Effect of chicken manure on chemical properties of a Mollisol and tomato production[1]

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ABSTRACT

An experiment was established on a San Antón soil (Cumulic Haplustolls) in southern Puerto Rico to evaluate the effect of chicken manure (0, 5, 10 and 15 t/ha) and nitrogen fertilizer (0, 56, 112 and 168 kg/h) on some soil chemical properties and tomato production. Chicken manure was broadcast and incorporated into the soil whereas urea, the nitrogen source, was applied by fertigation. A significant lineal effect was observed in exchangeable Mg^{2+} and K^{+}, electrical conductivity and Olsen available P with chicken manure applications. In the check treatment (no manure), exchangeable Mg^{2+} was 2.54 $cmol_c/kg$; exchangeable K^{+}, 0.99 $cmol_c/kg$; electrical conductivity, 0.79 mmhos/cm; and available P, 52.58 mg/kg. The application of 15 t/ha of chicken manure increased exchangeable Mg^{2+} to 2.70 $cmol_c$ kg, exchangeable K^{+} to 1.29 $cmol_c/kg$, electrical conductivity to 2.22 mmhos/cm and available P to 83.98 mg/kg. Soil pH decreased significantly with the same treatment from 7.50 in the check treatment to 6.98 in the 15 t/ha chicken manure treatment. Chicken manure increased soil exchangeable NO_3^- at a depth of 20 cm, but did not increase exchangeable NH_4^+. Application of chicken manure did not increase tomato yield significantly; however, it increased significantly the number of large and medium fruits. It is suggested that an exchangeable NO_3^- content of about 15 to 20 mg/kg is adequate for optimum tomato production in a San Antón soil.

RESUMEN

Ffecto de la gallinaza en las propiedades químicas de un Mollisol y en la producción de tomates

Se estableció un experimento en un suelo San Antón (Cumulic Haplustolls) del sur de Puerto Rico para evaluar el efecto de aplicaciones de gallinaza (0, 5, 10 y 15 t/ha) y nitrógeno inorgánico (0, 56, 112 y 168 kg/ha) en algunas propiedades químicas del suelo San Antón y en la producción de tomate. La gallinaza se aplicó a voleo y se incorporó al suelo; la urea, la fuente de nitrógeno inorgánico, se aplicó por fertigación. Se observó un efecto lineal significativo en el contenido de Mg^{2+} y K^{+} intercambiable, conductividad eléctrica y fósforo disponible. En el tratamiento testigo (sin gallinaza) el Mg^{2+} intercambiable era de 2.54 $cmol_c/kg$, el K^{+} intercambiable de 0.99 $cmol_c/kg$, la conductividad eléctrica de 0.79 mmhos/cm y el fósforo disponible de 52.58 mg/kg. La aplicación de 15 t/ha de gallinaza aumentó el magnesio intercambiable a 2.70 $cmol_c/$

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kg, el potasio intercambiable a 1.29 $cmol_c$/kg, la conductividad eléctrica a 2.22 mmhos/cm y el fósforo disponible a 83.98 mg/kg. El mismo tratamiento logró disminuir significativamente el pH del suelo. El pH disminuyó de 7.50 en el tratamiento control a 6.98 en el tratamiento de 15 t/ha de gallinaza. Las aplicaciones de gallinaza aumentaron el NO_3^- intercambiable en los primeros 20 cm de suelo, sin embargo, no se afectó el NH_4^+ intercambiable. No se observó efecto significativo de la gallinaza en la producción de tomate, pero si en el número de frutas grandes y medianas. Se sugiere que una concentración de NO_3^- intercambiable de 15 a 20 mg/kg sea adecuada para una producción óptima de tomate.

INTRODUCTION

Because poultry production has become one of Puerto Rico's most important industries, chicken manure disposal is a major problem. Proper management of this material is necessary to prevent damage to the environment. The risks of surface and groundwater contamination are of serious concern. A useful disposal of the manure is its use as a fertilizer. For years chicken manure has been applied to crops in place of nitrogen fertilizers or as a supplemental nutrient source (1,3,9,16,18).

Most of the research with chicken manure has been directed to its use as a nitrogen source with subsequent evaluation of the processes of mineralization and nitrification (4,5,7,15,16). Chicken manure may increase soil organic matter, exchangeable Mg^{2+} and K^+ and available P (2,9,14,18). Shortall and Liebhardt (14) found that chicken manure can also increase soil electrical conductivity to levels that may be detrimental to crops. Liebhardt (9) observed a significant increase in soil electrical conductivity with the application of 224 t of manure per hectare. He associated said effect with an increase in water extractable K^+. The same rate of manure also resulted in excessively high levels of available P. Bhangoo et al. (1) observed an increase in available P with chicken manure applications at a maximum rate of 9.0 t/ha.

