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EFFECT OF ORGANIC AMENDMENT ON P RELEASE IN SOILS OF SOUTHWESTERN NIGERIA

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Abstract

The study was conducted to assess the effect of amendment of soil with poultry manure on P fixing capacities of some soils and subsequently P uptake by maize. Eight soil series, representing the major soil types of southwestern Nigeria, were treated with five rates of P fertilizer and two rates of poultry manure in a laboratory incubation and greenhouse soil culture experiments. It was found that the addition of poultry manure significantly (at 1%) reduced the P-fixing capacities of the soils (by 23.2%), increased plant uptake of P (by 44%) and consequently increased the dry matter yields of maize. It was concluded that amendment of soil with poultry manure could be used to decrease the P- fixing capacity of soils and thus enhance the P available to crops.

INTRODUCTION

Tropical soils have high phosphorus-fixing capacities and therefore require large amounts of P fertilizer to enhance plant performance. The application of large amounts of P fertilizer is undesirable not only from an economic perspective, but also from an environmental one because of potential eutrophication of surface water through erosion of P-rich soil particles (Gilliam *et al.,* 1985). The incorporation of manure and crop residues into soils has been shown to increase the amount of soluble organic matter (O.M.) in soils (Zsolnay and Gorlitz, 1994). These soluble organic maters, which are mainly organic acids, increase the rate of desorption of phosphate (PO_4^{3-}) and improves the available P content in the soil. The functional groups of these organic acids prevent PO_4^{3} adsorption by blocking the adsorption sites on soil constituents thus enhancing P availability to plants (Nagarajah *et al.,* 1970).

The decomposition of added O.M. generally seems to modify the adsorption characteristics of soils. Ayodele, *et al.* (1984) observed a negative correlation between P sorption and O.M. content. Agboola and Oko (1976) reported that high organic matter content in soil (>3%) resulted in increased amounts of available P and should be taken into consideration when making fertilizer recommendations. Hue (1991) reported that three low molecular weight organic acids decreased P sorption by acidic soils. In addition, he found that the treatment of soils with organic acids resulted in higher yield of lettuce. Consequently, he concluded that the addition of green or animal manure could increase the efficiency of P fertilizers. Bolan *et al.* (1994) reported that the addition of organic acids typically found in soil, leaf liffer and poultry manure decreased P sorption. Fox *et al.* (1990), in a laboratory kinetic study, showed that organic acids typically desorbed P from spodosols via a ligand exchange reaction followed by re-precipitation of amorphous aluminum phosphate. Wild (1950) had earlier reported that O.M. is able to retain significant amounts of P in association with cations such as Fe, Al and Ca. Appelt *et al.* (1975) also reported that humic acids could react with Al from minerals such as allophane to form complexes which would provide new surfaces for P adsorption. The effect of an increase in the O.M. content of the soil would therefore increase P adsorption rather than decrease it.

Because of these contradictory findings on the effect of O.M. on P sorption by soil, this study was designed to assess the effect of organic amendment on P-fixing capacities of southwestern Nigerian soils and consequently P availability to the plant.

MATERIALS AND METHODS

Soil and poultry manure samples

Bulk topsoil sample (0 - 15 cm) were collected from some selected locations representing eight major soil series in southwestern Nigeria (Table 1). The soil samples were air-dried and sieved to pass through a 2 mm sieve. Some chemical and physical properties of these soils are shown in Table 2. Poultry manure was collected from the poultry unit of Obafemi Awolowo University Teaching and Research farm. The poultry manure was dried and ground to fine powder to pass through *0.5* mm sieve. The chemical composition of this is shown in Table 3.

Soil poultry manure and plant tissue analysis: The particle size distribution was determined by the hydrometer method of Bouyoucos (1951) using sodium hexametaphosphate as dispersing agent. Soil pH was measured in distilled water in 1:1 soil-water and 1:2 soil-solution in 0.01M $CaCl_2$. Organic carbon (O.C.) in soil and poultry manure was determined using the dichromate oxidation procedure of Walkley and Black (1934). Available P was extracted using Bray-1 method (Bray and Kurtz, 1945) and determined colorimetri... ly using molybdate blue method. Exchangeable bases were extracted in 1 N neutral ammonium acetate solution. Calcium (Ca), K and Na were determined using flame photometry while Mg was determined with atomic absorption spectrophotometer. Free iron (Fe) and aluminum (Al) oxides were extracted using dithionite-citrate-bicarbonate (DCB) method (Mehra and Jackson, 1960); Al and Fe in the extracts were determined using atomic absorption spectrophotometer. The plant tissues samples were ground to pass through 0.25 mm sieve. These were digested using H_2SO_4 and H_2O_2 and the P content determined using the vanadomolybdate method as described by Pieer (1944).

