EFFECT OF LIMING AN ULTISOL FOR THE ESTABLISHMENT OF A TROPICAL HARDWOOD IN SOUTHERN NIGERIA

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ALUKO, A. P. 1990. Effect of liming an ultisol for the establishment of a tropical hardwood in southern Nigeria. A soil culture experiment was set up in the greenhouse to evaluate the response of *Terminalia superba* Engl. and Diels (afara) to different pH levels through liming for plantation establishment. An acidic soil (ultisol) collected from Sapoba Forest Reserve in southwestern Nigeria was used.

The results indicated that optimum growth and total dry matter yields were obtained when the soil pH was between 5.9 and 6.1. Depressed growth and yields occurred at low and high pH. The effective cation exchange capacity (CEC) and exchangeable Ca in the soil increased significantly (P=0.05) with increasing lime addition while Mg, K, Na, Mn, and exchangeable Al+H decreased. Highest nutrient concentrations in the leaves of the plants occurred between pH of 5.7 and 6.1 for P, 6.3 and 6.5 for Ca, 5.9 and 6.5 for K and between 6.0 and 6.5 for Mg.

Key words: *Terminalia superba* - growth response - nutrient uptake - ultisol - pH - liming

Introduction

Terminalia superba Engl. and Diels (afara) is a tropical hardwood indigenous to Nigeria. The species is being planted in southern Nigeria for afforestation purposes. Research conducted so far on the establishment and growth of the species indicated growth failures at the seedlings stage. This has been attributed to soil variations. *T. superba* has been found to be sensitive to low pH due to application of $(NH_4)_2SO_4$ fertiliser which releases H^+ and SO_4^{2-} from the fertiliser to soil solution (Aluko 1982).

The 'acid' soils of Sapoba in Bendel State of southern Nigeria grouped as ultisol (Aurbert & Tavenier 1972) support tree crops which are of high economic importance. The soil of Sapoba is dominated by kaolinite and sesquioxide clay minerals; it is highly leached with low buffering capacity and base saturation, deficient in the exchangeable bases and high in exchangeable acidity. Liming is a common practice most often used in the control of soil acidity. Liming acid soils enhances the availability and plant uptake of elements such as P, Mg and Ca and reduces toxic concentrations of Fe, Al and Mn. Davison and Jefferies (1966) found that liming in combination with mineral fertiliser application resulted in very high response in the growth of plants. The critical factor for crop growth lies in the use of well balanced nutrient application in addition to liming (Fare & Okigbo 1973). Studies reported here were carried out to find out the effect of liming an ultisol on the performance of *T. superba*, its nutrient uptake, and soil chemical properties for plantation establishment.

Materials and methods

Bulk top soil samples (ultisol) were collected from Sapoba Forest Reserve, southwestern Nigeria. The sample, air dried and sieved (2 *mm* sieve) to remove roots and stones, was used for the greenhouse experiment. The soil contained 87.8% sand, 9.2% clay and 3.0% silt as determined by the hydrometer method (Bouyoucos 1962). The chemical composition of the sample used for the experiment was as follows: pH 4.6 (H_2O); pH 4.0 ($CaCl_2$); organic matter 1.28%; total N 0.09%; available P (Bray-1) 6.0 ppm; ammonium-acetate extractable Ca, Mg, K, Na and ECEC were 1.35, 0.62, 0.16, 0.03 and 2.92 *me* 100 g^1 soil, respectively; exchangeable acidity and aluminum were 0.76 and 3.59 *me* 100 g^1 of soil respectively. Six *kg* of the sieved soil was weighed into plastic buckets with drainage holes at the bottom. The soil in each bucket was limed with 0, 3.0, 6.0, 9.0, 12.0 and 15.0 *g* of Ca $(OH)_2$, watered to field capacity and incubated for three weeks to give predetermined pH values of 4.6, 5.7, 5.5, 6.1, 6.5 and 7.2. The lime levels are referred to as L_0 to L_5.