In Puerto Rico some farmers use chicken manure as fertilizer for papaya, plantain, banana, vegetables and pastures (10). Studies have recently been conducted in Puerto Rico to evaluate the effects of chicken manure on crop production. Muñoz and Martínez (11) evaluated time and mode of application of chicken manure for plantain production. An adverse effect was observed during germination with the application of 7.26 kg manure per plant at planting. However, the same amount of manure split into three or four applications resulted in plant growth and yields similar to those of the check treatment (the recommended inorganic fertilizer treatment). Rafols et al. (13) obtained significant increases in papaya yields attributable to the application of chicken manure. The application of 10 and 15 t/ha resulted in papaya yields of 42.18 and 54.75 t/ha, respectively. The highest yield obtained with inorganic fertilizer (15-15-15) was 42.60 t/ha. The effect of manure applications on chemical properties of Puerto Rican soils needs further evaluation.

The objective of the study herein reported was to determine effects of chicken manure on some chemical properties of a San Antón soil, a Mollisol from the south coast of Puerto Rico. This is the most important soil series used for vegetable production. A second objective was to evaluate the effect of manure applications on tomato yield and quality. The tomato variety Capitán, which has shown great potential for summer planting, was used as the test crop (19).

MATERIALS AND METHODS

The experiment was established on a San Antón soil (fine-loamy, mixed, isohyperthermic, Cumulic, Haplustolls) from the south coast of the island. The mean annual temperature for this region is 26 °C and the mean precipitation is 474 mm. The experimental design was a randomized complete block arranged in a split plot. The main plots were four levels of nitrogen fertilizer (0, 56, 112 and 168 kg/ha); the subplots, four chicken manure levels (0, 5, 10 and 15 t/ha) for a total of 16 treatments. Urea, the nitrogen source used, was applied by fertigation. A low pressure drip irrigation system and silver-coated plastic mulch were used. Chicken manure was broadcasted and incorporated into the soil at a depth of 10 cm. Four soil samplings of the top 20 cm were performed at 1.5-month intervals to evaluate pH, exchangeable Ca^{2+}, Mg^{2+} and K^{+}, electrical conductivity and available P. The soil samples were air-dried and ground to pass a 20-mesh sieve prior to analysis. Exchangeable basic cations were extracted with 1N ammonium acetate buffered at pH 7. Calcium and magnesium were determined by atomic absorption and potassium by atomic emission (Perkin Elmer 2380). Soil pH was measured on a 2:1 soil:water ratio. Electrical conductivity was determined by extraction of a saturated soil paste (12); available P by extraction with sodium bicarbonate (Olsen method). Available P was measured colorimetrically by using a Beckman DU 68 Spectrophotometer. Two months after planting, soil samples were collected at two depths (0 to 20 cm and 20 to 40 cm) to determine exchangeable NH_4^+ N and NO_3^- N. Ammonium and nitrate were extracted with 2N KCl and analyzed by steam distillation (12).

Table 1 presents chemical analysis of the manure. Available nutrients were determined by following a methodology similar to that for the soil samples. Total nutrients were determined by a digestion with sulfuric acid and hydrogen peroxide. Nitrogen and phosphorus were analyzed colorimetrically, calcium and magnesium by atomic absorption and potassium by atomic emission.

Tomatoes were planted 1 week after the application of chicken manure. Each subplot consisted of three beds 4.57 m long and 1.83 m wide, with a row of 11 tomato plants (variety, Capitán) in each bed. Harvest began 2.5 months after planting. Tomatoes were harvested in 11 pickings

TABLE 1.—*Chemical anlysis of chicken manure*

Available nutrient (mg/kg)				
Phosphorus	Potassium	Calcium	Magnesium	pH
1799	16100	4343	4895	7.34
Total nutrients(%)				
Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
3.35	2.24	2.09	4.41	1.02

performed at intervals of approximately 7 days. Tomato fruits were classified by diameter: large > 72.60 mm; medium < 72.60 > 64.10; small < 64.10 > 55.66. Number and weight of fruits were noted for each classification.

