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Effect of Lime and Phosphorus application on the sulphate Adsorption Capacity of South Western Nigerian Soils

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Abstract

The influence of phosphate and lime additions on the sulphate adsorption characteristics of some representative soils of South Western Nigeria was investigated in the laboratory. Preliminary studies revealed that the Lime Requirements (LR) of the soils varied from 1.6g/kg to 3.6g/kg, while the Standard Phosphorus Requirements (SPR) ranged from 80ppm to 185ppm. Lime and phosphate were added to the soil according to the LR And the SPR values. Reduction in sulphate adsorption varied from 20 to 31 % as a result of P addition alone and a more pronounced depression in sulphate adsorption was observed when lime alone was added. Adding both to soils the same time resulted in reduction of from 48 to 68% in sulphate adsorption capacity of soils. It was observed that the addition of lime and P did not only lower the adsorption of sulphate in soils but also caused the displacement of up to 70% of the adsorbed sulphate, suggesting high leaching losses of sulphur in soils receiving high phosphorous fertilizer application and the induced deficiency of sulphur in such soils.

Introduction

Sulphur as a yield limiting factor is becoming increasingly important in many Nigerian soils. Occurrence of S deficiency in various crops are becoming more frequent and extensive (Enwezor, 1976; Kang and Osiname, 1976; Kang et al., 1981, Adetunji and Adepetu, 1989). This could be attributed to the low S supplying capacity of these soils, continous and intensive cropping and the curent use of fertilizers which do not supply S. The movement, reactions and absorption of S by plants occur predominantly as sulphate. consequently, in attempting to determine S needs of crops or to indicate areas where the problem may arise, due consideration must be given to the behaviour of sulphate in soils. The behaviour of sulphate in soils predominantly involves sorptive and desorptive reacticns. Apart from soil factors that are very difficult to control, certain cultural practices such as liming and fertilizer phosphate application have been shown to profoundly affect these reactions, to the extent that the level of available S in a soil and the efficiency of applied S fertilizers are influenced by these management practices (Blair, 1979; Korentajer et al., 1983; Adetunji and Adepetu 1989). Presently, there is no information to establish a direct relationship between these common management factors and S adsorption in Nigerian soils. If such relationship is established, it would be useful for advisory service in planning lime and fertilizer practices.

The objective of this investigation was to determine the effect of liming and phosphate addition on the ability of South Western Nigerian Soils to absorb sulphate.

Materials and Methods

Surface (0-20cm) samples of soils collected from 5 locations (Ede, Ado Ekiti, Ibodi, Owode-Egba and Okitipupa) in south Western Nigeria were used in these studies. The soils have identical crop histories but differing properties and sulphur adsorption characteristics. some of the properties of the soils are listed in Table 1. The samples were air dried and passed through a 2mm sieve. The amount of lime. powdered reagent grade caCO3, needed to raise the pH of each soil to approximately 6.5 was estimated by incubating wet 50g sample with different concentrAtions of lime for 8 weeks. The estimated quantity for each soil formed the Li treatments in the sulphate adsorption studies.

In another preliminary study, the quantity of P required to achieve 0.2ppm solution concentration of P was determined for each soil. To a 5g soil sample, 50mL 0.01M CaCl2 solution containing graded concentration of P (2ppm to 500ppm) as K H2PO4 were added. Few drops of toluence were added to suppress microbial activity. The soils were then incubated at room temperature for 7 days. The samples were shaken daily for one hour. After seven days the solution phase was separated by centrifugation and the P content of the supernatant was determined colorimetrically by the molybdenum blue method. A P rate vs P in supernatant sloution curve was constructed for each soil and the amount of P needed to achieve 0.2ppm solution concentration was then estimated from the curves. The determined SPR formed the P1 treatments in the sulphate adsorption studies.

