THE EFFECT OF CHICKEN MANURE AND FERTILIZER ON SOME SOIL CHEMICAL CHARACTERISTICS

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ABSTRACT

THE EFFECT OF CHICKEN MANURE AND FERTILIZER ON SOME SOIL CHEMICAL CHARACTERISTICS

By

Pedro Godz

Soil samples from the surface down to 42 inches at 6 inch increments were taken from a field experiment involving one rate of fertilizer (150+66+126, N+P+K) and four rates of chicken manure (5.8, 11.6, 23.2, and 46.4 T/A).

The samples were analyzed for pH, nitrates, total nitrogen, total carbon, carbonates, chlorides, exchangeable ammonium, and available calcium, potassium, magnesium, sodium, iron, manganese, zinc, copper, and phosphorus.

The effect of manure on the soil chemical properties was great and significant, both in the surface and the subsurface horizons. The highest rate of manure naturally had the most significant effects. The nitrate, total carbon, total nitrogen, exchangeable ammonium, available phosphorus, potassium, sodium, zinc, and copper contents of the soil were increased by the treatments. The pH was lowered. The use of manure did not

significantly affect the chloride, carbonate, and available calcium, magnesium, manganese, and iron contents of the soil.

Generally speaking, the greatest changes caused by the treatments occurred in the surface soil samples, 0-6 and 6-12 inches, except for soil pH, nitrates, and total nitrogen which varied significantly throughout the profile.

Fertilizer had a statistically significant lowering effect upon soil pH at some depths and an increasing effect on nitrates in the 36-42 inch depth. It had little effect upon the other soil characteristics considered.

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Pedro Godz

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To Ema Margarita

To my wonderful wife for her continuous support, understanding and help during the 20 months at Michigan State University.

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INTRODUCTION

Manure is used for several reasons including the fact that it is a source of plant nutrients. This has been the case since the beginning of agriculture because frequently crop yields were increased with its use.

Today, there is an increasing interest in manure because of its close relationship to the quality of the environment. The interest is now more intense because of the increasing amounts of manure that are now produced by cattle, swine, and poultry on single farms which frequently are concentrated within small geographical areas. People are now vitally concerned about possible contamination of the air, soil, and water.

Manure contains large amounts of water-soluble or biodegradeable products that can contribute to the pollution of ground water when the products are leached through the soil. This hazard increases with the amount of manure used.

Manure applied to the soil causes changes in the physical, chemical, and biological characteristics of the soil. For the most part, the changes represent an improved condition for crop production. When manure is applied at high rates for an extended period of time, the changes in condition of the soil could result in decreased crop yields.

Manure should be used in such a way and at such a rate that there is little opportunity for the yields or quality of crops to be reduced and that the quality of the environment is not decreased.

The purpose of this investigation was to determine changes in the chemical condition of the soil as affected by the conventional use of commercial fertilizer and the use of both conventional and high to very high rates of poultry manure.

LITERATURE REVIEW

Manure and Crop Yields

Manure has beneficial effects upon the yields of many crops all over the world.

In 1927, D. W. Pitman and J. F. Fonder (32) said that "farm manure is of value to sugar beets not so much for its organic matter content or for its physical or bacteriological effect upon the soil as for the nitrogen it contains."

In 1930, D. W. Pitman (33) showed a high correlation between sugar beet yields and soluble phosphorus and nitric nitrogen which were derived from manure.

B. L. Brage, *et al*. (4) in 1952 reported on the effects of barnyard manure applied at different rates for a 30 year period on the yield of several crops, all of which were increased.

J. R. Guttay, *et al*. (11) in 1956 reported on crop yields being increased by manure applied every 2, 4, and 6 years. The effect of the manure was highest with the most frequent applications.

J. T. Cope, *et al*. (8) in 1958 showed increased yields of corn and cotton due to the application of both animal and green manures and from commercial fertilizer.

They showed that 5 T/A of manure for corn was equivalent to 57 pounds of commercial nitrogen. For cotton the manure was equivalent to 62 pounds. This work summarized 18 years of treatment.

C. W. Carlson, et al. (6) in 1961 reported on the effect of manure on corn, forage, and grain yields. The manure was applied to an undisturbed soil and to a soil where the surface horizon was cut and removed from location. There was a positive linear correlation between amount of manure used and yield from the cut plots. There was no significant increase in yield from the plots with the undisturbed soil.

R. F. Bishop, et al. (2) in 1962 reported on the results of long-term applications of manure and commercial fertilizer which had been applied since 1937 in Nova Scotia, Canada. There were increased yields of potatoes, oats, and hay. The greatest effect was on potatoes.

