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Chicken manure as an amendment to correct soil acidity and fertility[1]

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ABSTRACT

Crop production in tropical areas may be limited by soil acidity. The use of conventional liming sources is expensive for many developing countries. A possible alternative to correct soil acidity is the use of green and animal manure. An experiment was established to evaluate the effect of chicken manure on soil chemical properties. Six months after the establishment of this experiment, the soil was sampled at a 0 to 20 cm depth. Soil pH increased significantly from 4.92, in the control treatment, to 5.32 after the application of 15 t/ha of chicken manure. Potassium chloride (KCl) extractable aluminum decreased significantly from 0.38 to 0.20 $cmol_c/kg$ with the application of 15 t/ha of chicken manure. Aluminum saturation decreased by 7.71%, and available phosphorus increased significantly from 34.14 mg/kg, in the control treatment, to 178.04 mg/kg with the application of 15 t/ha of chicken manure.

Key words: chicken manure, soil acidity, aluminum complexation

RESUMEN

Utilización de gallinaza para corregir la acidez y fertilidad del suelo

La producción de cosechas en áreas tropicales puede limitarse debido a problemas de acidez del suelo. Para los países en vías de desarrollo el uso de fuentes convencionales para encalar puede resultar muy caro. Una posi-

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ble alternativa para disminuir la acidez del suelo es la utilización de residuos de cosecha y desperdicios de animales. Se realizó un experimento para evaluar el efecto de la gallinaza en las propiedades químicas del suelo. A los seis meses luego de establecerse el experimento se tomaron muestras de suelo a una profundidad de 0 a 20 cm. El pH del suelo aumentó significativamente de 4.92, en el tratamiento control, a 5.32 con la aplicación de 15 t/ha de gallinaza. En los mismos tratamientos el aluminio extraido con KCl disminuyó significativamente de 0.38 a 0.20 $cmol_c$/kg, lo que representa una reducción de 7.71 en el porcentaje de saturación de aluminio. La disponibilidad de fósforo aumentó significativamente de 34.18 mg/kg, en el tratamiento control, a 178.04 mg/kg con la aplicación de 15 t/ha de gallinaza.

INTRODUCTION

Soil acidity is a serious limitation for crop production in tropical areas where Ultisols and Oxisols predominate. Toxic levels of exchangeable aluminum and manganese are frequently observed in these soils, requiring applications of $CaCO_3$ to improve the conditions for plant growth (Foy, 1974; Abruña et al., 1975; Farina et al., 1980). In countries where liming is expensive, the use of green manure and animal waste is considered an alternative to correct acidity problems and improve soil fertility (Ahmad and Kan, 1986; Hoyt and Turner, 1975). A reduction in soluble and exchangeable aluminum ions has been observed after applying organic materials to very acid soils (Brogan, 1967; Hoyt and Turner, 1975; Wahab and Lugo-López, 1980). This effect has been related to complexation of ionic aluminum with products of organic matter decomposition (Mortenson, 1963; Cabrera and Tatibuden, 1977; Hue, 1992).

The use of animal manure may also affect other soil properties. For example, phosphorus availability is enhanced by chicken manure fertilization (O'Hallorans et al., 1993). The increase in available phosphorus is mostly the result of the phosphorus present in the manure. However, it has also been suggested that phosphorus solubility may be induced by exchange reactions between organic anions and phosphate absorbed on soil surfaces (López-Hernández et al., 1978; Medina and López-Hernández, 1979; López-Hernández et al., 1986). More recently, Hue (1992) emphasized the importance of organic compounds on phosphorus availability, indicating that ligand exchange reactions between organic anions and Fe/Al oxides block phosphorus sorbing sites and reduce aluminum in solution by complexation reactions.

The work herein reported was undertaken to determine the effect of chicken manure on soil acidity factors and fertility parameters of an Oxisol. A major concern of the study was the effect of manure on exchangeable aluminum and available phosphorus.