Ten gram soil each was weighed into a shaking bottle. To this the following treatments were applied: non lime check (Lo), Limed (Li), Plus P (P1) and minus P (Po) giving the main treatment combinations LoPo, LoP1, L1Po and L1P1. All the L1 subsamples were previously treated with Lime for 8 weeks, then air dried and sieved before they were used for the adsorption studies. To each treatment 50ml of K_2SO_4 solution of varying sulphur concentrations (2, 5, 10, 15, 20, 25, 50, 100, 150, and 200ppm S) were applied. Few drops of toluence were added to each bottle to inhibit microbial growth. The bottles were shaken twice daily for 7 days. The solution phase was then separated carefully by centrifugation for 5 minutes at 2,200rpm. 10ml aliquot of the supernatant was analysed for sulphate sulphur by the turbidimetric method of Chesnin and Yien (1951). The adsorbed sulphate was taken as the difference between sulphur in the supernatant solution and the sulpahte added. The soiul residues were then shaken with 50ml distilled water and the supernatant analysed for sulphate sulphsur. The amount of sulphate desorbed was then calculated.

Particle size analysis of the soils was determined by the hydrometer method (Bouyoucous, 1951). Soil pH was measured by glass electrodes in CaCl2 solution. Exchange acidity was determined by titration method (Page et al., 1982). Cation exchange capacity was by neutral potassium acetate saturation and neutral ammonium acetate displacement. K, Ca, Na and Mg were extracted using neutral 1 M ammonium acetate; K and Na were determined by flame photometer while Ca and Mg were determined using Atomic Absorption Spectrophometer, Perkin Elmer Model 420. Organic matter was determined by wet difestion of Walkey and Black (1935) as mofified by Piper (1942). Total nitrogen was determined by kjeldahl digestion and estimated by using Technicon auto analyser II. Phosphorous was extracted by Bray-1 procedure (Bray and Kurtz, 1945) and determined colorimetrically using molybdenum blue method. Free Fe and al oxides were extracted with Dithionite-Citrate-bicarbonate method (Jackson, 1962). The Fe content of the extract was determined colorimetrically using 1, 10 phenanthroline procedure. The free Al_2O_3 of the extract was also determined colorimetrically using the modified aluminon method. Available S was extracted with 0.01M $Ca(H_2PO_4)_2$ and determined by the turbidimetric procedue of Chesnin and Yien (1951) using B&L spectrometer at 420nm.

Results and Discussion

The properties of the soils used in this study are listed in Table 1. The soils, with the exception of Ibodi are light in texture suggesting high probability of nutrient leaching. They are generally low in available S ranging from as low as 3.8ppm at Ede a sandy loam soil of the Egbeda series to 10.4ppm at Ado Ekiti, a sandy clay loam soil of the Ondo series. They are slightly acid with pH ranging from 4.5 at Ibodi a clay loam soil of Itagunmodi series to 6.0 at Ede. The generally low clay, organic matter, and cation exchange capacity suggest low buffering capacity of these soils.

Effects of P Addition

Based on the critical level of 12-17ppm P suggested for maize in Nigerian soils (Okeya 1977; Udo, 1985) all the soils in this study are P deficient. Consequently the Standard P requirement (SPR) was determined for each soil. The SPR varied between soils from 80ppm in Ede to 185ppm in Ado Ekiti (Table 2). Addition of the quantity of P suggested by the SPR to the respective soils led to remarkable reductions in the sulphate adsorption capacities of the soils. The average reduction (Table 3) of between 20 - 31% was observed. This is clearly depicted in the sulphate adsorption isotherms shown in figures, 1 to 5. From the isotherms it could be inferred that the decrease in adsorption is proportional to the adsorption capacity of the soils. The higher the adsorption capacity the higher the depression as shown on the curves. A soil like Ibodi which adsorbs sulphate strongly, that should hold S firmly against leaching loss is evenmore vulnerable to reduction in adsorption than those that adsorb less sulphate, The desorption of the adsorbed sulphate by water showed that in the phosphate treated soils as much as 70% of the adsorbed sulphate was removed by a single washing with water (Table 3), where as only about 44% of the adsorbed sulphate was removed in the untreated soils. This shows that the addition of phospahte, not only lowers the adsorption of sulphate in soils, it also causes the displacement of the little adsorbed sulphate. Once the sulphate ions are desorbed from the soil surface or the capacity of the soil surface to adsorb S is decreased, the desorbed sulphate ions from the surface enters the soil solution and can be easily leached. Phosphate is able to influence sulphate adsorption in this way, becuase the same sites may be involved in the adsorption of the two anions on soil surfaces (Parfit, 1978; Rajan, 1978). However, phosphate is more strongly adsorbed than sulphate (Hingston et al., 1972; Barrow, 1967) and is adsorbed in larger amounts than sulphate (Marsh et al., 1987). consequently, phosphate easily displaces sulphate from the adsorption sites. In the present study, this behaviour is found to be unrelated to the soil properties (Table 4), indicating that irrespective of pH, organic matter, Fe_2O_3 contents of soils, the addition of phosphate led to the replacement of a large amount of sulphate on the adsorption sites and