R. A. Hedlin and A. O. Ridley (15) in 1964 reported 6 years of results on the effect of both fertilizer and manure on the yield of several crops grown in a crop sequence experiment. Manure used at the rate of 8 T/A substantially increased crop yields.

R. L. Halstead and F. S. Sowden (13) in 1968 published their summary of 20 years work on the application of different sources of organic matter to both sand and clay soils. The highest yields were from the manure treatments which were accompanied by an increase in N and P uptake by the crops.

J. Muller (27) in 1964 showed the results of a long-term experiment with mineral fertilizer and manure in France. The author reported that mineral fertilizers employed alone in sufficient quantity were able to produce higher yields than those obtained with the use of manure alone.

K. Rauhe (36) reported in 1964 the effect of different manurial and fertilization managements in a long-term experiment. He showed that manure alone maintained the soil fertility and crop yield levels, but that manure and fertilizer together resulted in an increase in humus and nitrogen contents of the soil.

J. Sarkadi, et al. (40) in 1964 reported on the results of using 35 T/Ha of farmyard manure every 4 years, compared with other treatments. The average yield of the manured plots for the first 4 years of experiment was 16% higher than from the check plots, but the application of manure with mineral fertilizer produced a 38% yield increase.

R. Wabersich (44) in 1964 reported similar results.

Summarizing, it seems that commercial fertilizer alone used at low or medium rates is able to cause higher yields than manure alone, but that the combination of fertilizer plus manure is likely to result in the highest yields. Not any of the research involved the use of high rates of manure (25 T/A or more) on an annual basis.

Manure and Soil Carbon and Nitrogen

In 1943 G. R. Muhr, et al. (26) reported significant differences in the nitrogen and oxidable material in soil from plots established in 1921. There was a decrease in nitrogen and oxidable material in the soil representing the surface 6 inches and treatments involving manure and manure plus lime.

In 1947 J. Kubota, et al. (18) presented results from an experiment established in 1912 on a Tripp very fine sandy loam. The experiment involved different cropping and manurial practices. In the check plot there was a 30% decrease in total soil nitrogen. Twelve T/A of manure applied every 3 years did not maintain the nitrogen level in the surface soil. Oxidable materials in the soil were reduced as were the nitrifiable materials.

In 1952 B. L. Brage, et al. (4) reported similar reductions in nitrogen and carbon after 30 years of manure applications.

J. T. Cope, Jr., et al. (8) in 1958 published on changes in the soil nitrogen and carbon contents of the soils after 30 years of manure applications. Five T/A of horse manure increased the soil carbon content 33%

and the soil nitrogen content 62%. The C/N ratio changed from 21 to 17.

R. A. Young, et al. (45) in 1960 showed the results of a long-term experiment involving both manure and fertilizer in a 4 year rotation. Manure was used at a 7-10 T/A rate and applied before corn in the rotation. The experiment was located on a Fargo clay. In this experiment the soil carbon and nitrogen declined 27% in the check plots and 20% in the manured plots. There was no change in the C/N ratio. The nitrification capacity of the soil was correlated with the total nitrogen content.

In contrast, R. F. Bishop, et al. (2) in 1962 reported that 30T/A every 3 years over a 20 year period maintain the nitrogen and organic matter contents of the soil.

R. L. Halstead, et al. (13) in 1968 in Canada showed that after 20 years, the use of 11.1 T/Ha of manure increased the carbon and nitrogen contents, and the nitrification capacity of the soil.

Again in contrast, D. F. Rothwell and C. C. Hortenstine in 1969 (38) reported that the nitrification rates decreased. Chicken manure was used in these laboratory experiments.

In 1970 R. J. Olsen, et al. (30) with laboratory experiments under aerobic conditions, reported increased nitrate production, with increasing rates of manure application, but the reverse under anaerobic conditions. The experiment utilized manure up to 621 T/A.

In 1971 D. C. Adriano, _et al_. (1) reported on the NO_3^--nitrogen of the ground water under corrals and under land utilized for disposal of dairy cattle manure. The NO_3^--nitrogen of the water was in excess of the 10 ppm, the limit recommended by the PHS for safe drinking water. T. J. Concannon and E. J. Genetelli (7) in 1971 reported similar results.

J. Muller (27) in 1964 also reported on losses of nitrogen from manured soils.

K. Rauhe (36) in 1964 showed that the use of manure compensates for the usual loss of nitrogen and humus that occurs in crop production. In combination with fertilizer the nitrogen and humus contents of the soil may increase.

R. Wabersich (44) in 1964 showed a positive correlation between carbon and nitrogen levels and yields. The highest fertility levels were obtained with the use of both manure and fertilizer.