Seeds of *T. superba* were collected from a single tree and pregerminated in sterilised soils. At six weeks, seedlings of near uniform height were selected at the four leaf stage and transplanted into the limed soils. Essential elements such as N, P, Ca, Mg, Cu, Zu, B and Mo were supplied as basal dressing at the rates of 100 ppm N, 50 ppm P, 50 ppm K, 25 ppm Ca, 25 ppm Mg, 5 ppm Fe, 5 ppm Mn, 5 ppm Cu, 5 ppm Zn, 0.54 ppm B and 0.5 ppm Mo. The plants were irrigated with a known volume of deionized water, determined from the calculated FMC and added when necessary to the buckets. The seedlings were allowed to grow for six months. After height and stem diameter measurements, the leaves, stems and roots were harvested separately, washed and dried in an oven at 65°*C* until constant dry weights were obtained. The weights of the leaves, stems and roots were added together to obtain the total dry matter yield. The harvested parts were ground to pass through 1 *mm* sieve prior to chemical analyses. At the end of six months, sample of soil was taken per pot and air dried for chemical analyses. Soil pH was measured in water and 0.01 M $CaCl_2$ suspension using a pH meter; the organic matter was determined by the wet oxidation methods of Walkley and Black (1934); available P was extracted by the Bray and Kurtz (1945) extraction method. Exchangeable cations were extracted using 1 N neutral NH_4 OAC solution (Chapman 1965), with K and Na determined using flame photometry, Ca and Mg by atomic absorption spectrophotometry. Exchangeable acidity and aluminium after extraction with 1 N HCl was determined by the method described by MacLean (1965). Effective cation exchange capacity (CEC) was obtained by the summation of the exchangeable cations, exchangeable Fe and Mn were determined by atomic absorption spectrophotometer after extraction with 1 N neutral NH_4OAC. Extracts of the ground leaves were prepared by wet ashing using a mixture of nitric acid and perchloric acids for the determinations of P by Vanado molybdate method of Barton (1948); K by flame photometer and Ca, Mg, Fe and Mn by Perkin Elmer atomic absorption spectrophotometer.

Results

Total dry matter yield and plant growth

The total dry matter yield increased significantly (P=0.05) as soil pH increased from 4.6 to 6.1 (Figure 1). The maximum yield obtained at pH 6.1 represented an increase of 86.3% over the control. Lime application beyond pH 6.5 markedly reduced the total dry matter yield. Liming to pH 7.2 resulted in a yield of 59.3% below the maximum. Plant height increased significantly (P=0.05) with liming from pH 4.6 to 5.9 representing an increase of 55.5% when compared to the unlimed plants. Further increase in pH depressed plant height (Figure 2). There was no significant difference in stem diameter when the pH of the soil was raised from 4.6 to 5.7 (Figure 3). However, raising the pH up to 6.2 significantly (P=0.05) increased the stem diameter by 72.2% over the control. Significant (P=0.05) depression in plant height and stem diameter occurred when the soil was limed to pH 7.2. The values obtained were significantly lower (P=0.05) than the control treatment at pH 4.6.

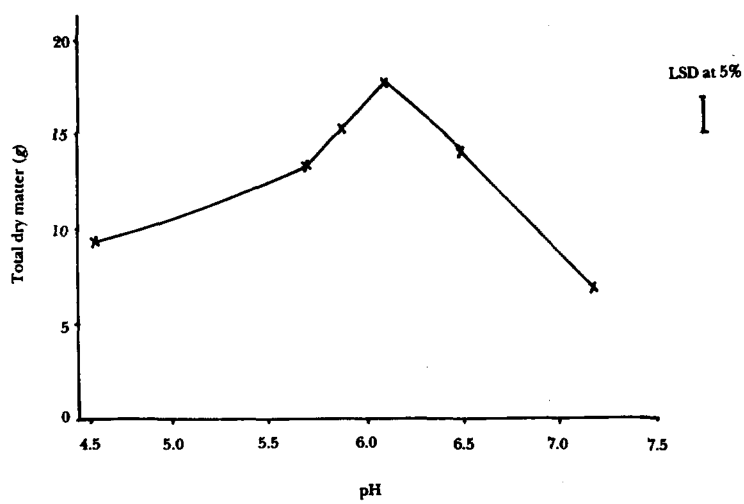

Figure 1. Effect of liming on the total dry matter yield of *Terminalia superba* at the end of 6 *mth* of growth