TABLE 1. PROPERTIES OF THE EXPERIMENTAL SOILS

Properties	Ede	Ado-Ekiti	Ibodi	Owode-Egba	Okitipupa
Exch. K Meq/100q	0.39	0.26	0.21	0.27	0.30
Exch. -Mg Meq/100g	1.76	0.96	0.96	1.42	0.68
Exch. Ca Meq/100g	3.52	2.00	2.81	3.04	1.82
Exch. Na Meq/100g	0.08	0.08	0.03	0.02	0.05
Exch. Acidity Meq/100g	0.18	0.20	0.22	0.18	0.18
Exch. CEC Meq/100g	11.5	8.60	6.10	5.8	4.80
Available P ppm	14.2	10.8	3.2	12.4	10.4
Available S ppm	3.8	10.4	9.8	5.5	6.2
Total N %	0.095	0.112	0.140	0.098	0.096
Organic matter %	1.60	3.17	2.93	2.98	2.90
pH ($CaCL_2$)	6.0	5.4	4.6	5.5	4.8
Sand %	79.2	65.0	48.5	74.6	74.8
Silt %	8.0	12.6	16.9	10.2	8.7
Clay %	12.8	22.4	34.6	15.2	16.5
Free Fe_2O_3	2.1	4.8	4.9	1.4	5.8
Free Al_2O_3 %	1.1	2.4	2.4	1.1	2.1
Texture	Sandy Loam	Sandy Clay-Loam	Clay Loam	Sandy Loam	Sandy Loam

TABLE 2. SPR AND LR REQUIREMENTS OF THE SOILS

	Ede	Ado Ekiti	Ibodi	Owode-Egba	Okitipupa
SPR (ppm)	80	185	158	125	175
LR (g/kg)	1.6	2.8	3.6	2.5	2.0

TABLE 3. MEAN PERCENT REDUCTION IN S ADSORPTION AS A RESULT OF PHOSPHATE AND LIME ADDITION.

	Phosphate only		Lime only		Lime + Phosphate	
Soil	% Reduction	% Desorption	% Reduction	% Desorption	% Reduction	% Desorption
Ede	20	58	24	65	48	54
Ado Ekiti	31	72	34	70	55	68
Ibodi	25	68	46	76	64	70
Owode Egba	29	65	29	60	53	70
Okiti Pupa	27	72	46	68	62	62

TABLE 4. CORRELATION BETWEEN SOME SOIL PROPERTIES AND PERCENT REDUCTION IN SULPHUR ADSORPTION AS A RESULT OF LIME AND P ADDITION

Soil property	Plus P minus Lime (P_1Lo)	Minus P plus Lime (PoLi)	Plus P, plus Lime (P_1L_1)	L.R.
Organic matter	0.629	0.583	0.631	0.661
Free Fe_2O_3	0.144	0.752	0.671	0.344
Free Al_2O_3	0.165	0.791**	0.771*	0.643
Clay	-0.169	0.651	0.925**	0.931**
pH	0.185	-0.973**	-0.990**	-0.649
SPR	0.505	0.749	0.734	0.532