L. S. Murphy, _et al_. (28) in 1972 reported large accumulations of nitrogen in the soil profile due to heavy applications of manure. They used up to 720 T/Ha (dry weight). Nitrates tended to collect in the soil profile at about 1.8 meters. At such rates of application, the total nitrogen naturally increased greatly. They predicted a continued nitrate penetration into the soil for a number of years.

Manure and Exchangeable Calcium, Magnesium, Sodium, and Potassium

G. R. Muhr, et al. (26) in 1943 reported an increase in exchangeable calcium in the soil when lime was used with manure. Otherwise calcium levels were not affected.

J. Kubota, et al. (18) in 1947 reported an increase in exchangeable potassium levels in treatments involving 120 and 180 T/A of manure over a 30 year period. Similar results were found by G. K. Smith and S. S. Obenshain (39) in 1948 in Virginia.

B. L. Brage, et al. (4) in 1952 showed increased exchangeable calcium, magnesium, sodium, and potassium levels in the soil, after 30 years of manure applications.

R. F. Bishop, et al. (2) in 1962 reported increases in the exchangeable calcium and magnesium levels in the soil after the use of up to 30 T/A of manure for 20 years.

R. L. Halstead and F. S. Sowden (13) in 1968 measure increased amounts of exchangeable calcium, magnesium, and potassium after 20 years of manure applications on both sand and clay soils.

Similar results were obtained by R. J. Olsen, et al. (30) who reported on their work in 1970.

L. H. Hileman (16) in 1971 discussed his results from the use of poultry manure applied at 5, 10, 15, and 20 T/A on three different soil series the Ruston, Captina, and Sharkey. The changes in soil potassium were greater than for calcium and magnesium. The changes in potassium levels were greatest in the Ruston and Captina series. The calcium level was significantly decreased in the Sharkey series but increased in the other two soils. Similar trends were shown with magnesium. In the Sharkey series plants presented symptoms of magnesium deficiency where the higher rates of manure were used.

L. S. Murphy, _et al_. (28) in 1972 showed the results of 2 years of work with beef feedlot solid wastes. The rates of applications were 0, 22, 45, 90, 180, 360, and 720 T/Ha on a dry weight basis. Both total sodium and exchangeable potassium in the top 30 cm of soil were linearly related to rates of application.

Manure and Micronutrients

M. B. Parker, _et al_. (31) in 1969 reported on the use of chicken manure in soybean production. They found manganese toxicity and measured high levels of water-soluble soil and leaf manganese on the check plots. The application of chicken manure slightly decreased the soil acidity and produced normal appearing plants.

B. L. Brage, <u>et al</u>. (4) in 1952 observed an increased available manganese level in a long-time experiment involving manure.

C. W. Carlson, <u>et al</u>. (6) in 1961 showed that zinc used with manure gave no yield response, but that it produced yield increases without manure. They said "it appears that the zinc contained in the manure was sufficient for plant needs."

In 1958, M. H. Miller and A. J. Ohlrogge (24,25) demonstrated the presence of water-soluble chelating agents in manure and in other organic materials. They concluded from a nutrient solution experiment that chelating agents held zinc and iron in a form that was less available to plants than ionic forms. The addition of manure and water extract of manure to a Brookston soil decreased the availability of zinc and copper but increased the availability of manganese.

K. H. Tan, <u>et al</u>. (42) in 1971, found complexing agents in sewage sludge treated with 0.1 N NaOH and then separated into high and low molecular weight fractions. The low molecular weight fraction had a high complexing capacity. The stability constant increased with increasing pH levels 1.8 at pH 5.5 to 6.8 at pH 7.0. There were coordinate covalent bounds between OH^- groups and zinc and electrovalent linkages between COO^- groups and zinc.

K. H. Tan, et al. (41) in 1971 reported on the metal complexing capacity and the nature of the chelating ligands of organic matter extracted from poultry litter. The extraction was made with water. Approximately 25% of the dried litter was water soluble. The extraction had a chelating effect on copper, zinc, magnesium, and aluminum. The organic matter complexed by the cations increased with increasing pH. The stability constants were increased with increasing pH levels. The stability decreased in the order of copper>zinc>magnesium. The extraction from the poultry litter showed the property to complex aluminum and iron from insoluble Al_2O_3 and Fe_2O_3. The metal complex formation involved carboxyl electrovalent linkages and probably hydroxyl and/or amino coordinate linkage.

L. S. Murphy, et al. (28) said that in soil of the Great Plains area with high pH levels and with applications of 20 T/Ha of manure, the problem of iron and zinc deficiencies are usually solved.