RESULTS AND DISCUSSION

Soil pH decreased linearly with chicken manure applications (fig. 1). Average soil pH for the check treatment was 7.50, whereas for the 5, 10 and 15 t/ha treatments pH was 7.31, 7.16 and 6.98, respectively. Nitrifi-

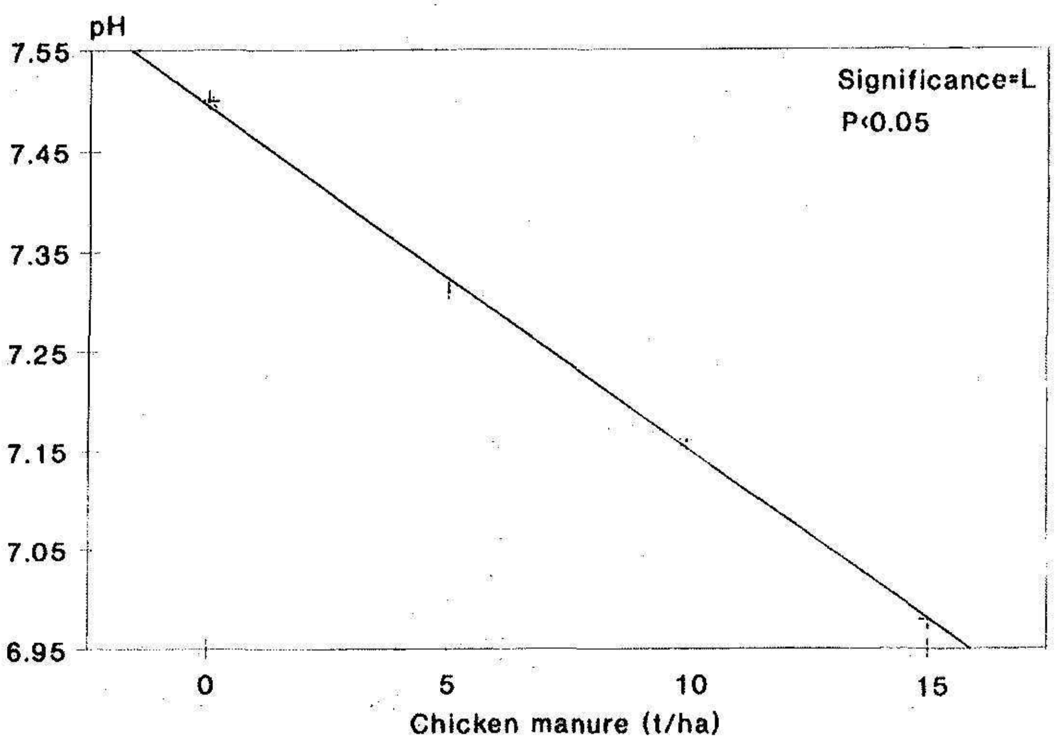

FIG. 1.—Chicken manure effect on soil pH

cation might be the major cause of the reduction in soil pH. During the transformation of NH_4^+ to NO_3^-, hydrogen ions are generated, causing acidification (17). Another factor influencing the pH is soil electrical conductivity. An increase in electrical conductivity also reflects an increase in the ionic strength of the soil solution, which favors the dissociation of H^+ ions from the surface charges (20). Figure 2 shows such an effect where soil pH decreases linearly as electrical conductivity increases.

Manure applications had a significant lineal effect on electrical conductivity (fig. 3). Before manure applications, electrical conductivity values fluctuated between 0.57 and 0.60 mmhos/cm. Applcations of 0, 5, 10 and 15 t/ha of manure resulted in conductivity values of 0.49, 1.20, 1.83 and 2.22 mmhos/cm, respectively. Several ions can contribute to increasing the electrical conductivity; however, the increase in exchangeable and water soluble K^+ has been strongly correlated with electrical conductivity in manure-amended soils (9,14). Our results indicated a linear increase in exchangeable K^+ with manure applications (table 2). Drip irrigation and rainfall influence the movement of salts into the soil profile, and thus the conductivity. For example, at 1.5 months after manure application (MAA) the 15 t/ha treatment showed a conductivity value of 2.81 mmhos/cm (fig. 4). On the second sampling (3.0 MAA), the conductivity was 2.43 mmhos/cm; on the third sampling (4.5 MAA) it was 1.42 mmhos/cm.

