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Adsorption studies of organic soils in the Tidewater area of North Carolina indicated that soils in which the colloids are organic had very low capacities to absorb phosphate. The adsorbed P was very soluble. Soluble P fertilizer was readily leached from an organic soil and a high-organic-matter sand which contained no inorganic colloids. The addition of $AlCl_3$, which resulted in large amounts of exchangeable Al, almost completely stopped the leaching of P.

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ADSORPTION AND LEACHING OF P IN ACID ORGANIC SOILS AND HIGH ORGANIC MATTER SAND[1]

R. L. Fox and E. J. Kamprath[2]

Abstract

Adsorption studies indicated that soils in which the colloids were organic had very low capacities to absorb P. The adsorbed P was very soluble. Soluble P fertilizer was readily leached from an organic soil and a high organic matter sand which contained no inorganic colloids. The addition of $AlCl_3$ which resulted in large amounts of exchangeable Al almost completely stopped leaching of P.

Additonal Key Words for Indexing: **P movement, P fixation by organic matter.**

In recent years there has been considerable interest in the agricultural development of organic soils in the Tidewater area of North Carolina. These soils vary in layer silicate mineral content from a trace to appreciable amounts. In some instances they consist of organic matter and quartz sand. Field observations have indicated that applications of water soluble phosphate fertilizers have less residual effect than water insoluble phosphate fertilizers. Soil analyses indicated that most of the applied P was no longer in the plow zone, which suggested that the P was being leached.

Movement of P in mineral soils is limited because of reaction of the fertilizer P with Al, Fe, and Ca compounds to form relatively insoluble phosphate compounds (4). Wild (5) points out that P adsorption by organic matter is negligible and any adsorption that occurs is due to the cations associated with the organic matter.

The objectives of this study were to determine the adsorption and movement of water soluble P fertilizer in acid soils in which the colloids are organic.

Methods and Materials

Bulk samples of the Ap horizon were collected from a St. Johns soil, a very poorly drained soil consisting of 90% quartz sand and 10% organic matter, and the surface and subsurface of an organic soil (muck—essentially no inorganic colloids) from the Tidewater area of North Carolina. The St. Johns soil is used primarily for blueberry production (*Vaccinium* Sp.) and the organic soil for corn (*Zea mays* L.) and soybean (*Glycine max* L.) production.

The P adsorption values were obtained by equilibrating the soils with 0.01*M* $CaCl_2$ containing from 0 to 1,000 μg of P, as monocalcium phosphate. Two grams of organic soil were equilibrated with 25 ml of solution and 4 g of St. Johns soil was equilibrated in 20 ml of solution. The soil suspensions were shaken twice daily for 6 days in order to achieve equilibrium. The samples were centrifuged and the supernatant liquid analyzed for P.

The leaching studies were conducted with the treated soils placed into leaching columns 40 cm long and having a surface area of 10 cm^2. Monocalcium phosphate solution was applied to the surface of the moist soil at 25 and 100 kg of P/ha (2.5 and 10 mg of P/column). Increments of 25 ml of water were added, and the leachate from each increment was collected. The amount of fertilizer P leached was calculated by subtracting the P collected from soils receiving no P from P collected in leachates from P-treated columns.

The St. Johns soil was treated to five systems which were primarily H saturated, Ca saturated, Al saturated, and a limed soil. The respective soil treatments were obtained by repeated leaching with 0.2*M* HCl or 0.5*M* $CaCl_2$, addition of 2.5 meq Al/100 g as $AlCl_3$, and addition of 2.5 meq Ca/100 g as $CaCO_3$. The amount of $CaCO_3$ applied was 1.5X exchangeable Al. The limed soil was not leached. Excess salts were leached from other systems. The columns of St. Johns soil retained 110 ml water and the muck soil 260 ml. This corresponds to field moisture capacities of about 27% and 200%.