MATERIALS AND METHODS

Chicken manure was evaluated as a soil amendment for Coto clay (very-fine, kaolinitic, isohyperthermic Typic Hapludox). The experiment was located at the Isabela Substation on the northwest coast of Puerto Rico. Chemical analysis of the first 20 cm of soil prior to treatment applications showed a pH of 4.88, exchangeable aluminum of 0.33 $cmol_c$/kg and available Bray-P of 9.67 mg/kg. Exchangeable potassium, calcium and magnesium content was 0.12, 1.80 and 0.50 $cmol_c$/kg, respectively. The experimental design was a randomized complete block (RCBD) with three replications. Treatments included all possible combinations of 0, 5, 10 and 15 t/ha of chicken manure and 0, 56, 112 and 224 g/plant (papaya)/month of fertilizer formulation 15-15-15. Chicken manure treatments were broadcast and incorporated into the soil before planting. At time of sampling, fertilizer treatments had been applied six times at rates of 56, 112 and 224 g/plant/month. Chemical analysis of the manure revealed a N, P and K content of 4.75%, 1.30% and 1.32%, respectively. Soil samples were taken at a 0- to 20-cm depth six months after the establishment of the experiment. The samples were air dried, ground and sieved to pass a 2 mm pore size.

The parameters evaluated were exchangeable cations (Ca^{2+}, Mg^{2+} and K^{+}), available phosphorus, pH and exchangeable aluminum. The exchangeable basic cations were extracted with 1N ammonium acetate, pH 7, and exchangeable aluminum with 1N KCl (Page et al., 1982). Their concentrations were measured with an atomic absorption spectrophotometer, Perkin Elmer 1280[5]. Available phosphorus was extracted with the Bray-1 solution and measured colorimetrically with a Beckman DU 68 spectrophotometer. Soil pH was determined in a 1:2 soil water ratio.

RESULTS AND DISCUSSION

Inorganic fertilizer applications resulted in a significant decrease in soil pH. The 0, 56, 112 and 224 g/plant/month of fertilizer formulation 15-15-15 resulted in pH values of 4.92, 4.74, 4.49 and 4.53, respectively. However, the chicken manure treatments significantly increased soil pH. The 0, 5, 10 and 15 t/ha resulted in pH values of 4.92, 4.84, 4.97 and 5.32, respectively (Figure 1). This significant increase in soil pH with chicken manure treatments was concomitant with a significant de-

[5]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico nor is this mention a statement of preference over other equipment or materials.

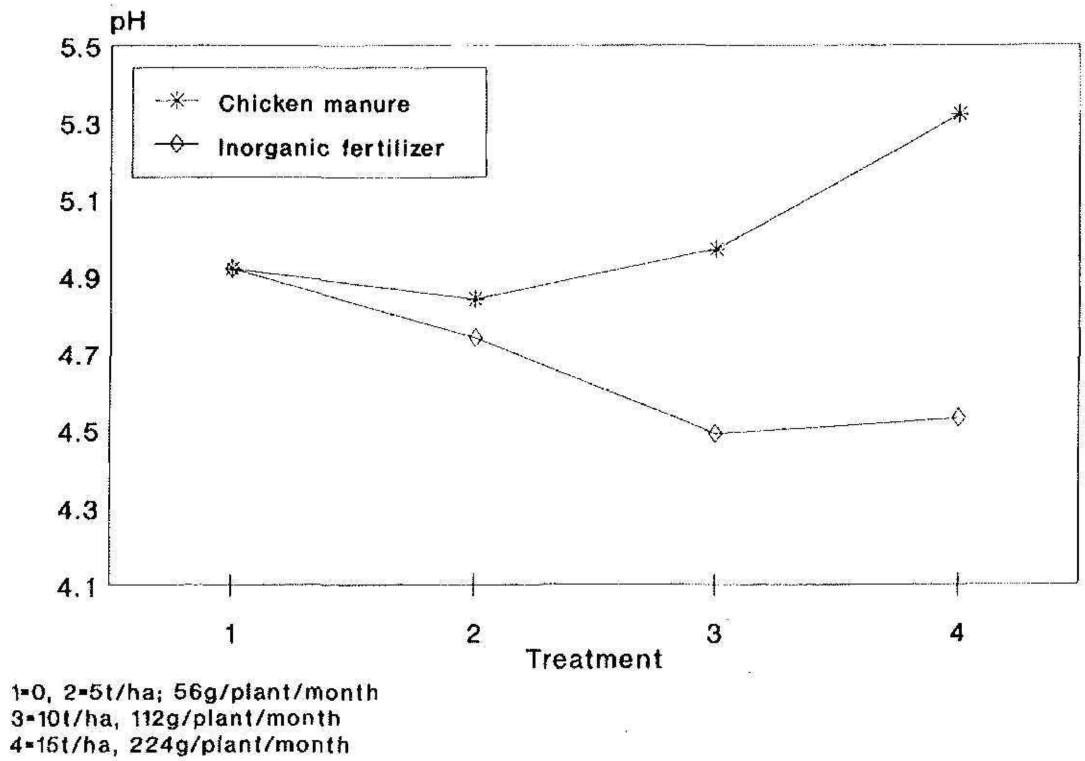

FIGURE 1. Effect of chicken manure and nitrogen fertilizer treatments on soil pH.