Laboratory incubation and adsorption studies: The poultry manure was added to the soil at the rates of 0 and 1 metric t/ha. The moisture content was maintained at 75% field moisture capacity. The samples were incubated for four weeks at room temperature and mixed daily during this period to enhance mineralization and contact of the organic manure with the soil. At the end of four weeks of incubation, the samples were dried. These were then used for adsorption studies.

Five gramme portions of soil sample were equilibrated with 50 ml of 0.0l M $CaCl_2$ solution containing varying concentrations of P ranging from 0 to 50 ppm in a centrifuge tube. Two drops of toluene were added to inhibit microbial growth. The soil suspension was shaken on a mechanical shaker for 30 minutes twice daily for a period of 12 days at room temperature. The tubes were centrifuged at 20,000 rpm for 5 minutes and aliquots of the supernatant solutions were taken for colorimetric determination of P using the molybdate blue method. Sorbed P was determined by the difference between P added and P remaining in the equilibrium solution. These data were used to plot sorption isotherm curves and were fitted into the Langmuir equation to estimate the adsorption maxima and the binding energy constant.

Greenhouse experiment

For the greenhouse studies, 1kg of soil was incubated with poultry manure in 1.5 litres black-painted plastic pots at the rates of 0 and 1 metric t/ha for 4 weeks. At the end of the incubation period, P was added as NaH_2PO_4 at four different levels of 0, 50, 100 and 200 kg P/ha. Each pot received an initial application of N and K as NH_4NO_3 and KCl at the rates of 120 at 100 kg/ha respectively.

Three seeds of maize (Zea mays L. cv. DMR-ESR-Y) were planted per pot and the seedlings were later thinned to 1 plant per pot. The soil moisture content was maintained at 75% field moisture capacity using deionised water. Four weeks after germination, plant tops were harvested, placed in paper bags and dried to constant weight at 65°C in a ventilated oven. The dry matter yields were recorded.

Statistical analysis

The data obtained were subjected to statistical analysis, that is, analysis of variance and the student t-test.

TABLE 1

The local names of soil series used for the study and the USDA and FAO/UNESCO equivalent

Local name	USDA	FAO/UNESCO
Egbeda	Rhodic Kandiudults[a]	Rhodic Ferralsols[a]
Iwo	Oxic Haplustult[b]	Orthic Acrisol[b]
Oba	Plinthic Kandiustult[c]	Plinthic Ferralsol[c]
Iregun	Oxic Ustropept[d]	Chromic Cambisol[d]
Itagunmodi	Tropetic Eutrorthox[f]	Ferric Luvisol[e]
Gambari	Petroferric Haplustult[c]	Dystric Leptosol[c]
Ondo	Oxic Paleustult[b]	Ferric Acrisol[b]
Balogun	Typic Rhodustult[b]	Orthic Acrisol[b]

a. Okusami *et al.*, 1997.

b. Periaswmy and Ashaye, 1982.

c. Okusami, 1990.

d. Ojanuga, 1980.

e. Ashaye *et al.*, 1988.

Harpstead, 1972

RESULTS AND DISCUSSION

Properties of soils and poultry manure

Some chemical and physical properties of the soil used are presented in Table 2. The soils are generally low in available P between 6.5 and 8.7 ppm, which indicated that they would respond to P fertilizer application. The textural class of the soils ranged from sandy loam to loam, with clay content ranging from 5.4 to 27.0 %. The pH of the soils (in 0.01 M $CaCl_2$) ranged from 5.8 to 7.3 indicating slightly acid to slightly alkaline. The organic-C content of the soils was relatively moderate, ranging from 0.87 to 2.8 %. The poultry manure was rich in organic C (18.1 %).