Manure and Phosphorus

W. H. Metzger (23) in 1939 reported an increase in easily soluble phosphorus on old manured plots.

J. Kubota, et al. (18) in 1947 showed the results of a long-term experiment where the amount of soluble phosphorus in the soil was related to the amount of manure used.

R. A. Young, et al. (45) in 1960 published on their long-time plots on a Fargo clay soil. The extractable phosphorus declined appreciably in the check plots, but less in the manured plots. The organic phosphorus decreased in all plots but not as greatly where the manure was used.

H. J. Hass, et al. (12) in 1961 discussed the effect of manure on changes in phosphorus levels of some Great Plains soils. In North Dakota, cropping reduced the total phosphorus levels by 8% but on the manured plots there was a 14% increase. Manure increased the inorganic phosphorus levels but had no effect on reducing the loss of organic phosphorus. The $NaHCO_3$ soluble phosphorus averaged nearly five times that of a virgin sod soil.

R. A. Hedlin and A. O. Ridley (15) in 1964 reported on the effect of crop sequence, manure and fertilizer upon phosphorus levels. Manure alone increased the levels of $NaHCO_3$-extractable phosphorus more than manure plus ammonium phosphate and more than ammonium phosphate alone. The crop yields however were similar.

R. J. Olsen, et al. (30) in 1970, in a laboratory experiment with manure, reported an increase in the available phosphorus levels in the soil from the use of manure.

In 1962, R. F. Bishop, et al. (2) showed an increase in absorbed and easily acid-soluble phosphorus.

L. S. Murphy, et al. (28) in 1972 reported a very large accumulation of absorbed and available phosphorus where heavy rates of manure, up to 720 T/Ha on a dry weight basis, had been used. Weak acid extractable phosphorus levels were as high as 600 ppm. Movement or accumulation of phosphorus was restricted in most cases to the surface 20 cm of soil.

Manure and Soil pH and Cation Exchange Capacity

W. H. Metzger (23) in 1939 reported an increase in cation exchange capacity due to the use of livestock manure.

J. Elson (9) in 1940 also reported an increased cation exchange capacity. His studies were conducted on plots that had received treatments for 30 years.

G. R. Muhr, et al. (26) in 1943 reported a significant increase in soil pH but no change in cation exchange capacity after 16 years of manuring. In this research lime was used with the manure.

B. L. Brage, et al. (4) in 1952 presented results from a long-time experiment with manure. Their treatments increased both the pH level and the cation exchange capacity of the soil.

R. F. Bishop, et al. (2) in 1962 showed increased soil pH for plots receiving 10, 20, and 30 T/A of manure every 3 years for a 30 year period.

R. L. Halstead and F. S. Sowden (13) in 1968 reported increased soil pH levels and cation exchange capacities in plots where 11.1 T/Ha of manure were used over a 20 year period.

L. H. Hileman (16) in 1971 reported on the effect of different rates of poultry manure on some soil chemical properties. The amounts of manure used were 5, 10, 15 and 20 T/A on three soils. There was a rapid increase in soil pH on all soils which was followed by a slight decrease in levels. After 7 months the soil pH was still higher than previous to the application of manure for two soils where the original pH was acid, on the third soil with a neutral reaction the soil became more acid.

Manure and the Physical Condition of the Soil

Several of the researchers, who have already been reviewed, noted that the use of manure, on occasions, affected the physical condition of the soil. From a plant growth viewpoint, the effect upon the physical condition may be as great as the effect upon the chemical condition. The following references all pertain to the effect that manure can have upon the physical condition of the soil: J. Elson (9); J. Elson (10); J. R. Guttay, *et al*. (11); A. P. Mazurak, *et al*. (21); A. P. Mazurak, et al. (22); P. J. Salter, et al. (39); R. A. Young, et al. (45).

MATERIALS AND METHODS

In 1967 Dr. Lynn S. Robertson of the Department of Crop and Soil Sciences and Dr. J. Wolford of the Poultry Department initiated a field experiment involving the use of chicken manure. The plots were located in Huron County, Michigan. The purpose was to determine how much chicken manure could be used before corn yields would be adversely affected.

The soils in the plot area were mapped as Breckenridge loam (Mollic Haplaquepts) and Parkhill loam (Mollic Ochraquepts) both naturally poorly drained. The field where the plots were located was tile drained in 1957. The depth varied between 3 and 4 feet.

The experiment was terminated in 1971. This is one of the summaries of the work.

The treatments were:

A--No manure and no fertilizer (check)

B--150+66+126 lbs/A (N+P+K)

C--5.8 T/A chicken manure

D--11.6 T/A chicken manure

E--23.2 T/A chicken manure

F--46.4 T/A chicken manure

Treatment F was incorporated into the experiment in 1968, one year after the others were initiated.