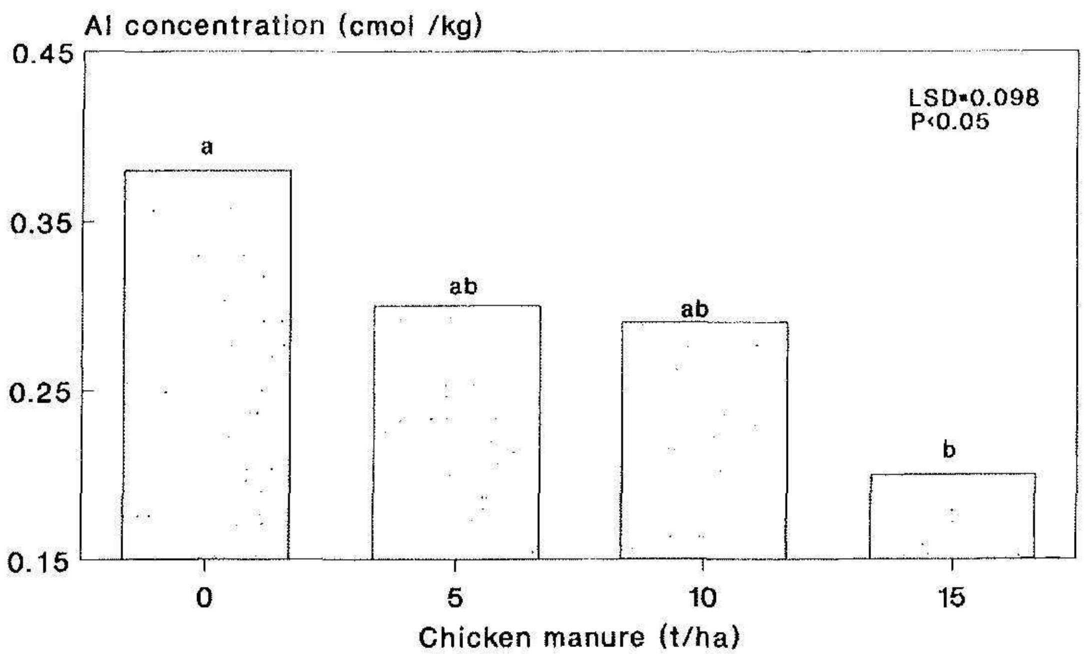

FIGURE 2. Effect of chicken manure on soil aluminum concentration.

crease in exchangeable aluminum (Figure 2). Exchangeable aluminum decreased significantly with chicken manure applications. The 0, 5, 10 and 15 t/ha of chicken manure treatments resulted in exchangeable aluminum content of 0.38, 0.30, 0.29 and 0.20 $cmol_c/kg$, respectively. However, the opposite effect was observed with the inorganic fertilizer treatments. The 0, 56, 112 and 224 g/plant/month of fertilizer treatments resulted in an aluminum concentration of 0.23, 0.25, 0.32 and 0.37 $cmol_c/kg$, respectively. The decrease in exchangeable aluminum observed in the chicken manure treatments from 0.38 to 0.20 $cmol_c/kg$ represented a decrease in aluminum saturation from 12.97% to 5.26%. In addition to the release of OH^- ions, aluminum ions are taken out of the soil solution. Aluminum detoxification may be possible by ligand exchange reactions that might occur between organic anions, which may result from the decomposition products of chicken manure and terminal hydroxils of iron and aluminum oxide in the soil (Hue and Amien, 1989; Parfitt et al., 1979). Similar reactions have been reported for organic anions like urate and phthalate, which are produced by microbial decomposition of the organic materials, which can detoxify aluminum (Hue, 1992). The organic anions produced by chicken manure are adsorbed by the soil and in return OH^- ions are released into the soil solution.