Adsorption characteristics of the soils

The P adsorption capacities (b) of the soils ranged from 235.2 to 794.3 ìg/g for the unamended and 183.0 to 624.1 for the amended soils (Table 3). The composition of the poultry manure used as the organic amendment is presented in Table 4. The sorption curves for the organic amended and unamended soils are shown in Figures 1a and 1b. The slope of the adsorption isotherms were lowered by organic amendment of the soils, thus lowering the amount of inorganic P to be applied to obtain a unit change in the concentration of P in the equilibrium solution. This is in agreement with the findings of Singh and Jones (1976), Lobartini *et al.* (1994), Berton and Pratt (1997), that P sorption capacity decreased with increasing S.O.M. content. Several mechanisms have been proposed to be responsible for the reduction in the P fixation associated with high content of S.O.M. One suggestion was that large humic molecules could adhere to the surface of clay and sesquioxide particles thus masking the P adsorption sites and preventing or reducing the interaction between P in solution and the clay mineral surface. Organic acids produced from the decomposition of the organic amendment can also serve as organic anions, which may compete with phosphate ion for the adsorption sites. Also, these organic acids can form stable surface complexes with Fe and Al, thus preventing their reactions with P. These reactions were well illustrated in Figure 2.

Uptake and the dry matter yield of maize

A general increase in P uptake by the plants in response to inorganic P application was observed for all the soils as shown in Table 5. Significant negative correlation (r = 0.91**) was observed between plant uptake of P and P sorption capacities of the soils. The dry weight of plant tops also followed the same trend with P uptake by the plants (Table 6). This confirmed the fact that the P sorption characteristic of soils is an important factor governing P availability to plants and consequently plant growth.

The addition of organic amendment to the soil significantly (at 1%) increased the P uptake and the dry yields of plant tops at the same level of inorganic P application (Tables 5 and 6). It was also found that the P uptake by the plant from the organic amended was significantly higher than that of the unamended soil (Table 5). This suggested that the addition of organic amendment increased the availability of P to the plants. The greater release of P and hence the greater availability of P with the addition of organic amendment might be due to the adherence of humic molecules to the surfaces of clay metal hydrous oxide particles, thus masking the fixing sites and consequently preventing P adsorption (Fig. 2). This effect can be due to the production of organic acids which complex P in soil solution forming soluble phosphohumate complexes or chelates which prevent its adsorption or precipitation. These organic acids can also form stable surface complexes with Fe and Al thus preventing their reaction with P (Brady and Weil, 1999). This was confirmed by Lobartini *et al.* (1994) who reported that humic acids play an important role in preventing or decreasing P fixation by chelating the ions responsible for the reaction. Further mineralization of P from the soil organic matter pool due to increased microbial activity caused by the presence of the organic amendment may also account for the greater availability of P to the plant from the organic amended soil. The reductions observed in the binding energy indices on addition of organic amendment to the soil was also indicative of the greater ease of release of P since P was held more loosely (Table 4).