The plot design was a randomized block with 4 replications. The size of each plot was 28 x 80 feet. Manure and fertilizer were applied to the treatments B-C-D and E in the spring and fall of 1967 and in the fall of 1968, 1969, and 1970. All manure applications for treatment F were made in the fall of 1967, 1968, 1969, and 1970, after the corn had been harvested.

The chemical characteristics of the chicken manure utilized in the experiment are shown in Table 1.

TABLE 1.--Chemical characteristics of chicken manure.*

Chemical		% expressed on "as-received" basis		
Water	(H_2O)	72.01	to	74.01
Nitrogen	(N)	1.00	to	1.50
Phosphorus	(P)	0.68	to	0.71
Potassium	(K)	0.70	to	0.74
Calcium	(Ca)	2.79	to	3.01
Magnesium	(Mg)	0.26	to	0.29
Copper	(Cu)	0.00009	to	0.00011
Iron	(Fe)	0.22	to	0.25
Manganese	(Mn)	0.008	to	0.008
Sodium	(Na)	0.24	to	0.24
Zinc	(Zn)	0.13	to	0.16
	pH	7.17	to	7.33

*Data from Robertson and Wolford (37).

The water content of the manure may be as much as 10% higher during warm weather. The other values shown remain similar throughout the year. It is necessary to point out the similarity in phosphorus and potassium levels. This is in contrast with manure from other classes of animals. The data are from a cage laying operation. The manure contained no bedding.

The amount of nutrients incorporated into the soil each year and for the 5 year period of the experiment are shown in Tables 2 and 3.

The data in Tables 2 and 3 were calculated from the averages of the chemical composition of the chicken manure.

Soil Sampling

In November, 1971, after the corn was harvested, each experimental plot was sampled. The soil profile samples were taken at 6 inch increments down to a depth of 42 inches.

The same day the samples were taken, they were spread out in the greenhouse on 25 pound paper bags to dry. The samples were mixed twice a day to accelerate the drying process. After becoming air dry, the samples were crushed and screened and then stored in new pint plastic ice cream containers.

TABLE 2.--Nutrients applied in fertilizer and manure each year (lbs/A).*

Nutrients	Treatments				
	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A
N	150.0	145.0	290.0	580.0	1160.0
P	66.0	81.2	162.4	324.8	649.6
K	126.0	84.1	168.2	336.4	672.8
Ca		336.4	672.8	1345.6	2691.2
Mg		32.48	64.96	129.92	259.84
Cu		0.0116	0.0232	0.0464	0.0928
Fe		27.8	55.7	111.4	222.7
Mn		0.928	1.856	3.712	7.424
Na		27.84	55.68	111.36	222.72
Zn		16.8	33.6	67.3	134.5

*Data from Robertson and Wolford (37).

TABLE 3.--Total nutrients applied in fertilizer and manure in 5 years (lbs/A).

Nutrient	Treatments				
	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A
N	750.0	725.0	1450.0	2900.0	4640.0
P	330.0	406.0	812.0	1624.0	2598.4
K	630.0	420.5	841.0	1682.0	2691.2
Ca		1682.0	3364.0	6728.0	10764.8
Mg		162.4	324.8	649.6	1039.36
Cu		0.058	0.116	0.232	0.3712
Fe		139.2	278.4	556.8	890.9
Mn		4.64	9.28	18.56	29.696
Na		139.2	278.4	556.8	890.88
Zn		84.1	168.2	336.4	538.2

Soil Reaction

A pH meter, model DR Sargent, was used for pH determinations. Ten grams of air dry soil and 10 cc of distilled water in a 50 cc beaker were stirred and allowed to react for 30 minutes. The measurements were made with the aid of a magnetic stirrer.

Phosphorus

Bray's P 1 method was used with a 1:7 soil-extracting solution ratio. The extracting solution was 0.025 N NH_4F and 0.03 N HCl. A Chloromolybdic acid-boric acid solution was used to develop the blue color. F-S solution was used as reductor. 2.85 grams of soil were placed in a 125 cc Erlenmeyer flask with 20 cc of extracting solution. This was shaken for 5 minutes on a rotatory shaker at 200 RPM. The suspension was filtered through a No. 42 paper. An aliquote varying between 2 and 10 cc depending upon the phosphorus concentration, was poured into a 50 cc volumetric flask. The volume was then made to about 20 cc with distilled water. Then 2 cc of F-s reducing agent was added and the flask shaken. After this, the volume was completed to 48 cc with distilled water and 2 cc of chloromolybdic acid-boric acid was used to make up to volume and to develop the blue color. The solution then was shaken again. Measurements were made between 15 and 30 minutes after the addition of the chloromolybdic-boric acids solution with an Evelyn photoelectric colorimeter containing a 660 mμ filter.