Exchangeable Mg^{2+} and K^+ increased significantly with manure applications; however, exchangeable Ca^{2+} decreased (table 2). This effect can

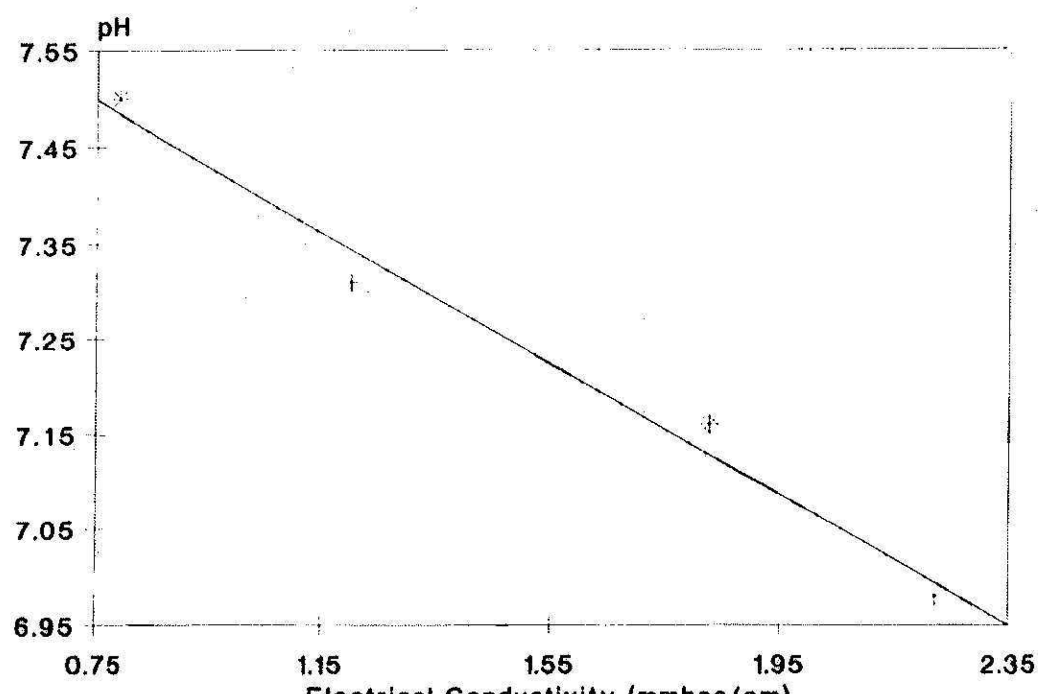

FIG. 2.—Relationship between pH and soil electrical conductivity

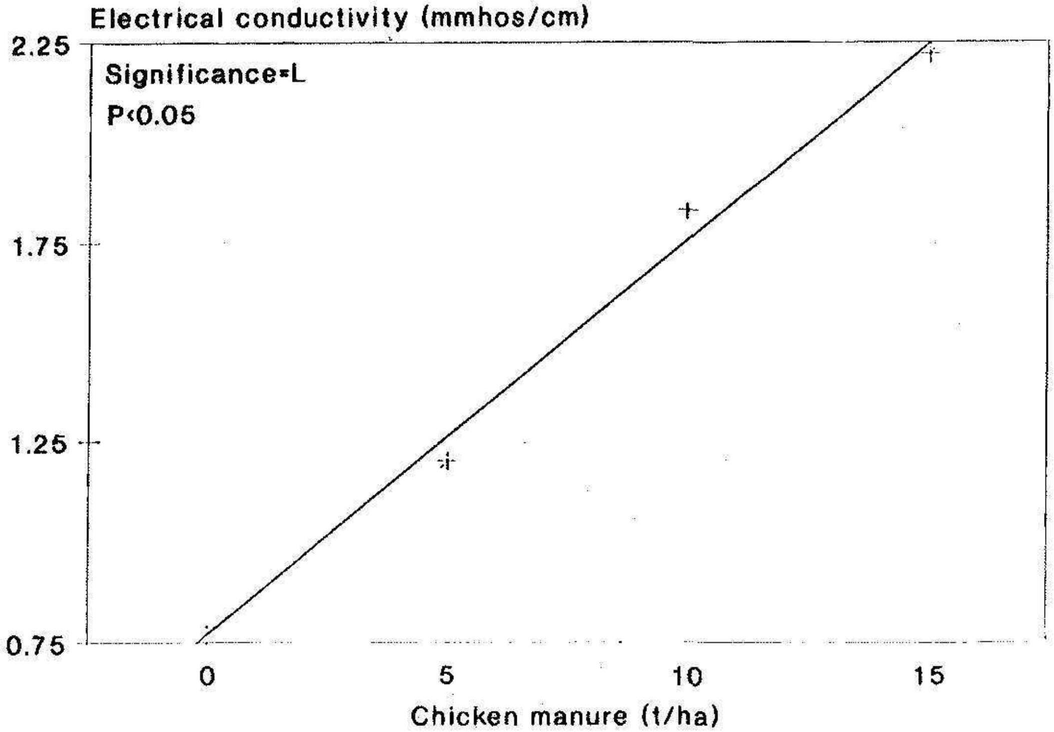

FIG. 3.—Chicken manure effect on soil electrical conductivity

be related to the reduction in pH and the increase in electrical conductivity. Calcium ions are replaced in the exchange sites of the soil by H^+ ions resulting from nitrification, and by Mg^{2+} and K^+ ions present in the manure. The Ca^{2+} in the manure is apparently less soluble than the Mg^{2+} and K^+. The chemical analysis of the manure (table 1) indicated that although the Ca^{2+} content in the manure was larger than the Mg^{2+} and K^+, the fraction considered available (ammonium