TABLE 2

Some chemical and physical properties of the soils used in this study

Soil Series	Exchangeable cations															
	K^+	Mg^{2+}	Ca^{2+}	Na^+	Exchange acidity	ECEC	Available P (ppm)	%C	pH		Free Fe_2O_3 (%)	Free Al_2O_3 (%)	Sand %	Silt %	Clay %	Textual Class
	← Cmol (+)Kg^{-1} Soil →								0.01M $CaCl_2$	H_2O						
Iwo	0.21	1.0	2.32	0.05	0.25	3.83	7.8	1.0	6.1	6.5	1.00	0.60	73.6	19.4	7.0	Sandy Loam
Iregun	0.11	1.19	4.81	0.06	0.28	6.45	6.5	1.62	6.2	6.6	1.25	0.81	70.9	18.3	10.8	Sandy Loam
Oba	0.14	1.10	2.35	0.05	0.29	3.93	7.2	1.29	6.1	6.5	1.17	1.04	72.2	18.4	9.4	Sandy Loam
Egbeda	0.13	0.68	1.35	0.05	0.21	2.42	7.2	0.87	5.8	6.3	0.91	0.52	76.2	18.4	5.4	Loamy Sand
Itagunmodi	0.39	1.75	8.58	0.09	0.26	11.07	8.7	2.80	5.9	6.2	3.63	1.84	42.2	30.3	27.0	Loamy Sand
Gambari	0.29	1.11	4.25	0.09	0.27	6.01	7.7	1.56	6.4	6.7	2.77	1.42	64.2	14.5	21.3	Loamy Sand
Ondo	0.12	1.37	8.27	0.07	0.27	10.10	8.2	1.46	7.3	7.8	2.25	1.73	63.2	18.2	18.6	Loamy Sand
Balogun	0.15	0.72	6.57	0.05	0.31	7.08	7.0	1.29	7.1	7.4	1.84	1.10	60.2	25.9	13.7	Sandy clay loam
Range	0.11-	1.0-	1.35-	0.02-	0.21-0.31	3.83-	6.5-8.7	0.87-	5.8-7.3	6.2-	0.91-	0.52-	42.2-	14.5-	7.0-	
	0.39	1.75	8.58	0.09		11.07		2.80		7.8	3.63	1.84	76.2	30.3	27.0	
Mean	0.19	1.12	4.81	0.06	0.27	6.36	7.54	1.49	6.36	6.8	1.85	1.13	65.3	20.5	14.2	