A standard curve was made with solutions of 0.0, 0.5, 1.0, 2.0, and 3.0 ppm of phosphorus. The results were plotted on semilogaritmic paper.

Sodium and Potassium

The NH_4Ac 1 N, adjusted to pH 7, was used to extract Na and K. Five grams of soil were placed into a 125 cc Erlenmeyer flask with 50 cc of extracting solution. This was shaken for 60 minutes on a rotatory shaker at 200 RPM. The suspension was filtered through a No. 2 paper. Aliquotes varying from 2 to 10 cc of the filtrate, depending upon the concentration of sodium and potassium, were added to a 25 cc volumetric flask and made to volume with distilled water. The determination was made with a Coleman model 21 flame photometer.

Standard curves were made with solutions of 0, 2, 4, 6, 8, and 10 ppm of sodium and 0, 2, 4, 6, 8, and 10 ppm of potassium. The results were plotted on a milimetric paper with ppm of sodium or potassium vs percent transmition.

Calcium and Magnesium

One N NH_4Ac adjusted to pH 7 was used as an extracting solution. Five grams of soil were placed into a 125 cc Erlenmeyer flask with 50 cc of extracting solution. This was shaken for 60 minutes on a rotatory shaker at 200 RPM. The suspension was filtered through a No. 2 paper. A 0.5 cc aliquote and 5 cc of a 60,000 ppm of La_2O_3 solution were added to a 25 cc volumetric flask, and then diluted to 25 cc with distilled water. The evaluation was made with a Perkin Elmer model 303 atomic absorption spectrophotometer.

A standard curve for calcium was made with solutions of 0, 1, 2, 4, 6, 8, and 10 ppm of calcium. The results were plotted on semilogaritmic paper, ppm of calcium vs absorbance.

A standard curve was made with solutions of 0.0, 0.25, 0.5, 1.0, 1.5, 2.0, and 2.5 ppm of magnesium.

Iron, Manganese and Zinc

Hydrochloric acid 0.1 N, was used for extracting these metals. Two grams of soil were placed into a 125 cc Erlenmeyer flask with 20 cc of extracting solution. This was shaken for 30 minutes on a rotatory shaker at 200 RPM. The suspension was filtered through a No. 2 paper. The measurements of iron, manganese and zinc were made with a Perkin Elmer model 303 atomic absorption spectrophotometer.

Standard curves were made with solutions of 0.0, 0.1, 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.0 ppm of iron, manganese or zinc, and plotting ppm vs absorbance on semilogaritmic paper.

Copper

Hydrochloric acid 1 N was used as an extracting solution. Two grams of soil were placed into a 125 cc Erlenmeyer flask with 20 cc of extracting solution. This was shaken for 60 minutes on a rotatory shaker at 200 RPM. The suspension was filtered through a No. 2 paper. The measurements were made with a Perkin Elmer model 303 atomic absorption spectrophotometer.

A standard curve was made with solutions containing 0.0, 0.1, 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.0 ppm of copper. The results were plotted on semilogaritmic paper.

Total Carbon

Total carbon was analyzed by dry combustion with a Leco model 750-100 instrument. After calibrating the instrument, the samples were analyzed by standard procedures for the instrument using 0.1 grams of finely ground soil.

Carbonate

Carbonate was evaluated by determining the inorganic carbon according to the titration method described by L. G. Bundy and J. M. Bremmer (5).

Ammonium

Into a 100 cc Kjeldahl flask, 5 grams of soil with 10 cc of distilled water and 10 cc of 0.1 N NaOH were added. After steam distillation the distillate was collected in a 50 cc Erlenmeyer flask with 5 cc of a boric acid solution, bromocresol green and methyl red indicators, until the distillate reached the 30 cc level. The distillate was then titrated with 0.013 N H_2SO_4.

Total Nitrogen

Micro-Kjeldahl and steam distillation were used for total nitrogen analysis. In a 100 cc Kjeldahl flask 0.5 grams of finely ground soil, 0.8 grams of a catalitic mixture (selenium, copper sulfate, and potassium sulfate), and 3 cc of sulfuric acid, were digested for 3 hours. Ten cc of 10 N NaOH was added and then steam distilled. The distillate was collected in a 50 cc Erlenmeyer flask and then the method already described for ammonium was used.