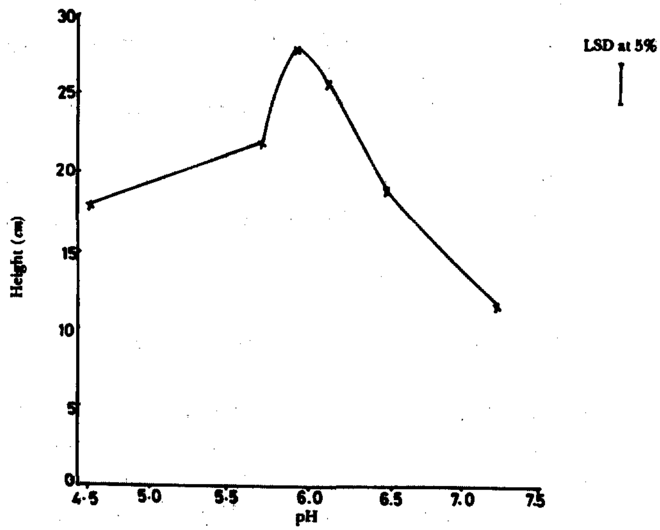

Figure 2. Effect of liming on plant height of *Terminalia superba* at the end of 6 *mth* of growth

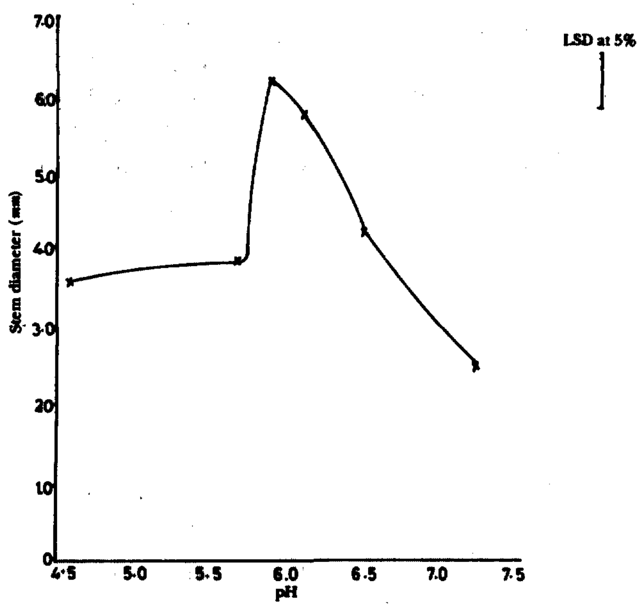

Figure 3. Effect of liming on stem diameter of *Terminalia superba* at the end of 6 *mth* of growth

Leaf - P, K, Ca and Mg

A non-significant increase in P concentration in the leaves of *T. superba* was obtained as pH increased to 6.1. Increasing pH beyond this level decreased P concentration. The effect was not significant at 5% level (Figure 4). Low concentrations of K, Ca and Mg were obtained at low and high pH levels. Optimum concentrations occurred at pH between 6.3 and 6.5 for Ca, 5.9 and 6.5 for K, 6.0 and 6.5 for Mg (Figure 5).

