantations forestières est discutée en ce qui concerne la partie septentrionale de la zone de savane guinéenne du Nigéria.

ABSTRACT

The effects of total nitrogen, available phosphorus and potassium of soils on growth of seven-year old Pinus caribaea stands were studied at Afaka Forest Reserve in Kaduna State of Nigeria. The results show significant correlation between tree growth and available phosphorus status of the soils but there was no significant correlation in the case of nitrogen and potassium in the study area. The implication of the findings as regards site selection and establishment of forest plantations in the Northern Guinea Savanna are discussed.

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INTRODUCTION

The natural savanna vegetation of Nigeria has been much affected by past cultivation, fire, grazing and intrinsically slow growth rate and is incapable of meeting, either in terms of quantity or quality, the rapidly increasing requirements for all classes of forest produce. Consequently, reliance must be placed on plantations of introduced tree species.

Since 1960, a large species trials programme was started in seven savanna areas of the country with the objective of finding the suitable tree species for large scale forest plantations in those varied 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. khasya*, Royle ex Gordon, and *P. merkusii*, Jungh and De Vriese. Of the four pine species, *P. caribaea* has proved the obvious first choice for large scale planting, with *P. oocarpa* as good second choice in the Northern Guinea Savanna area of Nigeria. Kaduna State Government has already established few stands of both *P. caribeae* and *P. oocarpa* with a view to supply raw materials for pulp wood industry in the Nigeria savannas.

Although these trial plots show reasonably good prospects for future larger scale plantations, marked difference in growth and general aspect occur among the stands.

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. 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. Many authors including AUTEN (1945), COILE (1948), ENSPAHR & McCOMB (1951, CARMEAN (1965), BROADFOOT (1969), PLATTEBORZE (1970) and EZENWA (1987, 1988) have in recent years made studies in various areas in which soil properties have been correlated with forest tree growth. It has been noted that physical and chemical properties of soils are closely interrelated and that their affects cannot be separated (ENSPAHR & McCOMB, 1951).

The differences in the performances of pines in the Northern Guinea soils have led to the study on soil properties in connection with growth data. EZENWA (1987, 1988) has found significant correlation between the growth of both pines and *Gmelina arborea* and some soil physical properties in the same Savanna zone of Nigeria. He also found significant correlation between the growth of *Gmelina arborea* and some soil chemical properties in the same area (EZENWA, 1987).

The main object of this study is to determine the effects of some chemical properties of soil, such as total nitrogen, available phosphorus and potassium on the growth of *Pinus caribaea* at Afaka in Kaduna State of Nigeria and as a result to gain a better knowledge of the needs in nutrients of *P. caribaea* and the ecology of this species under Northern Guinea Savanna conditions.

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 main yearly temperatures range from 17° C to 32° C and relative humidities from 19 to 87 percent. The topography varies from flat to a gentle slope. The soils of Afaka Forest Reserve are classified under Ferruginous Tropical Soils derived from the Basement Complex rocks (D'HOORE, 1964). 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 & 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.

BARRERA & 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 x 3 m with mycorrhiza innoculated seedlings.

MATERIALS AND METHODS

Five sample plots of 16 trees each were laid on each of three different soil units namely Anara sandy loam (shallow soil), Afaka sandy loam (moderately deep soil) and Dandadi sandy loam (deep to very deep soil), covered by seven year old stands of *Pinus caribaea* var. *hondurensis* Bar and Gulf. 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. 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. The soil samples were processed and analysed. Total nitrogen was determined colourimetrically using Autoanalyzer II after digestion. Available phosphorus was determined by extraction with 0,2 M sulphuric acid and determined colourimetrically. Exchangeable potassium was extracted by ammonium acetate at pH 7 (PEECH *et al.*, 1947) and determined flame photometrically. Simple correlation coefficient tests were used in the analysis of the data.

RESULTS

Table I shows the distribution of individual plot values of total nitrogen, available phosphorus, available potassium and tree growth data for each soil mapping unit.Mean

Tab.I. - The distribution of individual plot values of total nitrogen, available phosphorus, available potassium and tree growth data for each soil mapping unit in different forest sites.