Nitrate

The nitrate electrode was used for the nitrate determination. Twenty grams of air dry soil in a 125 cc Erlenmeyer flask and 50 cc of a saturated solution of $CaSO_4$ were shaken for 30 minutes at 200 RPM on a rotatory shaker. The evaluation was made with an electrode for nitrate determinations and a pH meter model DR Sargent which measured emf milivolts in the magnetically stirred soil suspension.

A standard curve was made with solutions of 1, 5, 10, 50, and 100 ppm of nitrate. The ppm of nitrate and emf milivolts were then plotted on semilogaritmic paper.

Chloride

In a 125 cc Erlenmeyer flask, 5 grams of soil with 10 cc of distilled water were shaken on a rotatory shaker for half an hour at 200 RPM. The suspension was filtered with No. 2 paper. Five cc of the filtrate and 0.2 cc of potassium chromate solution were titrated with 0.0132 N $AgNO_3$.

RESULTS AND DISCUSSION

To expedite discussion the treatments and the sampling depths are coded as follows:

Soil sample code

Code	Sample Depth
1	0- 6 inches
2	6-12 inches
3	12-18 inches
4	18-24 inches
5	24-30 inches
6	30-36 inches
7	36-42 inches

Soil treatment code

Code	Treatments
A	no fertilizer and no manure
B	fertilizer only+150+66+126 (N+P+K)
C	chicken manure-- 5.8 T/A
D	chicken manure--11.6 T/A
E	chicken manure--23.2 T/A
F	chicken manure--46.4 T/A

Soil Reaction

The pH of the soil material in the seven depths as affected by both fertilizer and chicken manure are shown in Table 4. The values represent the averages for the four replications.

As can be seen, the soil within the plot area was naturally alkaline and increased in pH with depth.

The use of fertilizer alone had a tendency to make the soil less alkaline. This was especially evident at depths 2 and 3 (6-18 inches). This is probably due to the fact that 150 pounds of nitrogen fertilizer were plowed down each year.

While there were some variation in the data associated with soil depth, the use of increasing amounts of manure tended to make the soil less alkaline at all depths. The acidifying effect was noticeable even at tile depth, 36 to 42 inches (see Figure 1).

The decrease in soil pH in the lower depths for some treatments could be attributed to (1) slight natural differences in the soil, (2) the effect of nitrogen mineralization on the production of nitrates which were leached through the profile and which carried certain cations with them, and (3) the leaching of water-soluble chelating agents which carry cations with them. Several workers have shown the presence of chelating agents in manures. Tan, et al. (41) reported that about 25% of

TABLE 4.--pH in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	7.58	7.42	7.53	7.38	7.37	7.03	0.003	0.25
6"-12"	7.59	7.34	7.51	7.38	7.27	6.91	<0.0005	0.22
12"-18"	7.83	7.58	7.74	7.54	7.50	7.20	0.002	0.25
18"-24"	8.07	7.69	7.86	7.64	7.75	7.27	0.007	0.36
24"-30"	8.14	7.91	8.09	7.75	8.04	7.36	0.001	0.31
30"-36"	8.31	8.12	8.10	7.95	8.08	7.61	0.004	0.29
36"-42"	8.29	8.05	8.07	8.14	8.19	7.85	0.012	0.21

*Significance probability of F statistics.