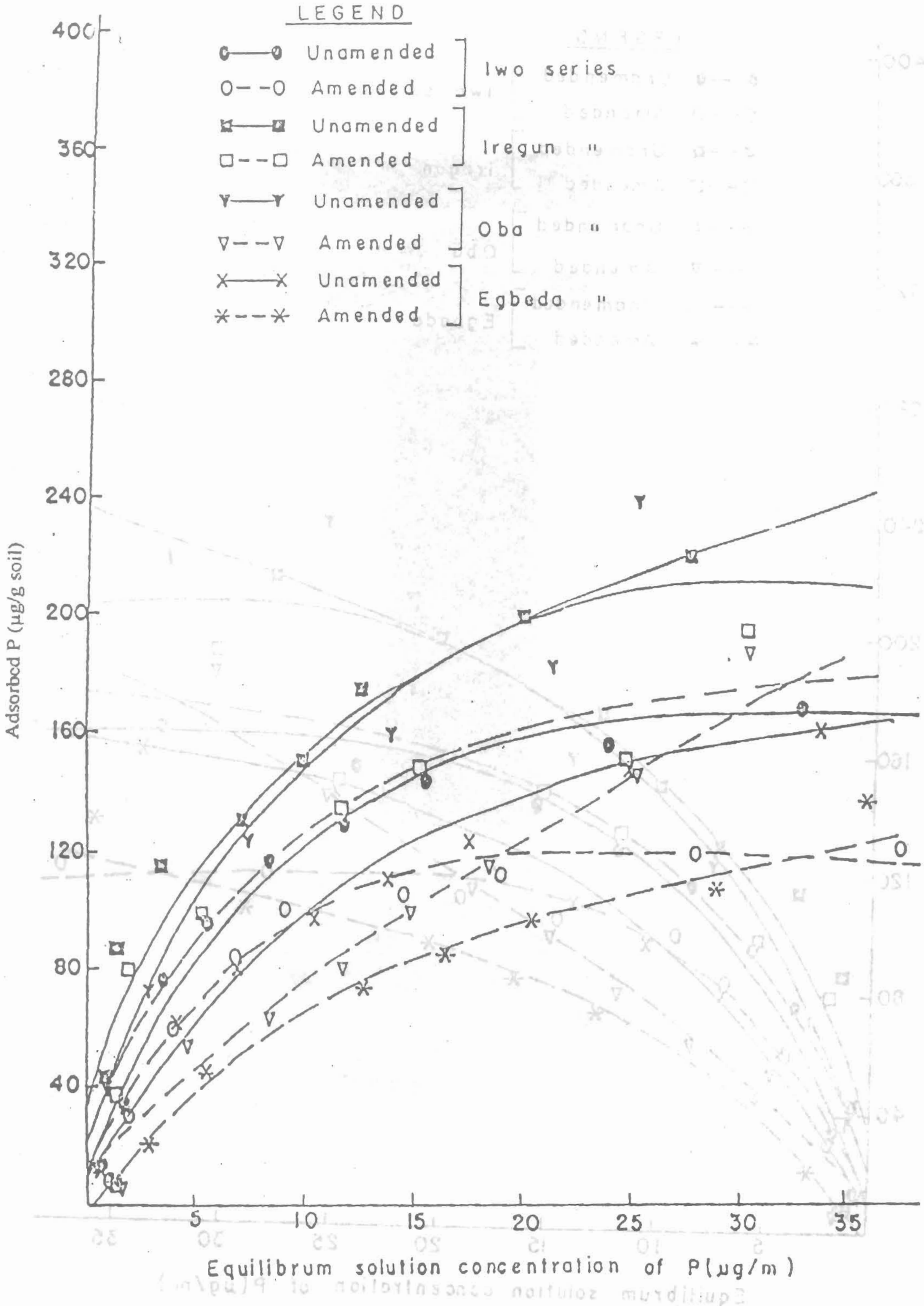
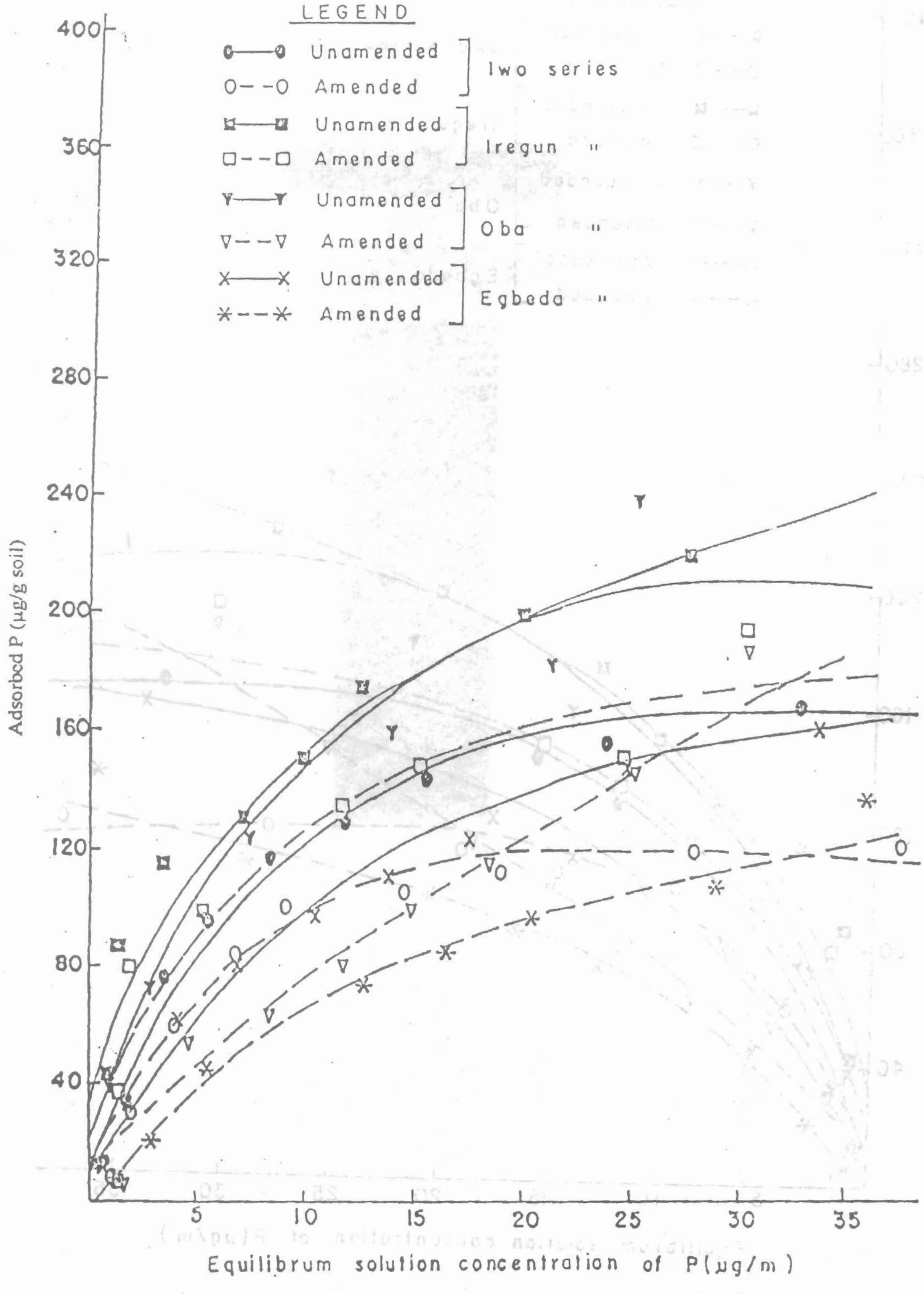