* **Significant at 5% probability level.**

** **Signigicant at 1% probability level**

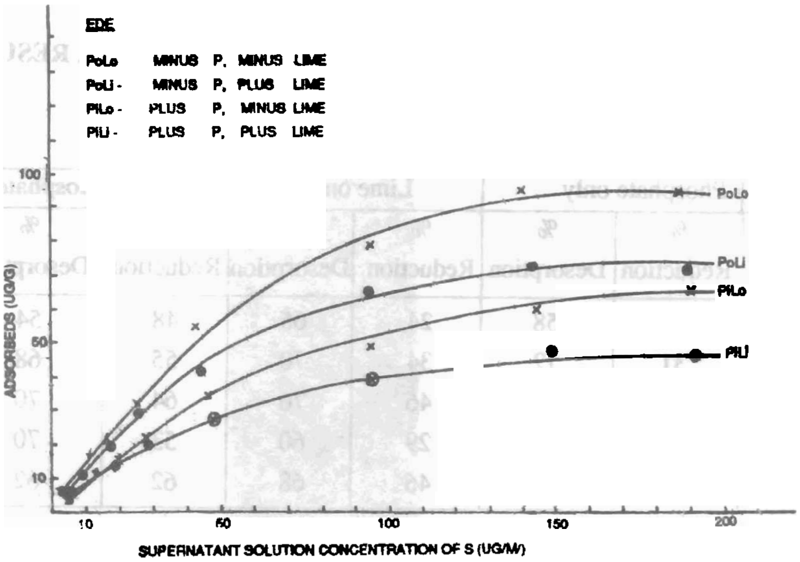

FIG. 1 EFFECT OF PHOSPHORUS AND LIME ADDITION ON THE SULPHUR ADSORPTION ISOTHERM

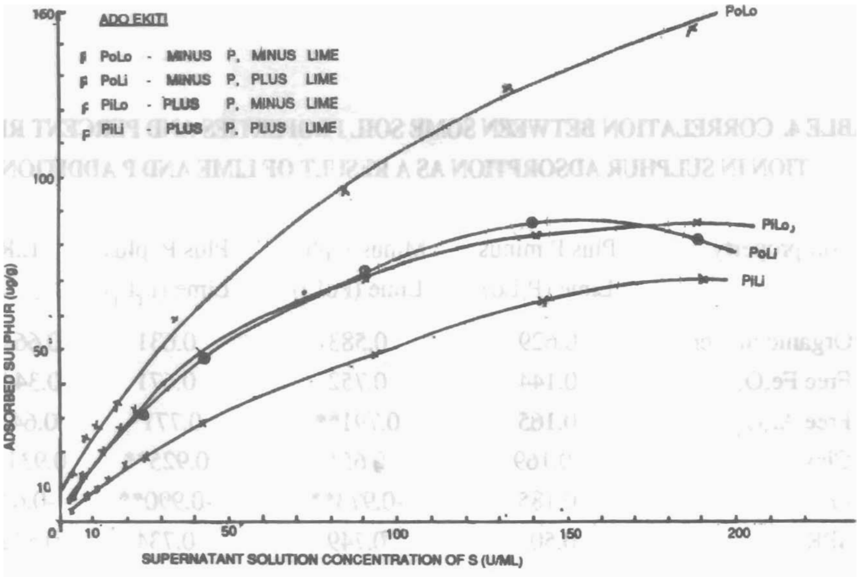

FIG. 2 EFFECT OF PHOSPHORUS AND LIME ADDITION ON THE SULPHUR ADSORPTION ISOTHERM

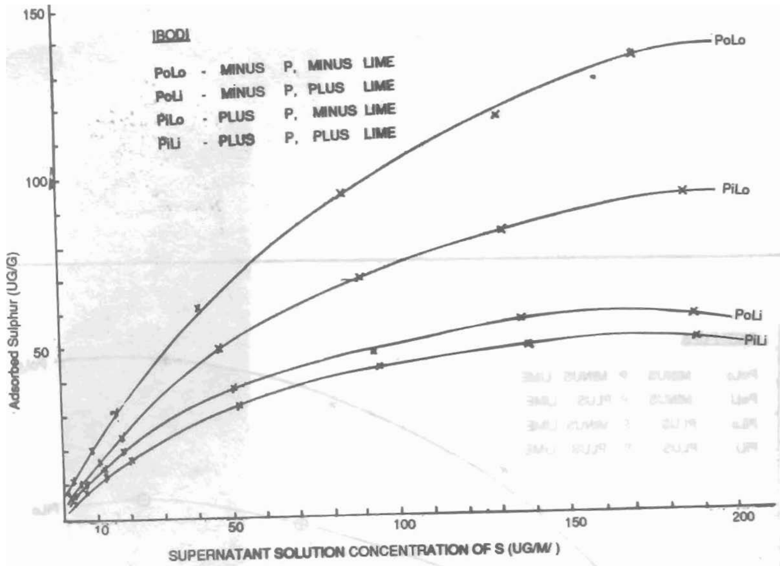

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FIG. 3 EFFECT OF PHOSPHORUS AND LIME ADDITION ON THE SULPHUR ADSORPTION ISOTHERM

