EVALUATION OF SUITABLE SOIL TEXTURE FOR MAHOGANY (*KHAYA SENEGALENSIS*) PRODUCTION

I. Verinumbe

Department of Biological Sciences, Faculty of Science, University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria

Received December 1990

VERINUMBE, I. 1993. Evaluation of suitable soil texture for mahogany (*Khaya senegalensis*) production. Effects of the principal textural components (sand, silt, clay) of semi-arid soil on the performance of potted mahogany (*Khaya senegalensis*) seedlings were investigated in northeastern Nigeria. Quadratic regression equations for each of the three textural components adequately modelled the relationship between percent content of each soil textural component and species performance. The three equations identified silt as the most important textural factor whose proportion in the soil determined mahogany seedling performance. It is predicted that the soils in which mahogany seedlings would perform best would contain approximately 50% sand, 10% silt and 40% clay. Soil containing lower or higher levels of these textural components would give lower yields. The identification of sandy clay soil as the best for mahogany seedling growth is expected to facilitate the process of selecting plantation sites and potting mixtures for the species, especially in semi-arid regions.

Key words: Growth - mahogany - seedling - sand - silt - clay

VERINUMBE, I. 1993. Penilaian tekstur tanah yang sesuai untuk penanam mahogani (*Khaya senegalensis*). Kesan-kesan komponen tekstur utama (pasir, kelodak, tanah liat) tanah semi-kersang ke atas prestasi anak benih tabungan mahogani telah dikaji di Timur-laut Nigeria. Persamaan regressi kuadratik untuk setiap saru dari ketiga-tiga komponen tekstur dapat dibuat model perhubungan antara kandungan peratus setiap komponen tekstur tanah dan prestasi spesies. Ketiga-tiga persamaan mengenalpasti kelodak sebagai faktor tekstur yang terpenting di mana kadarnya di dalam tanah menentukan prestasi anak benih mahogani. Adalah diramalkan anak benih mahogani akan memberi prestasi paling baik di tanah-tanah yang mengandungi 50% pasir, 10% kelodak dan 40% tanah liat. Tanah yang mengandungi tekstur komponen-komponen ini pada paras yang lebih rendah atau lebih tinggi akan memberi hasil yang rendah. Penentuan tanah liat berpasir sebagai tanah yang terbaik untuk pembesaran anak benih dijangkakan akan membantu proses pemilihan tapak-tapak ladang dan campuran tanah untuk penabungan spesies ini terutama sekali di kawasan-kawasan semi-kersang.

Introduction

Demand for wood in the sub-Sahara is increasing very rapidly. Jackson and Ojo (1971) indicated that the demand can only be met if there is a considerable increase in production. Such production increase requires an improvement in the productivity of existing forest sites, the expansion of community forest woodlands, and the establishment of plantations of fast-growing species. The introduction of new species to new sites requires the successful prediction of the productive potential of the soil of the site in question if wastage of resources arising from incorrect selection of sites is to be avoided. Forecasting wood production requires adequate knowledge about the relationship between soil productivity and growth of trees.

Soil productivity is principally a function of soil chemical and physical properties. While soil chemical properties can easily be improved through addition of fertilisers, physical properties are difficult to alter by such simple means. Indeed, Lal (unpublished) confirmed that inadequate soil physical properties can result in crop failure in some instances, even if chemical properties are favourable. Adequate knowledge of soil physical properties in relation to performance of species is therefore required for successful matching of species with sites. The present study was undertaken to define such soil texture-tree growth relationships for semi-arid tropical regions in Nigeria.

The objective was to quantify the influence of proportions of sand, silt and clay in soil on the germination and early growth of mahogany (*Khaya senegalensis*), and to define the optimum levels of sand, silt and clay required to give maximum germination and growth of this species. Mahogany was chosen as a test tree because of its importance as a timber, medicinal and fodder species in the region.