Fig. 1a : Phosphorus adsorption isotherms of organic amended and unammended soils



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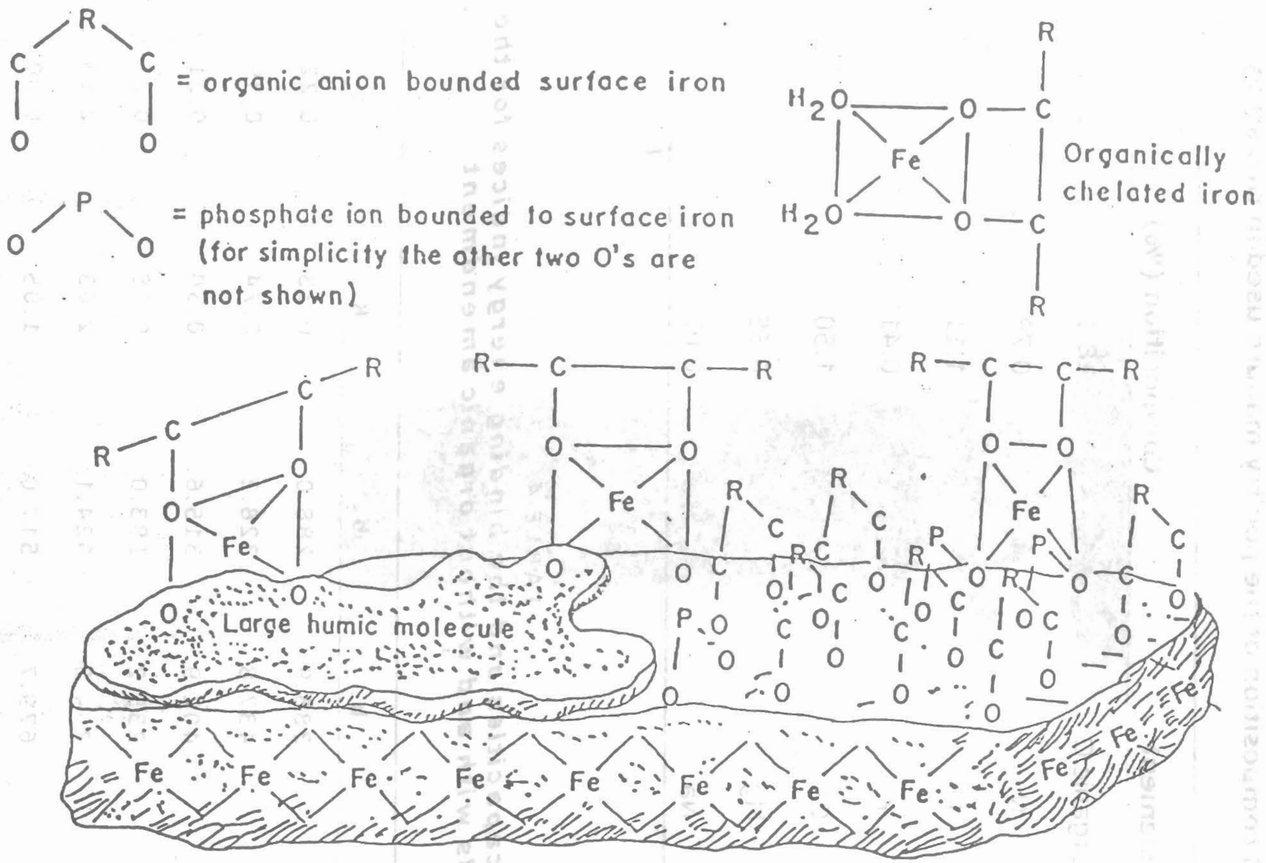

Fig. 2: Reduction of available P fixing sites by organic anions, large organic molecules and certain strongly fixed inorganic anions.