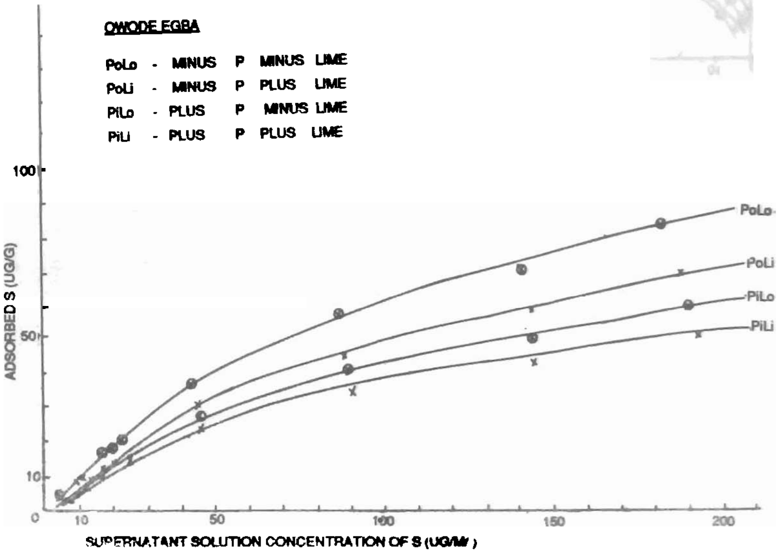

FIG. 4 EFFECT OF PHOSPHORUS AND LIME ADDITION ON THE SULPHUR ADSORPTION

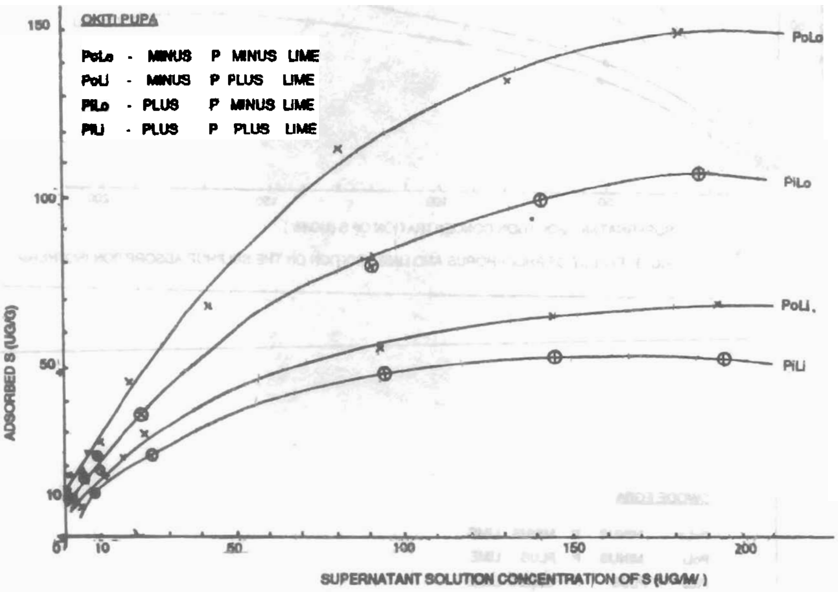

FIG. 5 EFFECT OF PHOSPHORUS AND LIME ADDITION ON THE SULPHUR ADSORPTION ISOTHERM

ISOTHERM

reduced the sulphate adsorption capacity of soils. This has serious implication on the present soil fertilization practice in South Western Nigeria, where non sulphur containing fertilizers are presently being recommended. This may aggravate the S problems in these soils, which is already manifest in the increasing responses to sulphur application observed in recent time. A similar conclusion could be drawn from Broofield (1972) studies in Northern Nigeria, where the sulphate level in the zero to 7.5cm layer in his experiement was observed to decline from 10ppm where ammonium sulphate had been applied down to 4ppm where a combination of ammonium sulphate and single super phosphate had been applied, in spite of an extra 277kg/ha of S in super phosphate over the 19 year period of the experiment.

It is possible that the displaced sulphate could be readsorbed at lower depths. However, only deep rooted crops may benefit from the sub-oil deposits.

Effect of Lime Addition

The soils are generally acid in reaction and the amount of lime required to raise the pH of each soil to about 6.5 was determined by incubation method. The values are presented in Table 2. The lime requirement related significantly with the clay content (r = 0.930**) and less with pH (r = -0.649) (Table 4). When the amounts of lime determined in the incubation experiment was added to the respective soils, the ability of the soils to adsorb sulphate depressed appreciably and greater than the effect of phosphate addition (Fig. 1). On the average, decrease in the adsorption capacity ranged from 24 to 46%. The reduction related significantly to the initial soil pH (r = -0.973**), free