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EFFECT OF LIME ON SOIL PROPERTIES, N NUTRITION AND NUTRIENT UPTAKE OF MAIZE IN SOME NIGERIAN SOILS

M.T. ADETUNJI and F.O. BAMIRO
Department of Soil Science and Agricultural Mechanisation,
University of Agriculture, Abeokuta, Nigeria.

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ABSTRACT

Incubation and pot experiments were conducted to evaluate changes in soil properties due to liming and to determine the interaction effect of lime and N addition on maize growth and nutrient uptake in some Nigerian soils. Soil CEC, exchangeable Ca^{2+}, Olsen P, and available S increased significantly within the first 3 weeks of incubation while the exchangeable Mg^{2+} and K^{+} increased only slightly. Liming to pH 6.0 reduced Al^{3+} saturation to less than 5% and gave maximum nutrient uptake and dry matter yield. For every cmolc kg^{-1} of Al^{3+}, 1.88 g of lime kg^{-1} of soil was required to keep the pH and Al^{3+} saturation at optimum levels for efficient nutrient utilization by maize. The interaction between N and lime was positive and significant. However, lime addition had greater influence on P and S uptake than on N addition while N addition had grater influence on N and K uptake of maize.

***Key Words*: Aluminium saturation, liming, nutrient uptake.**

RÉSUMÉ

En vue d'évaluer les changements de propriétés du sol suite à un apport extérieur de chaux et de déterminer l'effet de l' interaction chaux-azote sur la croisssance du maïs et la prise de nutriments dans certains sols nigérians, des essais d'incubation en pots ont été effectués. Le CEC du sol, (Ca^{2+} échangeables), Olsen P, et le S disponible ont augmenté de façon significative, les 3 premières semaines de l'incubation alors que Mg^{2+} et K^{+} échangeables out subi une augmentation légère. L'apport de chaux à un pH de 6 a provoqué une réduction de la saturation en Al^{3+} à une valeur <5% et induit le maximum de prise de nutriments et un surplus en matière sèche. Pour maintenir le pH, la saturation du sol en Al^{3+}, à son niveau de rendement optimum, pour une utilisation efficiente des nutriments par le maïs, il fallu 1.88 g de chaux/kg pour chaque cmol kg^{-1} de Al^{3+}. L'interaction azote chaux était positive et significante. Cependant l'apport de chaux a démontré une influence plus grande sur la prise de P et de S comparativement à l'apport d'azote alors que l'apport azoté a eu une plus grande influence sur la prise d'azote et de K par le maïs.

***Mots Clés:* Saturation en aluminium, appport de chaux, prise de nutriments.**

INTRODUCTION

Many Ultisols in South Western Nigeria have low organic matter and low total N content. Clay mineralogy is predominantly kaolinitic. These, coupled with the coarse texture confer on the soils low capacity to hold nutrients against leaching. Because the soils are located in the high rainfall area, they are strongly leached and deprived of basic cations and N. Consequently, they are acidic with soil pH generally below 5.0 and rarely exceeding 4.7. For intensive and continuous crop production on these soils, liming is necessary. Lime is scare in the country and fairly expensive for small holder farmers. This calls for judicious and economic use of lime. Unfortunately, the data base for determination of lime requirement is still sketchy. Earlier work (Kamprath, 1970; Juo and Kamprath, 1979) has shown that liming to a pH that gives optimum fertilizer efficiency, nutrient uptake, and Al^{3+} saturation should be the basis for LR measurements in these soils. That pH level has not been defined for most Nigerian soils.

This study was conducted to examine the lime rate that would give favourable soil chemical properties, fertilizer use efficiency and low Al^{3+} saturation for optimum growth of maize.