acetate-extractable) was lower. The sum of cations remained constant. This finding indicates that the manure did not contribute significantly to the cation exchange capacity (CEC) of the soil (table 2).

TABLE 2.—*Effect of chicken manure on soil exchangeable Ca^{2+}, Mg^{2+} and K^+ and the sum of cations*

Manure t/ha	Ca	Mg	K	Sum of cations
		----------cmol$_c$/kg----------		
0	15.68	2.54	0.99	19.21
5	15.34	2.54	1.05	18.93
10	15.32	2.76	1.20	19.28
15	14.99	2.71	1.29	18.99
	L*	L	L	
$P < 0.05$				

(*L = Lineal effect)

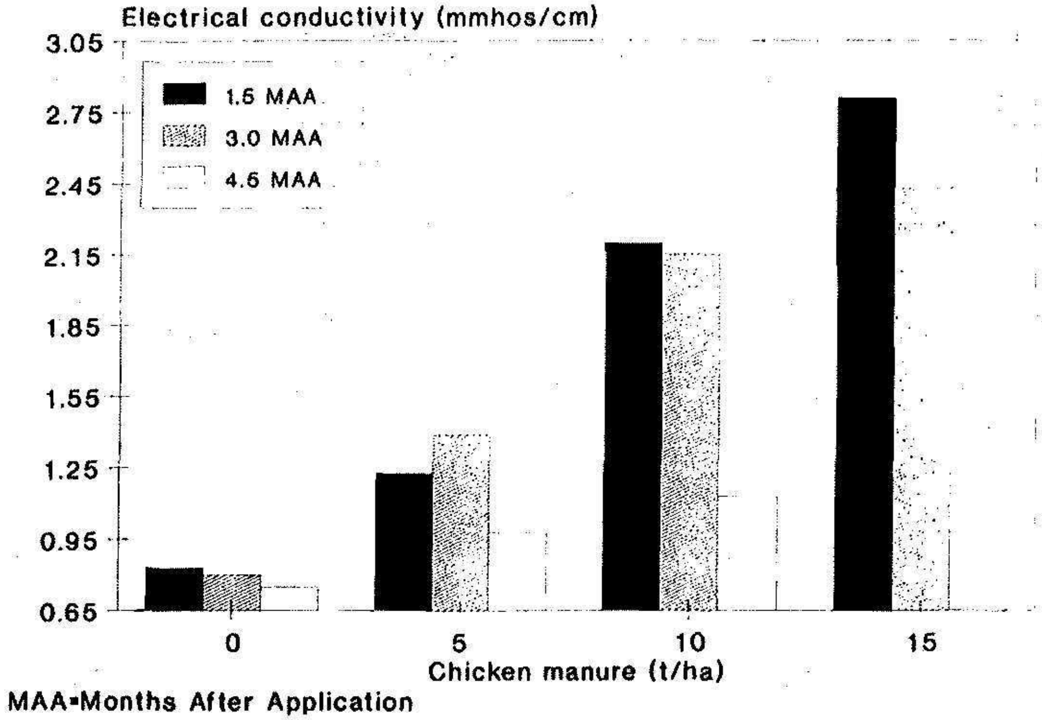

FIG. 4. Effect of manure applications and time of sampling on soil electrical conductivity

Soil available-P increased significantly with manure applications (fig. 5). This increase is partially the result of the phosphorus present in the manure (table 1). Also, the pH reduction may have enhanced the solubil-