Source: Brady and Weil (1999)

TABLE 3

Elemental composition of the poultry manure used in this study

Element	Composition (%)
Organic C	18.1
N	0.79
P	1.11
K	0.41
Ca	1.50
Mg	0.65
Na	0.07

TABLE 4

Adsorption capacities and the binding energy indices for the soils with and without organic amendment

Soil series	b_-	b_+	k_-	k_+
Iwo	386.9	288.0	0.33	0.22
Iregun	437.8	328.2	0.74	0.39
Oba	402.9	315.6	0.50	0.21
Egbeda	235.2	183.0	0.95	0.27
Itagunmodi	794.3	624.1	2.65	2.13
Balogun	679.7	517.0	1.05	0.80
Ondo	765.2	581.8	0.65	0.41
Gambari	790.4	610.5	0.41	0.26
Mean	561.5	431.0	0.91	0.59
% Change	23.2		35.2	

Note: + = amended soil

a. = unamended soil

% = change is the reduction observed in the adsorption characteristics of the soils after the addition of poultry manure.

TABLE 5

Phosphorus uptake (mg / 100g) by maize plant (Zea mays L.) in soil with and without organic amendment followed by treatment with different rates of P (kg/ha)

Applied P (kg/P.ha)

Soil series	Applied P (kg/ P/ha)								
	0		50		100		200		LSD
	+	-	+	-	+	-	+	-	
Balogun	0.23	0.10	0.23	0.19	0.38	0.30	0.45	0.33	0.0087
Egbeda	0.39	0.23	0.62	0.41	0.91	0.65	1.40	0.95	0.0091
Gambari	0.27	0.18	0.37	0.26	0.60	0.39	0.67	0.58	0.0090
Iregun	0.28	0.17	0.45	0.31	0.68	0.43	0.85	0.77	0.0087
Itagunmodi	0.20	0.10	0.26	0.17	0.30	0.25	0.37	0.31	0.0081
Iwo	0.34	0.23	0.52	0.36	0.88	0.54	1.25	0.88	0.0095
Oba	0.35	0.17	0.49	0.31	0.89	0.47	0.99	0.83	0.0087
Ondo	0.27	0.13	0.36	0.21	0.45	0.35	0.52	0.42	0.0081
Mean	0.29	0.16	0.41	0.28	0.64	0.42	0.81	0.63	

: + = amended soil

- = unamended soil

TABLE 6

Dry matter yields (g) of maize plant (Zea mays L. in soil with and without organic amendment followed by treatment with different rates of P (kg/ha)

eries	Applied P (kg/ P/ha)								
	0		50		100		200		LSD
	+	-	+	-	+	-	+	-	
ɹn	0.494	0.450	0.636	0.514	0.743	0.602	0.811	0.615	0.0091
a	0.815	0.700	1.015	0.871	1.364	0.927	1.589	1.007	0.0090
ari	0.584	0.543	0.737	0.580	0.790	0.648	0.933	0.694	0.0093
ı	0.629	0.564	0.785	0.592	0.823	0.633	0.929	0.669	0.0083
ımodi	0.413	0.387	0.517	0.409	0.681	0.493	0.728	0.541	0.0087
	0.741	0.660	0.904	0.716	1.218	0.853	1.432	0.901	0.0091
	0.672	0.562	0.825	0.613	0.968	0.717	0.996	0.741	0.0081
	0.517	0.490	0.694	0.544	0.766	0.637	0.897	0.675	0.0085

Note: + = amended soil

- = unamended soil

CONCLUSION

The addition of poultry manure to the soil significantly improved P availability to maize (Zea mays L.) under greenhouse condition. Organic amendment of soils having high P Sorption capacities decreased their sorption capacities and thus improved the release of P to the plant. These results indicated that the amount of P fertilizer that is needed to obtain for optimum crop yield could be reduced through organic amendment of soils. Hence, the incorporation of organic amendment into the soil is a recommended management option for high P fixing soils of the tropics.

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