MATERIALS AND METHODS

In a preminary study, soil samples (0–15 cm depth) from 10 locations in South Western Nigeria were selected to give soil pH range of between 4.25 and 5.00. The soil samples were air-dried and sieved to pass through 2 mm sieve. The quantities of lime required (LR) to bring soil pH to about 5.5 (L_1), 6.0 (L_2), 6.5 (L_3) and 7.0 (L_4) were determined for each soil in the laboratory after 8 weeks of incubation using reagent grade $CaCO_3$. Five kg samples were taken from each of the 10 soils. Five rates of lime were applied as L_0 (no lime), L_1 (L.R to pH 5.5), L_2 (L.R to pH 6.0), L_3 (L.R to pH 6.5) and L_4 (L.R to pH 7.0) as determined in the preliminary study. The limed samples were mixed thoroughly in plastic pots and incubated at field capacity (moisture %) for four different period of 3, 6, 9 and 12 weeks. After each incubated period the samples were analysed for some soil chemical properties. Organic matter was determined using the method of Walkley and Black (1934). Total N was determined by the Kjeldhal procedure. Available P was extracted using Olsen solution and determined colorimetrically by the molybdenum blue method. Soil pH was measured in 1:1 Soil:Water slurry with a glass electrode. Sulphate-Sulphur was determined turbidimetrically. Exchangeable K^+, Ca^{2+} and Mg^{2+} were determined in the 1N NH_4OAc soil extract by flame photometry (K^+) and atomic absorption spectrophotometry (Ca^{2+} and Mg^{2+}). Potassium chloride extracted Al^{3+} was determined by titration using 0.1M NaOH.

In another experiment, 2 kg each of the 10 soils were transfered into pots; N as NH_4NO_3 was applied at three levels O mg N kg^{-1} (N0), 80 mg N kg^{-1} (N_1) and 120 mg N kg^{-1} (N_2). Lime was applied at five levels as in the first experiment (L_0, L_1, L_2, L_3, L_4). The soils were mixed thoroughly before planting. The treatments were replicated thrice in a completely randomised design. All treatments received initially 60 mg P kg^{-1} as $Na_2HPO_4.12H_2O$, 60 mg K kg^{-1} as KCl and 25 mg S kg^{-1} as $CaSO_4$. Maize (*Zea mays* L.) was planted at the rate of 3 seeds per pot and later thinned to 2 seedlings per pot. Two successive maize crops were grown each for 6 weeks. The whole plant tops were harvested, oven-dried at 70°C for 24 hr and weighed. The dried material was milled and digested with 1:1 H_2H_4 and $HClO_4$ mixture after predigestion with concentrated HNO_3.

The N in the digest was determined by the micro-Kjeldahl procedure, P by the molybdenum blue method, K^+ by the flame photometry, and the S by the trubidimetric method of Tabatabai (1974).

RESULTS AND DISCUSSION

The physico-chemical properties of the experimental soils are given in Table 1. The soils are low in total N, available P, and available S based on the critical concentrations established for maize in south Western Nigerian Soils. They are light in texture with clay content ranging from 4.8 to 30%. The mean lime requirement (LR) to raise the pH of the soils to 5.5, 6.0, 6.5 and 7.0 were 1.67, 2.00, 2.31 and 3.00 g kg^{-1}, respectively (Table 2). Significant relationships existed between the LR values and the clay content and between LR values and exchangeable Al^{3+} but the relationships between LR and other soil properties including pH and soil organic matter were insignificant.

It was observed that liming led to increase in Ca^{2+} saturation by 20% within the first 3 weeks and

TABLE 1. Some initial properties of the soil used (Ultisols)