It is known that heavy phosphorus applications may increase soil pH. In our study, chicken manure significantly increased soil Bray-1

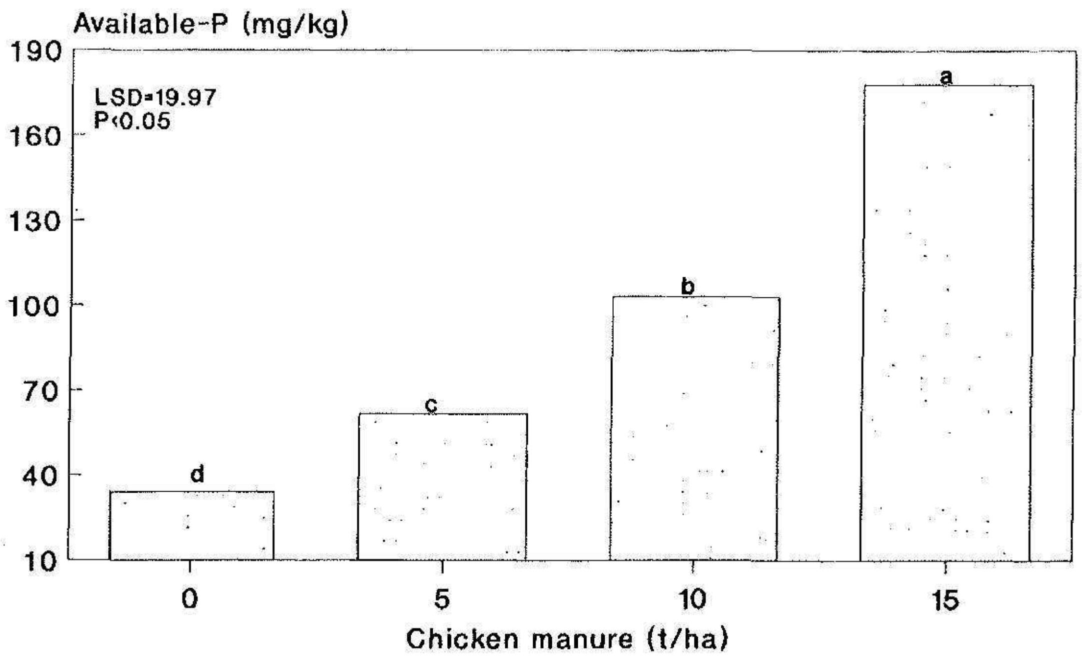

FIGURE 3. Effect of chicken manure on soil available phosphorus.

TABLE 1.—*Effect of chicken manure and fertilizer applications on soil exchangeable cations.*

Chicken Manure (t/ha)	Exchangeable Cations ($cmol_c$/kg) Ca	Mg	K
0	1.68c[1]	0.46b	0.41b
5	1.84bc	0.45b	0.50ab
10	2.04b	0.54ab	0.50a
15	2.42a	0.61a	0.57a
LSD	0.30	0.11	0.94
Fertilizer (g/plant/month)			
0	2.01	0.58	0.30d
56	2.09	0.49	0.45c
112	2.05	0.53	0.55b
224	1.82	0.45	0.67a
LSD	NS[2]	NS	0.94

[1]Means followed by the same letter in a column do not differ significantly at the $P \leq 0.05$ level.

[2]NS = No significance.

phosphorus. The check treatment had a phosphorus concentration of 34.18 mg/kg, whereas after the application of 15 t/ha of chicken manure the phosphorus concentration was 178.04 mg/kg (Figure 3). Earlier studies established the direct contribution of chicken manure to soil available phosphorus (O'Hallorans et al., 1993). Considering a phosphorus content of 1.30% in the manure, the application of 5, 10 and 15 t/ha represents a phosphorus addition of 65, 130 and 195 kg/ha. At the time of sampling the 56, 112 and 224 g/plant/month of fertilizer treatments had received a phosphorus addition of 65, 130 and 260 kg/ha, respectively. The phrase "liming with phosphorus" is frequently used in the literature referring to the increase in soil pH with the addition of phosphate fertilizer to acid soils (Sánchez and Uehara, 1980). Exchangeable aluminum reacts with phosphate fertilizer to form compounds with the general formula of variscite (Sánchez, 1981). Such increase is more evident in high phosphorus fixing Oxisols. However, in our study a significant decrease in soil pH was observed with increasing fertilizer rate as well as an increase in exchangeable aluminum. Consequently, the occurrence of variscite formation seems unlikely. Exchangeable basic cations increased significantly with chicken manure applications (Table 1). The increase in exchangeable potassium in manure amended soils has been strongly correlated with electrical conductivity (Liebhardt, 1976; Shortall et al., 1975). Aluminum ions in the soil are replaced by calcium, magnesium and potassium ions present in the manure. As a direct contribution from the fertilizer formulation 15-15-15, exchangeable potassium increased significantly. However, no significant differences were observed among fertilizer treatments for exchangeable calcium and magnesium.