Fe2O3 (r = 0.752) and free Al2O3 (r = 0.791*). This reduction in adsorbed sulphate could be attributed to the adsorption behaviour of sulphate. Sulphate anion(SO_4^{2-}) is fully dissociated in soils system and therefore cannot adsorb on to negative or uncharged surfaces, unlike the undissociated phosphate (H2PO-4) anion. Because the surface positive charge decreases with pH, any practice that raises the pH of the soil, such as lime addition will invariably lower the sulphate adsorption of soil. complication may also arise becasue phosphate compound may be more soluble at higher pH (Metson and Blakemore, 1978) in which case, there may be more phosphate ions to compete for the sites as well at the limed pH. When the adsorbed sulphate was desorbed in water, similar results (Table 3) were obtained, as with phosphate treatment.

Addition of Both Lime and Phosphate

Addition of lime and phosphate to the soils resulted in a substantial reduction in the sulphate adsorption. Decrease in adsorption was more pronounced at Ibodi and Okitipupa where more than 60% decrease in adsorption was recorded for each soil (Table 3). The reduction is significantly related to the clay content (r = 0.975**), soil pH (r = -0.990**) and free Al2O3 (r = 0.771*).

When the adsorbed sulphate was washed with water, the amounts of sulphate removed was about 70% on the average. This is similar to the efect of adding lime or phosphate.

The present study shows clearly that lime and phosphate addition are very effective, both in displacing adsorbed sulphate and in reducing the capacity of the soil to adsorb additional sulphate. As earlier suggested by Korentajer et al., (1983) timing of lime and P applications and avoidance of excessive liming may be important in preventing sulphate leaching losses and sulphur deficiency in South Western Nigerian soils.

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