Soil location	pH	N%	Organic matter %	Avail P mg kg^{-1}	Avail P mg kg^{-1}	Exchangeable cations C mol$_c$ kg^{-1} K^+	CA^{2+}	Mg^{2+}	Na^+	CEC	Al^{3+}	% Sand	% Silt	% Clay
Agunmona	4.85	0.102	1.63	8.9	4.4	0.15	1.6	0.52	0.10	3.8	0.65	84.2	7.8	8.0
Okunowa	4.90	0.146	1.82	12.6	7.5	0.23	2.3	0.29	0.06	9.6	2.20	60.5	9.2	30.3
Ado Odo	4.60	0.112	1.73	7.3	5.2	0.18	1.9	1.96	0.04	7.4	0.96	75.4	10.0	14.6
Ijebu Ode	4.65	0.064	1.25	4.9	4.1	0.32	2.4	1.15	0.07	6.2	1.01	88.7	6.5	4.8
Odeda	4.56	0.058	1.36	9.2	4.5	0.29	1.8	0.98	0.02	7.0	1.10	83.3	4.6	12.1
Ibadan	4.70	0.080	1.48	3.8	4.9	0.11	1.0	1.75	0.01	8.1	0.98	80.9	10.0	9.1
Ile-Ife	4.65	0.098	1.52	11.1	6.3	0.28	2.1	1.99	0.04	8.2	1.25	76.5	9.5	14.0
Oke-Ako	4.60	0.080	1.10	5.9	7.2	0.21	1.4	1.12	0.03	4.1	0.60	89.2	3.9	6.9
Irele	4.25	0.075	1.50	7.4	4.5	0.55	2.2	1.56	0.05	6.6	0.59	80.1	4.9	15.0
Ibodi	4.69	0.101	1.36	6.5	4.0	0.36	2.6	1.20	0.01	7.5	1.79	74.0	6.0	20.0

TABLE 2. Quantity of lime required (g $CaCO_3$ kg^{-1}) to attain pH 5.5, 6.0, 6.5 and 7.0 in some Nigerian soils

Soil location	pH 5.5 (L_1)	pH 6.0 (L_2)	pH 6.5 (L_3)	pH 7.0 (L_4)
Agunmona	1.0	1.2	1.5	1.9
Okunowa	2.6	2.8	3.8	4.5
Ado Odo	1.4	2.0	2.2	2.9
Ijebu Ode	1.6	1.8	2.0	2.6
Odeda	1.1	1.9	2.4	3.1
Ibadan	1.6	1.9	2.1	2.7
Ile-Ife	1.8	2.2	2.4	3.1
Oke-Ako	0.9	1.0	1.4	1.8
Irele	1.8	2.0	2.1	2.6
Ibodi	2.9	3.2	3.6	4.8

thereafter remained relatively constant (Table 3). There was no difference in liming to either pH 6.0, pH 6.5 or pH 7.0 in this respect. Available P and S, and CEC also increased significantly with liming within the first 6 weeks of incubation. Correspondigly, Al^{3+} saturation decreased to less than 5% within the first few weeks especially when the soil was limed to achieve pH 6.0 and above. The increase in Olsen P may have been consequent to the solubilisation of Al^{3+} which decreases its saturation and thereby reduces its capacity to fix P and S. The influence of lime on exchangeable K^+ and Mg^{2+} was insignificant while its influence on organic matter was not consistent but appeared to decrease with liming. This may be due to increased mineralisation of soil organic matter as suggested by Curtin and Smillie (1983).

The incubation experiment suggests liming to pH 6.0 to be optimal for it resulted in the most favourable agronomic soil conditions. This was further supported by the results of the pot experiment. The average dry matter yield as affected by N and lime treatments are shown in Table 4. All the soils responded significantly to N and lime application either singly or in combination.

The interaction between N and lime addition was positive and significant. While the dry matter yield increased by about 25% as a result of lime addition alone and about 50% due to N addition alone. Higher increases were recorded as a result of a combination of lime and N application than with either alone. This suggests a promotive effect of liming on N utilisation by plants. The yield depression often observed at near neutral pH levels (Faring et al., 1980) was not significant in this experiment.

TABLE 3. Mean changes in some properties as a result of liming to pH 6.0

		Periods of incubation in weeks			
Soil property	0	3	6	9	12
Exch. Ca^{2+} $cmol_c$ (Kg^{-1})	1.93	2.33	2.39	2.40	2.41
Exch. Mg^{2+} $cmol_c$ (Kg^{-1})	1.26	1.41	1.52	1.56	1.58
Exch. K^{+} $cmol_c$ (Kg^{-1})	0.27	0.29	0.30	0.29	0.32
Exch. Al^{3+} $cmol_c$ (Kg^{-1})	1.11	0.65	0.48	0.44	0.38
CEC $cmol_c$ (Kg^{-1})	6.9	9.5	10.7	10.9	10.8
Available P (mg kg^{-1})	7.8	9.7	10.6	11.2	11.6
Available S (mg kg^{-1})	5.3	7.3	8.1	9.3	9.9
Total N (%)	0.09	0.09	0.08	0.09	0.09