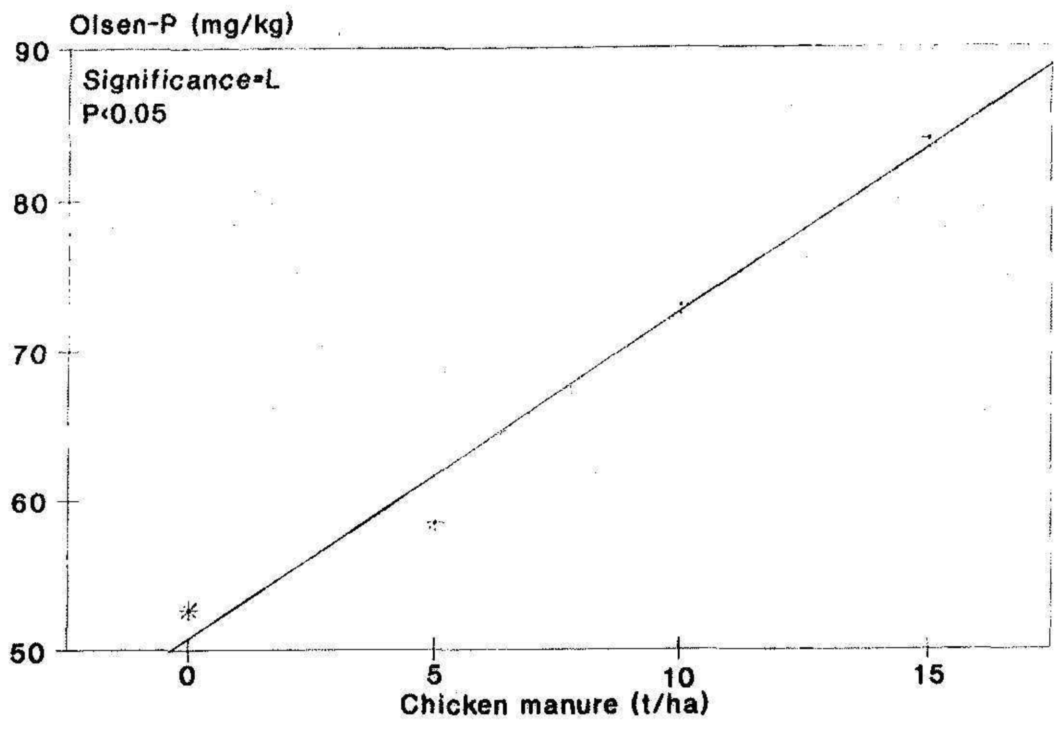

FIG. 5. Chicken manure effect on soil available P

ity of Ca and Mg phosphates present in the soil. Available P concentration decreased with time of sampling in the 5, 10 and 15 t/ha manure treatments. The first sampling (1.5 MAA) showed the highest concentration of available P. However, in the 4.5 MAA sampling an increase was observed over the 3.0 MAA sampling. This effect may be attributed to the application of phosphoric acid, used to clean the irrigation lines. After 6.0 months the available P levels were significantly lower than at 1.5 months (fig. 6). The decrease in available P observed after 6 months can be attributed to plant uptake and microorganism assimilation.

A significant lineal effect of manure applications was observed in exchangeable NO_3^- at a depth of 20 cm (fig. 7). The check treatment showed a value of 14.57 mg/kg and the 15 t/ha treatment 24.1 mg/kg. A significant effect was also observed in NO_3^- content at a depth of 20- to 40-cm depth (fig. 8). The check treatment presented a value of 3.5 mg/kg and the 15 t/ha 11.0 mg/kg. The NO_3^- present in the soil at a depth of 20 to 40 cm may be of limited use for tomato plants. Tomato roots develop in the first 20 cm of soil, especially when a plastic mulch is used (8). Therefore, exchangeable NO_3^- below that depth may be lost by leaching. Ammonium nitrogen did not vary significantly with chicken manure or nitrogen fertilizer applications. The lack of significant differences may be due to