Plot. N°	Total Nitrogen (mean %)	Available Phosphorus (mean ppm)	Available Potassium mean me. /100 g of soil	Mean Tree height. (cm)	Mean Basal area (cm^2)
		Dandadi soil Unit			
1	0.04	39.3	0.39	7.8	84.5
2	0.04	61.0	0.41	7.5	79.9
3	0.04	60.8	0.42	6.4	122.8
4	0.05	58.3	0.41	8.1	95.2
5	0.04	35.3	0.42	7.8	84.5
Total	0.21	254.7	2.05	37.6	466.9
Mean	0.04	50.9	0.41	7.5	93.4
		Akaka Soil Unit			
1	0.04	21.0	0.13	7.8	82.4
2	0.03	18.5	0.09	7.9	81.4
3	0.03	28.0	0.10	7.5	75.5
4	0.03	20.0	0.12	7.2	72.0
5	0.03	33.0	0.14	7.2	74.0
Total	0.16	120.5	0.58	37.6	385.3
Mean	0.03	24.1	0.12	7.5	77.1
		Anara Soil Unit			
1	0.05	3.4	0.15	5.7	51.7
2	0.05	4.0	0.14	4.9	42.4
3	0.05	3.1	0.17	5.0	55.4
4	0.05	3.0	0.18	4.7	44.3
5	0.04	3.6	0.14	4.6	34.6
Total	0.24	17.1	0.78	24.9	228.4
Mean	0.05	3.4	0.16	5.0	45.7

total nitrogen of 0.04, 0.03 and 0.05 percent; mean phosphorus contents of 50.9, 24.1 and 3.4 ppm and mean available potassium contents of 0.41, 0.12 and 0.16 me/100 g of soil were obtained from Dandadi, Afaka and Anara soil units respectively. Mean tree heights of 7.5 m, 7.5 m and 5.0 m and mean basal areas of 93.4 cm^2, 77.1 cm^2 and 45.7 cm^2 respectively were obtained on Dandadi, Afaka and Anara soil series respectively.

Tab.II. - Correlation coefficient associating chemical characteristics with tree growth.

Soil Property/Tree Growth	Correlation Coefficient
Phosphorus content vs tree height	+ 0.70*
Phosphorus content vs basal area	+ 0.88*
Nitrogen content vs tree height	- 0.45
Nitrogen content vs basal area	- 0.33
Potassium content vs tree height	+ 0.29
Potassium content vs basal area	+ 0.31

* significant at the 0.01 level

Table II shows that soil available phosphorus is significantly and positively correlated with tree heights and basal areas while there is no significant correlation between nitrogen content and tree growth and between available potassium and tree growth parameters.

DISCUSSION

The results reveal that there is a marked gradation in available phosphorus contents of the three soil units. The highest phosphorus content is obtained in Dandadi soil unit while the lowest is obtained in Anara soil unit. These are equally reflected in the growth of pine in the three locations (Tab. I). These available phosphorus levels are still regarded as very low and extremely low respectively (BENJAMINSON, 1971). The result indicates that Anara soil mapping unit is not only limiting in soil depth but also very deficient in available phosphorus.

The positive correlation between the available phosphorus content of the soil and tree growth supported the findings of some authors such as JACKSON (1973), LAURIE (1974) and KADEBA (1978) that phosphorus fertilizer application has been very critical to the establishment, survival and growth of pines in different savanna zones of Nigeria. This effect could be atributable partly to the favourable influence of phosphorus on mycorrhizal structure formation. It should be noted that it is impossible to judge the growth potential of pine, unless and until it is certain that the site has become fully infected with suitable fungi and that the pine roots are freely forming mycorrhizal association.

Lack of significant correlation for nitrogen and potasium (Tab. II) indicates that there might not be positive response by pines to nitrogen and potassium fertilizer application on these soil units. However, there may be possibilities of fertility interactions important to tree growth that may exist among these nutrient elements.

From the findings of this study and within the limitations imposed by the paucity of available pine plots in the study area, soil available phosphorus status appears to be an important factor affecting growth of *Pinus caribaea* and could be used among other factors for prediction of growth of *Pinus caribaea* in well drained soils formed on the Basement Complex rocks of the Northern Guinea Savanna area of Nigeria. However, it should be noted that some difficulties in using soil phosphorus status to estimate productivity may be encountered where soil depth becomes very crucial.

It should also be noted that throughout 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* in the Northern Guinea areas of Nigeria are directly attributed to inherent available soil phosphate status and this should be taken into consideration during establishment of pines in these areas. Fertilizer trials are required to define more precisely the role of phosphorus and other nutrients not yet studied in the growth rate and health of pine plantations in the Nigerian savannas.

CONCLUSION

The study on the effect of nitrogen, phosphorus and potassium on growth of seven-year old *Pinus caribaea* stands show significant correlation between tree growth and available phosphorus state of the soils. It was found that there was no significant correlation in the case of nitrogen and potassium in the study area. This preliminary study paves the way for more detailed investigations and fertilizer trials for forest establishment not only in the savanna areas of Nigeria but also in West African savannas.

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