Measurement of exchangeable H and Al were made by extracting the soil with N KCl and titrating the filtrate with 0.1N NaOH (3). Soil pH was measured potentiometrically on a 1:1 soil-water suspension.

Results and Discussion

Phosphorus adsorption isotherms for the two soils are presented in Fig. 1. These soils, in relation to mineral soils, have relatively small P-adsorption capacities. The St. Johns soils did not adsorb P until the P concentration was quite high. This suggests that only small amounts of Fe and Al compounds were available for reacting with P. The adsorption isotherms also indicate that the reaction product formed has relatively high solubility. The subsurface sample from the organic soil was quite acid, pH 3.3, and adsorbed considerably less P than the surface soil which had a pH of 4.6.

Leaching effectively removed fertilizer P from the original soil, the H treated soil, and the Ca treated St. Johns soil (Table 1). The aluminum-treated St. Johns retained the P added. The elution patterns from the variously treated St. Johns soils are shown in Fig. 2. Removal of P from the H and Ca soils was very rapid in comparison to the limed and untreated soils. Phosphorus in high concentrations appeared in leachates from H- and Ca-soil columns corresponding to one water filled pore volume.

Retention of P by organic matter of the St. Johns soil was related to the kind and amount of adsorbed cations and

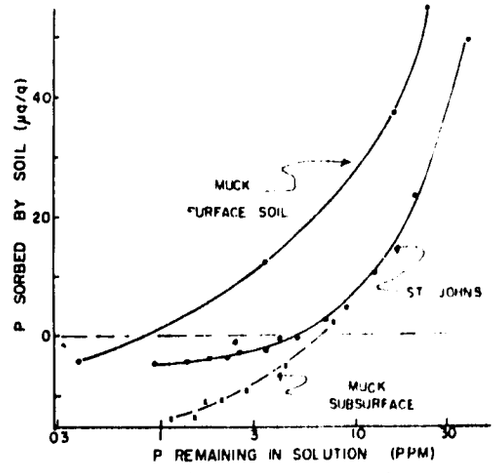

Fig. 1—P sorption by soils containing primarily organic colloids.

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Table 1—Leaching of fertilizer P from a St. Johns soil as related to chemical treatment and chemical properties (10 mg of P as Ca $(H_2P_4)_2$ added per column)

Treatment	pH*	Exchangeable* H	Exchangeable* Al	P leached	Fertilizer P adsorbed
		meq/100 g		mg/column	
Original soil	3.4	1.92	1.63	4.6	-
Original soil + P				14.5	0.1
H soil + P	2.5	4.95	0.80	16.0	0
Al soil + P	3.9	0.35	4.65	4.7	9.9
Ca soil + P	4.0	0.40	0.40	15.8	0
Limed soil + P	4.1	0.55	0.60	13.2	1.4

* Soil pH and exchangeable cations were measured prior to phosphate additions and leaching.

the pH of the system. With the H system the pH was so low that any metal phosphates formed would have been dissolved. Similarly with the Ca soil at pH 4, calcium phosphates are soluble. The elution pattern with a sharp peak also suggests very soluble P compounds.

Although the original St. Johns soil contained 1.63 meq/100 g of exchangeable Al, all of the added fertilizer was removed by leaching. Retention of the P by Al is influenced by several factors. Coleman et al. (2) found that Al had to be hydrolyzed from exchange sites before appreciable reactions occurred with P. Some aluminum is bound strongly by organic matter. Reaction between this "bound" Al and P would be limited (1). The St. Johns soil contained essentially no mineral colloids. Although the soil was very acid (pH 3.4), there was no reservoir of aluminum which could be released to precipitate P by mass action. The elution pattern suggests that initally there was some retention of the P by the aluminum, but with continued leaching even this P was removed.

The limed St. Johns soil retained some P against leaching although pH and exchangeable H and Al were similar to the $CaCl_2$ leached soil. Retention of P was probably due to more aluminum being available for reaction due to the hydrolysis and precipitation of Al from exchange sites by lime.