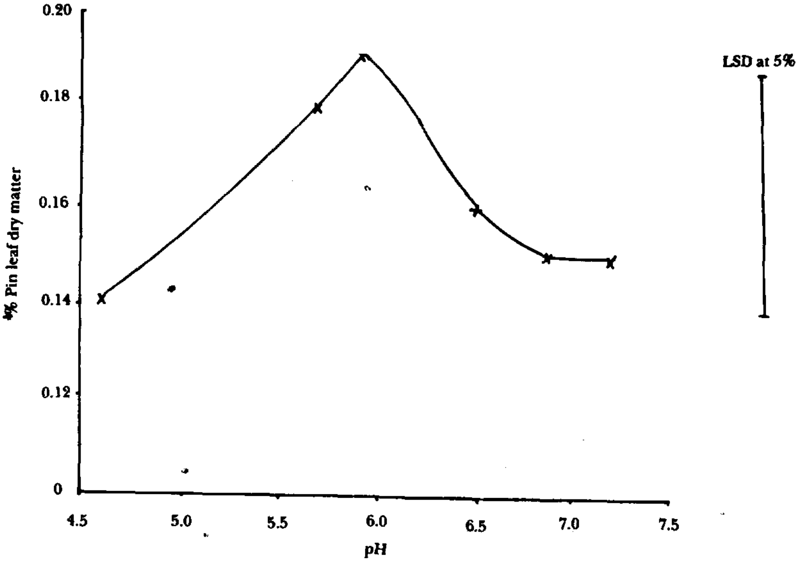

Figure 4. Effect of liming on concentration of P in the tissue of *Terminalia superba* at the end of 6 *mth*

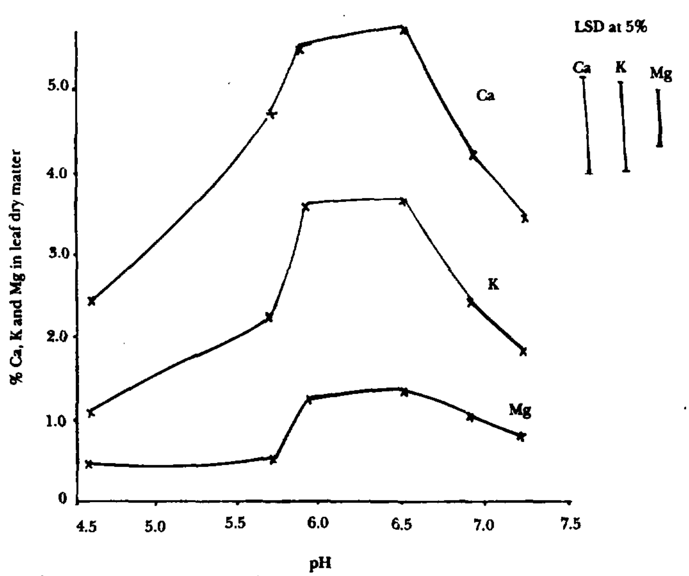

Figure 5. The effect of liming on concentrations of Ca, K and Mg in the tissue of *Terminalia superba* at the end of 6 *mth*

Leaf - Fe and Mn

The tissue concentrations of Fe and Mn decreased significantly (P=0.05) with increasing application of lime (pH 4.6 to 5.9), representing a decrease of 14.7 and 36.7% respectively when compared to the control. Significant decrease in concentration (P=0.05) was, however, observed between pH 5.9 and 7.2 (Figure 6). This represented a decrease of 32.2 and 10% over the control.

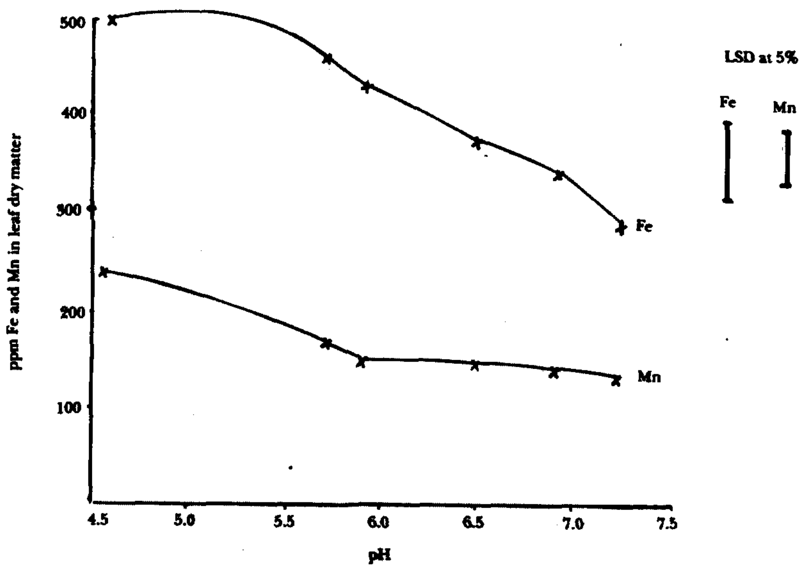

Figure 6. The effect of liming on concentrations of Fe and Mn in the tissue of *Terminalia superba* at the end of 6 *mth*