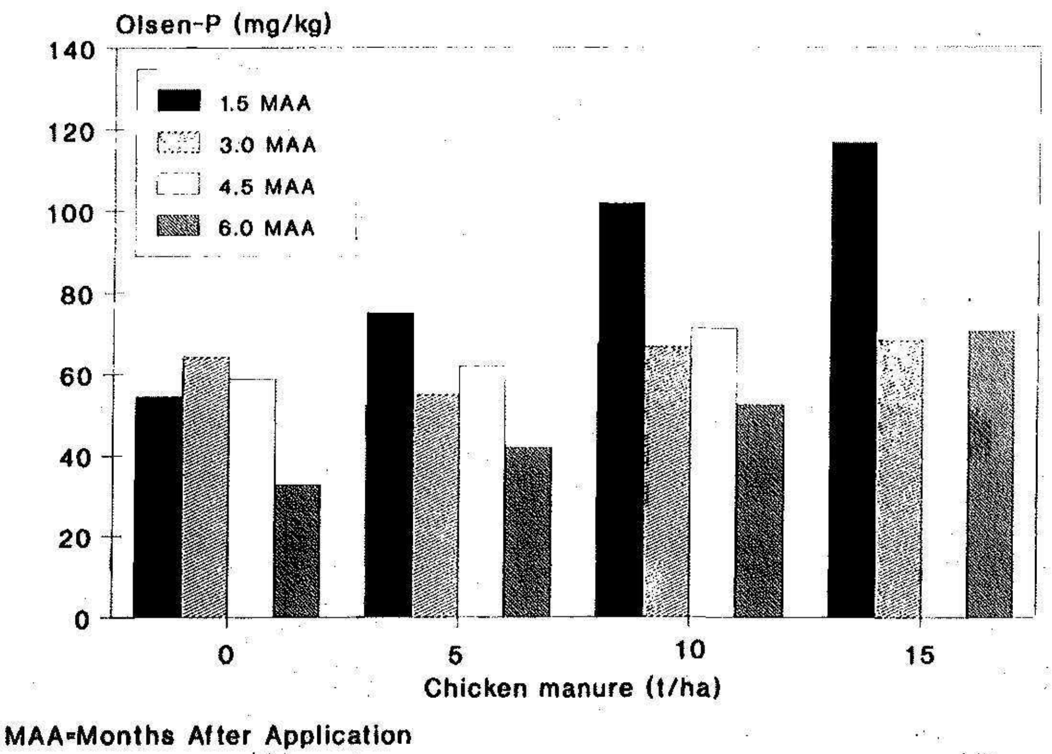

FIG. 6.—Effect of manure application and time of sampling on soil available P

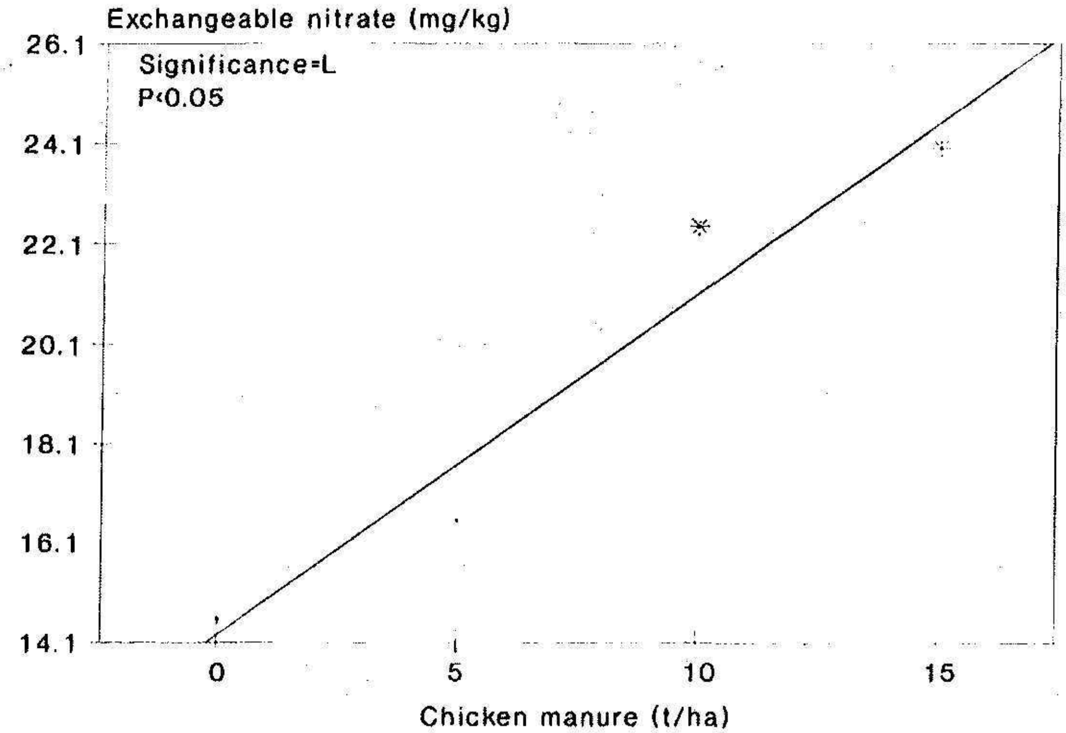

FIG. 7.—Chicken manure effect on soil exchangeable NO_3^- (0 to 20 cm)