Essentially all of the added P was retained by the St. Johns soil to which $AlCl_3$ was added. Compared with the untreated soil, more Al was available for reaction with P, and probably this added Al was not bound tightly. Therefore, P was precipitated.

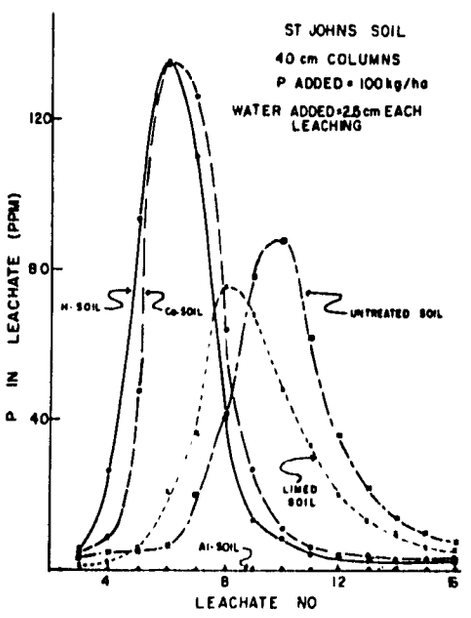

Fig. 2—Leaching of fertilizer P applied to the surface of a St. Johns soil lined or treated with various cations.

Table 2—The leaching of fertilizer P from an acid organic (muck) soil

P added	pH	Exch. Al	P leached	Fertilizer P absorbed
mg/column		meq/100 g	mg/column	
		Surface Soil		
0	4.6	0.02	0.48	
2.5	4.6	0.02	2.95	0.03
10.0	4.6	0.02	8.67	1.81
		Subsurface Soil		
0	3.3		0.54	-
10.0	3.3		10.22	0.32

Phosphorus also leached from the acid organic soil which contained only trace amounts of mineral matter (Table 2). At the low rate of P, 2.5 mg/column or 25 kg/ha, all of the P was removed from the surface soil. At the higher rate of P, 10 mg/column or 100 kg/ha, most of the P also was leached from the surface soil. A small amount, however, was not recovered, which probably reacted with the metal cations contained by organic matter. Essentially all of the fertilizer P, 100 kg/ha, was leached from the subsurface sample. These organic soils with only a trace of inorganic minerals have no reservoir of Al and Fe to be released. Any Al and Fe present would be bound quite tightly by the organic matter, and reaction with fertilizer P would be limited. The elution patterns for fertilizer P in the organic soil are shown in Fig. 3. The elution curves for the organic soil were not as sharp as those for the St. Johns soil, which is probably due to the much higher organic matter content of the organic soil and greater water holding capacity. Leachate no. 10 corresponds to one water filled pore volume.

The results of this study indicate that soluble fertilizer P will leach from soils in which the colloids are organic and contain only traces of mineral matter.

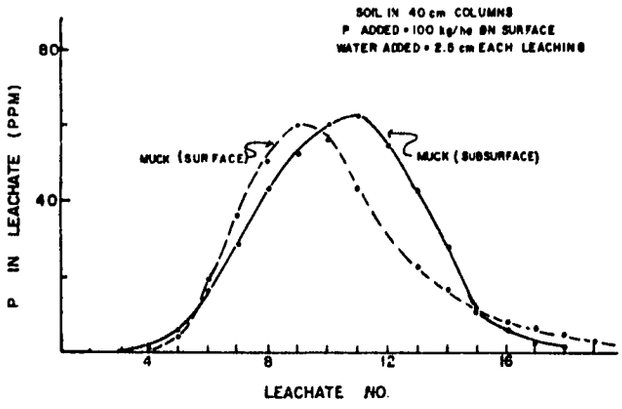

Fig. 3—Leaching of fertilizer P in an acid organic soil.

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