Soil chemical composition

The effects of liming on available P, effective CEC and the distribution of exchangeable cations of the soil after harvesting is shown in Table 1. A non-significant decrease in available P (P=0.05) was obtained as pH increased from 4.6 to 6.5. A significant (P=0.05) reduction was observed at pH 7.2. Non-significant reductions (P=0.05) in the exchangeable Mg, K and Na were observed with increasing pH (pH 4.6 to 7.2). At pH 7.2 however, significant reduction in exchangeable Mg was obtained when compared to the control. Increasing soil pH significantly (P=0.05) reduced the exchangeable Fe and Mn in the soil. A decrease of 50 and 21.7% of exchangeable Mn and Fe was obtained when raising soil pH from 4.6 to 7.2.

Table 1. Effect of liming on P, ECEC and exchangeable cations at the end of 6 *mth* growth of *Terminalia superba*

Treatment lime level	pH H_2O	Available P (ppm)	Exchangeable Al+H	Ca	Mg	K	Na	ECEC	Mn	Fe
			(*me* 100 g^1 soil)						(ppm)	
L_0	4.6	6.0	4.35	1.35	0.62	0.16	0.03	2.92	26	138
L_1	5.7	5.8	1.20	4.52	1.60	0.09	0.02	6.44	19	119
L_2	5.9	5.8	0.29	6.26	1.58	0.06	0.02	7.99	16	114
L_3	6.5	5.7	0.11	7.40	1.52	0.05	0.01	9.03	15	110
L_4	6.9	5.6	0.02	8.10	1.48	0.04	0.01	9.65	13	110
L_5	7.2	5.4	0.03	9.12	1.40	0.04	0.01	10.62	13	108
Mean		5.7	1.0	6.12	1.37	0.07	0.02	7.8	17.0	116.5
SE±		0.18	0.53	0.69	0.25	0.09	0.03	0.68	0.91	1.37
LSD at 5%		0.47	1.37	1.76	0.64	0.23	0.09	1.74	2.3	3.5
CV%		3.6	17.0	46.1	52.2	63.1	48.9	35.7	29.0	9.6

Discussion

The improved growth obtained between pH levels of 5.9 and 6.2 may probably be due to direct nutritive and regulatory action of the nutrients like P, Ca and Mg and the neutralization of compounds of Fe, Al and Mn which under acid conditions are likely to be present in toxic quantities. In maize, maximum yield was obtained at pH 6.2 while liming an ultisol to pH 7.1 resulted in a yield 42% below the maximum (Juo & Uzu 1977). The yield in maize declined when high lime rates were applied (Heylar & Anderson 1974).

Maximum uptake of P by the plant occurred at pH 5.9. Liming the soil to pH values above this level apparently increased fixation of P through precipitation as calcium phosphate (Kamprath 1971). Jensen (1970) reported also that high Ca concentration favours phosphate absorption. At high application of lime to an ultisol of Sapoba, the uptake of K, Mg, Fe and Mn were reduced. Ultisols, derived from acidic parent materials generally have large pH-dependent charge. This may drastically alter the cationic exchange equilibrium and affect the solubility of other cations (Juo & Uzu 1977). The increase in effective CEC and exchangeable Ca and decrease in Mg, K and Na may be a result of increased absorption of the cations associated with increase in CEC. The reduction in exchangeable Mg in the soil at high pH may probably be due to the formation of $MgAl(OH)_5$ which is unlikely at low pH values (Hunsaker & Pratt 1970). The decrease in exchangeable Al and Mn are in accordance with the effect of pH on solubility of Al hydroxides and oxidation of divalent Mn (Coleman & Thomas 1967).

The results of the present investigation show that low and high pH affected the availability of P, K, Ca, Mg, Fe and Mn which are required for plant growth.

Low and high pH depressed the growth of *T. superba*. In order to ensure optimum plant performance in terms of growth and dry matter accumulation, availability of nutrients for plant uptake at Sapoba, the soil should be amended by liming to pH ranges between 5.7 and 6.5.

Acknowledgements

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