Materials and methods

Soils (0.30 *cm* depth) were sampled from five sites located on predominantly Vertisols and Entisols in the semi-arid region of northeastern Nigeria. The soils were analysed for sand, silt and clay content employing the hydrometer method (Day 1965). From results of the analysis, five soil textural classes were identified (sandy clay loam, sandy loam, loamy sand, clay and sand) using the soil textural triangle devised by the United States Department of Agriculture (Brandy 1974).

Each of the five soil treatments was replicated eight times in medium size polythene pots and sown with mahogany seeds at the rate of five seeds per pot. After germination the seedlings were thinned to one per pot. To eliminate effects of nutrient deficiencies, adequate levels of N (as urea), P (as single superphosphate) and K (as muriate of potash) fertilisers were applied two weeks after seed germination. The rates of application were equivalent to 60 kg N ha^{1}, 75 kg P ha^{-1} and 75 kg K ha^{-1} identified as being the optimum fertiliser requirements of mahogany on the soils in the region (Verinumbe unpublished). All the plants were adequately watered uniformly twice daily in the morning and evening throughout the study period.

Daily seed germination counts were recorded and plant height were measured weekly for 12 weeks. Total aerial portions of the seedlings were harvested after 12 weeks growth and dry matter yields determined after oven drying to a constant weight at 70°*C*.

For each of the five soil treatments, germination rate was obtained from a linear regression of the number of germinants over the number of days after sowing. The resultant slope of the regression was the estimate for germination rate. Similarly, the slope of the regression of plant height (*cm*) over plant age (weeks) was substantiated by considerably high and statistically significant ($p<0.05$) correlation coefficient values obtained from the regressions, with R^2 values ranging from 70 to 90% in all cases.

To identify the relative influence of sand, silt and clay on the performance rates of mahogany, the percent proportions of each textural component from all five soil treatments were partitioned and related to the respective data for plant performance rates in quadratic regression analyses. Use of the quandratic model was necessitated by both the distribution of points in a scatter diagram and by the need to use a model that would allow derivation of maximum response levels for the textural components. The three resultant models (one for each textural component) were maximised and solved to obtain the optimum levels of sand, silt and clay in soil that gave the maximum germination rate and early growth rate of mahogany.

Results and discussions

Data from the soil textural analysis for the five soil treatments indicated that sand contents ranged from 21.5 to 91.5%, silt from 2.5 to 12.5% and clay from 6.0 to 68.5% (Table 1). Regression equations of sand, silt and clay contents against mahogany seedlings performance rates are given in Table 2.

The results identified silt as the most important soil texture component determining mahogany germination rate and initial seedling growth rate. This was indicated by the very high R^2 values and regression coefficients (b) associated with silt. The R^2 values which ranged from 40 to 78% indicate that on average, 61 ± 24% of all variations in the performance rate of mahogany (germination rate, height growth rate and yield at 12 weeks) were caused by differences in silt content. The parameter most influenced by silt was the final height of seedlings, followed by germination rate, height growth rate and aerial dry matter yield.

Clay, with associated R^2 values ranging from 35 to 46%, had a mean R^2 value of 42 ± 4% and ranked next to silt in influencing mahogany seedling performance rate. The seedling parameter most affected by clay was aerial dry matter yield, followed by

Table 1. Soil textural composition and the performance rates of mahogany seedlings

	Textural composition			Mahogany seedling performance					
Soil treatment	Sand	Silt	Clay	Germination per day		Final plant ht. *cm*/plant	Biomass *g*/plant	Growth Coefficient *cm*/plant/*wk*	
A	91.5	2.5	6.0	7.85	(.70)	13.45	0.464	0.904	(.93)
B	21.5	10.0	68.5	15.71	(.87)	14.85	0.505	0.980	(.99)
C	69.0	12.5	18.5	11.99	(.94)	13.80	0.673	1.036	(.98)
D	81.5	7.5	11.0	21.62	(.99)	18.95	0.973	1.326	(.99)
E	66.5	5.0	28.5	25.99	(.94)	17.20	0.900	1.265	(.99)

( ) indicate R^2 values for the linear regression coefficients.