The mechanisms involved in aluminum detoxification by animal manure require further study. Future research should address the mechanisms involved and the rates and frequency of manure application.

LITERATURE CITED

Abruña, F., R. W. Pearson and R. Pérez-Escolar, 1975. Lime response of corn and bean in typical Ultisols and Oxisols of Puerto Rico. p. 261-282. *In* Bornemiza and Alvarado (ed.) Soil Management in Tropical America. The University Consortium on soils of the Tropics, North Carolina State University, Raleigh.

Ahmad, F. and K. H. Kan, 1986. Effect of organic matter on soybean seedlings grown in aluminum toxic soil. *Soil Sci. Soc. Am. J.* 50:656:661.

Brogan, J. C., 1967. The effect of humic acid on aluminum toxicity. Trans. Int. Congr. Soil Sci., 7th 3:227-234.

Cabrera, F. and O. Tatibudeen, 1977. Effect of soil pH and organic matter on labile aluminum in soil under permanent grass. *J. Soil Sci.* 28:259-270.

Farina, M. P. W., M. E. Summer, C. O. Plank and W. S. Letzsch, 1980. Exchangeable aluminum and pH as indicators of lime requirements for corn. *Soil Sci. Soc. Am. J.* 44:1036-1040.

Foy, C. D.,1974. Effect of aluminum on plant growth. p. 601-642. *In* E. W. Carson (ed.) The plant roots and its environment. University Press of Virginia, Charlottesville.

Hoyt, P. B. and R. C. Turner, 1975. Effect of organic materials added to very acid soils on pH, aluminum, exchangeable cations and crop yield. *Soil Sci.* 119:227-237.

Hue, N. V. and I. Amien, 1989. Aluminum detoxification with green manures. *Commun. Soil Sci. Plant Anal.* 20:1499-1511.

Hue, N. V., 1992. Correcting soil acidity of a highly weathered Ultisol with chicken manure and sewage sludge. *Commun. Soil Sci. Plant Anal.* 23:(3&4)241-264.

Liebhardt, W. C., 1976. Soil characteristics and corn yield as affected by previous applications of poultry manure. *J. Environ. Qual.* 5:459-462.

López-Hernández, D., D. Flores, G. Siegert and J. V. Rodríguez, 1979. The effect of some organic anions on phosphate removal from acid and calcareous soils. *Soil Sci.* 128:321-326.

López-Hernández, D., G. Siegert and J. V. Rodríguez, 1986. Competitive adsorption of phosphate with malate and oxalate by tropical soils. *Soil Sci. Soc. Am. J.* 50:1460-1462.

Medina, A. and D. López-Hernández, 1978. Methods of desorbing soil phosphate for applications to p-desorption isotherm construction. *Trop. Agr.* (Trinidad) 55:69-76.

Morteson, J. L., 1963. Complexing of metals by organic matter. *Soil Sci. Soc. Am. Proc.* 27:179-186.

O'Hallorans, J. M., M. A. Muñoz and O. Colberg, 1993. Effect of chicken manure on chemical properties of a Mollisol and tomato production. *J. Agric. Univ. P.R.* 77(3&4):181-191.

Page, A. L., R. H. Miller and D. R. Keeney, 1982. Methods of soil analysis Part 2: Chemical and microbiological properties. Second Ed. Monograph No. 9. Amer. Soc. Agron., Madison, Wisconsin. 1159 p.

Parfitt, R. L., 1979. The availability of P from phosphate-goethite bridging complexes. Desorption and uptake by ryegrass. *Plant Soil* 53:55-65.

Sánchez, P. A. and G. Uehara, 1980. Management considerations for acid soils with high phosphorus fixation capacity. p. 471-514. *In* Khasawneh, Sample and Kamprath (ed.) The role of phosphorus in agriculture. ASA, CSSA and SSSA, Madison, Wisconsin.

Sánchez, P. A., 1981. Suelos del trópico: características y manejo. Primera Edicion. IICA, Costa Rica.

Shortall, J. C. and W. C. Liebhardt, 1975. Yield and growth of corn as affected by poultry manure. *J. Environ. Qual.* 4:186-191.

Wahab, A. and M. A. Lugo-Lopez, 1980. An approach to minimize Al toxicity in Ultisols through organic matter addition. *J. Agric. Univ. P.R.* 64(1):1-8.