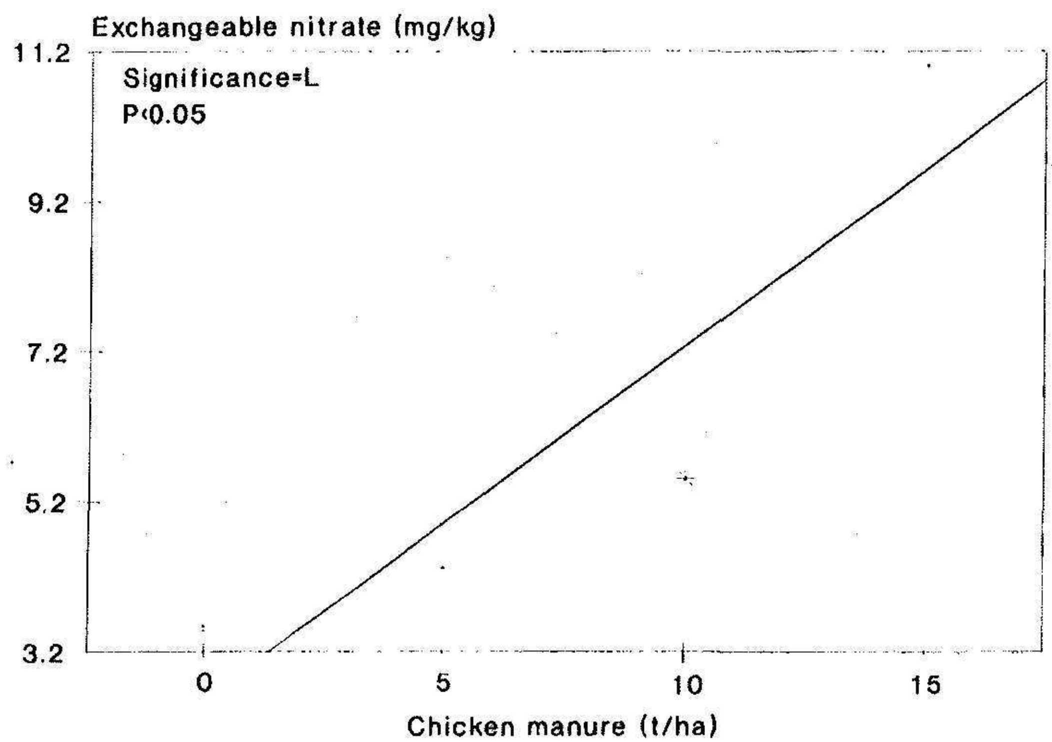

FIG. 8.—Chicken manure effect on soil exchangeable NO_3^- (20 to 40 cm

nitrification processes and nitrogen volatilization. No significant differences were observed in NO_3^- N content with nitrogen fertilizer applications.

No significant differences were observed in tomato production (table 3). However, manure treatments did increase significantly the number of large and medium fruits (table 4). The 15 t/ha manure treatment resulted in an increment of 10,615 large fruits and 30,807 medium fruits when compared to the check treatment. The high fertility of San Antón soil is determinant in the absence of significant differences. In our study exchangeable NO_3^- levels in the range of 15 to 25 mg/kg were associated with optimum tomato yields. Recent studies with corn (2,6), a more demanding crop in terms of nitrogen requirement, have shown that exchangeable NO_3^- N levels of 25 mg/kg were associated with optimum yields.

Chicken manure has a potential as an organic fertilizer because of its nutrient content. Its application to the soil in adequate amounts increases soil fertility and thus increases crop production. However, a farmer using chicken manure should be aware of the environmental problems that excessive accumulation and poor handling can cause. An excess of chicken manure applied to the crop can result in nutrient imbalance, salinity problems and nitrate losses by runoff and leaching.

TABLE 3.—*Effect of chicken manure and nitrogen fertilizer on tomato (t/ha) production*

	Nitrogen (kg/ha)				
Manure t/ha	0	56	112	168	X
0	79.9	87.0	89.4	84.8	85.2
5	91.2	91.4	95.8	89.2	91.9
10	91.1	91.7	100.2	84.7	91.9
15	93.0	84.6	96.9	88.4	90.7
X	88.8	84.6	95.6	86.6	

TABLE 4.—*Effect of chicken manure on tomato fruit number and size (fruits/ha).*

Manure t/ha	Large	Medium	Small
0	35,863	195,980	150,336
5	44,979	217,233	163,703
10	45,875	224,447	166,915
15	46,028	226,787	157,053
	L*	L	L

(*L = Lineal effect; NS = no significance).

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