Table 2. Results of quadratic regression ($y=a+bx-cx^2$)* analyses of sand, silt and clay concentrations against the germination rate, growth rate, and biomass of mahogany trees

Textural component	Regression component	Values of regression equations: Germination rate (germinants/day)	Height growth rate (*cm*/week)	Height at 12 weeks (*cm*/plant)	Aerial yield at 12 weeks (g/plant)
Sand	a	- 3.77	0.57	11.90	- 0.08
	b	0.96	0.02	0.16	0.03
	c	- 0.01	- 0.000202	- 0.00142	- 0.00279
	R^2	0.36	0.38	0.11	0.51
Silt	a	- 5.40	0.60	8.42	0.16
	b	7.67	0.17	2.58	0.19
	c	- 0.52	- 0.01	- 0.18	- 0.01
	R^2	0.69	0.55	0.78	0.40
Clay	a	4.97	0.92	14.29	0.47
	b	0.99	0.02	0.14	0.02
	c	- 0.01	- 0.000262	- 0.00186	- 0.000356
	R^2	0.45	0.35	0.40	0.46

y = mahogany performance; a = intercept; b and c = regression coefficients; x = levels of sand, silt or clay; R^2 = correlation coefficient

germination rate, final height and growth rate. With R^2 values of between 11 and 51% and with a mean R^2 value of 34 ± 14%, sand was the least important of the principal soil textural component that influenced the performance of mahogany seedlings in this experiment.

In Table 3 the optimum levels of sand, silt and clay in soil required to give maximum germination and early growth rates of mahogany are given. Increases in sand, silt or clay proportions in the soil would result in improved seedling growth until the predicted optimum is reached, after which any further increase will result in a considerable decrease in the rate of seedling growth. As percent proportions were used, the total values in each column of Tabled 3 should add up to 100%. The small deviations from 100% recorded might have resulted from the use of a mathematical model (quadratic model) to estimate a purely biological phenomenon (growth) in which such optimum values fall within a narrow range and can deviate somewhat from the mean.

From the result of this pot experiment, the ideal soil for optimum mahogany germination and early growth rates is predicted to contain 50% sand, 10% silt and 40% clay (sandy clay soil). It is thus recommended that sites with sandy clay soil be selected for conversion to mahogany plantations. The general performance of mahogany seedlings on any site may also be predicted using the result of this study if the sand, silt and clay content of the soil is known. However, the results are most relevant for forest nurseries where it is recommended that a mixture of sand, silt and

Table 3. The proportions of sand, silt and clay content of soil required to give maximum germination, growth and yield of mahogany

	Optimum percentage proportion of sand, silt and clay				
Textural Component	Germination	Growth rate	Plant height	Yield	Total mean performance
Sand	48.00	49.50	56.34	53.76	51.90
Silt	7.38	8.50	7.17	9.50	8.14
Clay	49.50	38.17	37.63	28.09	38.35
Total	104.88	96.17	101.14	91.35	98.39

clay in 5:1:4 proportions be used to give maximum germination and initial growth of mahogany seedlings.

References

BRANDY, N.C. 1974. *The Nature and Properties of Soils.* Eighth Edition. Macmillan Publishers, London.

DAY, P.R. 1965. Hydrometer method of particle size analysis. Part 1 in Methods of Soils Analysis. *Agronomy Monograph* 9: 562-567.

JACKSON, J.K. & OJO, G.O.A. 1971. Productivity of natural woodland and plantations in the savanna zones of Nigeria. *Nigerian Journal of Forestry* 1(2): 57-60.

LAL, R. Modification of soil fertility characteristics by management of soil physical properties. (Unpublished).

VERINUMBE, I. Fertiliser response of mahogany (*Khaya senegalensis*) seedlings on a semiarid soil in Nigeria. (Unpublished).