TABLE 4. Effect of lime and nitrogen treatments on maize dry matter yield (g pot^{-1}) (mean of two harvests)[a]

Treatment	Range	Mean
N_0L_0	5.0–8.4	6.02[a]
N_0L_1	4.5–9.2	6.86[ab]
N_0L_2	4.9–10.9	7.52[b]
N_0L_3	6.0–10.8	8.12[b]
N_0L_4	6.3–10.1	7.80[b]
N_1L_0	7.0–13.5	9.71[c]
N_1L_1	8.1–14.2	10.27[cd]
N_1L_2	8.8–14.8	11.04[de]
N_1L_3	8.8–14.6	11.33[e]
N_1L_4	8.8–14.2	11.50[e]
N_2L_0	9.5–14.0	11.65[ef]
N_2L_1	9.5–14.0	11.76[ef]
N_2L_2	10.8–14.5	12.63[f]
N_2L_3	10.5–14.8	12.90[f]
N_2L_4	10.5–16.7	12.42[f]

[a]Values followed by the same letter in a column are not significantly different at 5% level.

Application of lime increased the uptake of N markedly with or without N application (Table 5). Furthermore, differences in liming to pH 6.0, 6.5 and 7.0 were not significant indicating that liming to pH 6.0 is sufficient to correct the effect of soil acidity on crop performance in these soils as evidenced also in Table 4. It was also observed that the effect of lime on N uptake was more pronounced at higher N rates indicating that liming is especially important in these soils at high N rates than at low rates. This could be attributed to a compensation effect of liming on the acidity usually generated as a result of high N application, particularly in the form of ammoniacal N.

The uptake of K^+ was improved significantly with both lime and N addition but the effect of N application on K^+ uptake was more significant than that of lime alone. Combination of lime and N significantly enhanced the uptake of K^+, which is optium when the soil is limed to pH 6.0

TABLE 5. Effect of lime and nitrogen addition on nutrient uptake (mg pot^{-1}) by maize (mean of 10 soils)[a]

Treatment	Nitrogen	Phosphorus	Potassium	Sulphur
N_0L_0	10.0 a	6.5 a	15.0 a	7.0 a
N_0L_1	16.8 b	13.4 c	22.0 b	11.2 b
N_0L_2	20.0 c	15.2 cd	20.5 b	14.5 c
N_0L_3	20.6 c	16.0 d	21.6 b	16.8 d
N_0L_4	20.8 c	15.8 d	22.0 b	16.8 d
N_1L_0	21.6 c	9.8 b	35.4 c	8.4 a
N_1L_1	25.8 d	16.5 d	38.6 cd	13.5 c
N_1L_2	29.2 e	19.6 e	39.5 cd	17.2 d
N_1L_3	31.5 ef	21.3 efg	40.6 d	18.5 de
N_1L_4	32.3 f	22.4 fg	39.6 d	19.0 e
N_2L_0	24.6 d	9.6 b	39.6 d	8.8 a
N_2L_1	28.4 e	16.2 d	42.5 d	16.0 d
N_2L_2	31.5 ef	20.8 efg	40.0 d	19.0 e
N_2L_3	33.2 f	21.4 efg	42.0 d	19.5 e
N_2L_4	34.6 f	22.5 g	42.5 d	20.1 e

[a]Values followed by the same letter in a column are not significantly different at 5% level.

The uptake of P was greatly enhanced by liming and very little variation in these values was noticed due to N levels. However, the addtion of both lime and moderate level of N resulted in greater increases in P uptake than at higher N rates. This is consistent with the earlier observed solubilisation of Al^{3+} which minimises P adsorption and renders the nutrient more readily available for crop uptake. The same case appears to be true for the trend in S uptake.

In conclusion these experiments have shown that liming to pH 6.0 reduces Al^{3+} saturation to insignificant level and leads to increased efficiency of fertilizer utilisation by maize crops. Therefore, liming to pH 6.0 is suitable as the basis for assessing lime requirement in these soils and similar altisols in tropical areas.

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