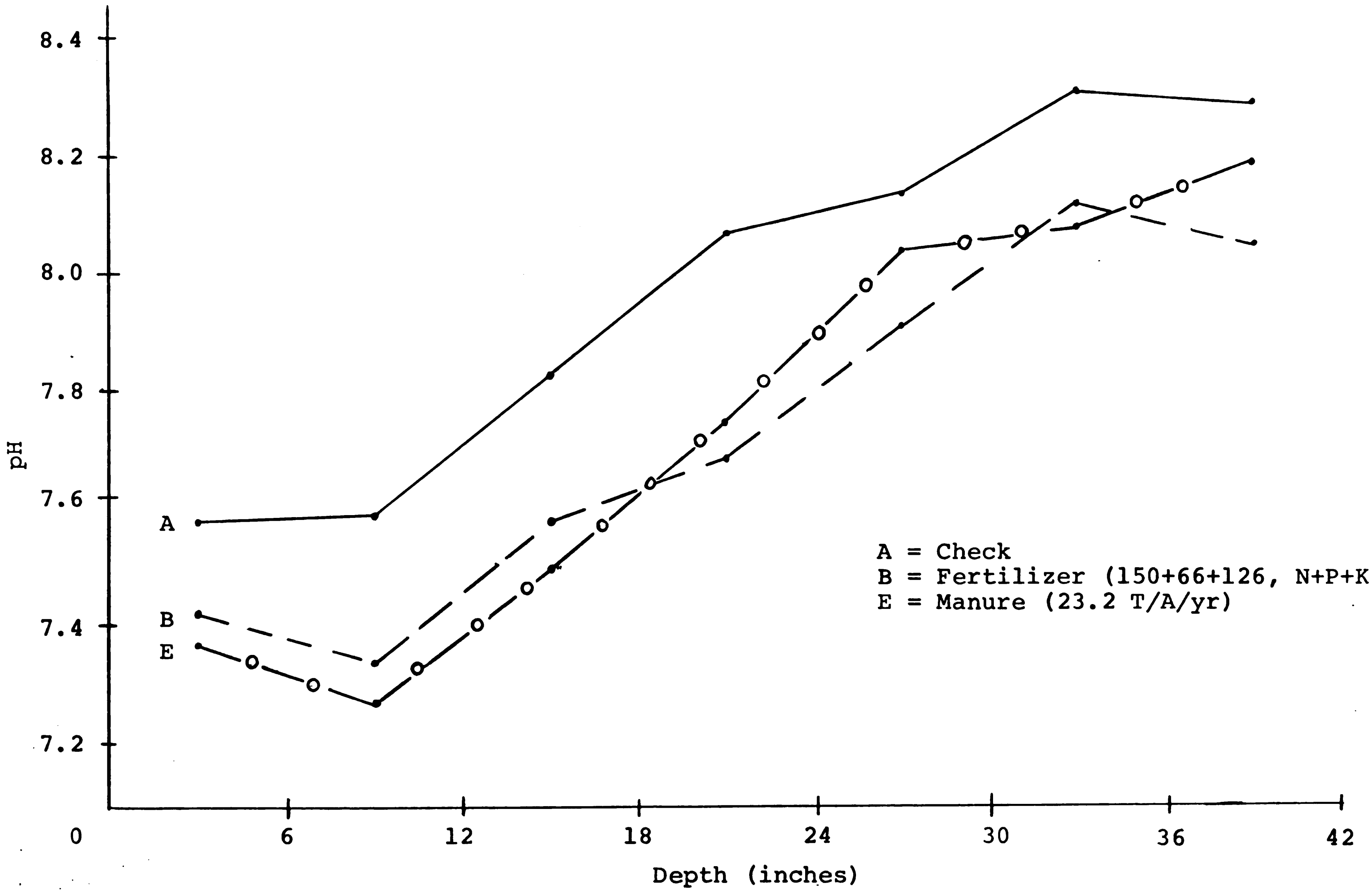

Figure 1.--pH in the soil profiles as affected by fertilizer and chicken manure.

the dry matter of chicken manure was water-soluble with the capacity to complex cations.

Available Phorphorus

The available phosphorus levels in the soil profiles as affected by treatments are shown in Tables 5 and 6. Again, and in the following tables, the data are average values for the four replications.

In this experiment, the plowing depth varied from year to year but averaged approximately 10 inches deep. The effect of soil management previous to the initiation of the experiment is shown by the relatively high values for available phosphorus within the first two sampling depths. Since the soil was never plowed to a depth of 12 inches, it is natural that the second depth should test lower than the first.

The total available phosphorus in the surface 12 inches of the soil is shown in Table 6. All of the test results were in the so-called high range and all demonstrate the effect of treatments whether they be fertilizer or manure. The data in Table 5 shows that phosphorus moves within the soil profile very little if at all. Therefore it can be assumed that if manure is plowed under soon after application, there will be little opportunity for pollution to occur unless the soil is eroded.

TABLE 5.--Available phosphorus levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
	Treatments							
0"- 6"	33.4	46.9	47.8	91.9	103.8	101.6	0.002	37.3
6"-12"	28.7	41.7	42.4	70.8	88.2	80.9	<0.0005	24.4
12"-18"	6.4	8.2	9.6	14.0	17.9	10.0	N.S.	N.S.
18"-24"	7.6	7.3	6.0	7.7	8.7	8.9	N.S.	N.S.
24"-30"	8.0	7.0	5.6	7.2	7.2	9.2	0.033	2.0
30"-36"	3.1	3.4	3.8	3.5	3.2	5.6	N.S.	N.S.
36"-42"	3.8	3.9	4.2	4.0	3.5	6.6	N.S.	N.S.

*Significance probability of F statistics.

TABLE 6.--Pounds per acre of available phosphorus in the soil profiles to depths of 12 and 42 inches.

Depth	A	B	C	D	E	F	L.S.D. (.05)
	Treatments						
0-12"	124.2	177.2	180.4	325.4	384.0	365.0	90.6
0-42"	182.0	236.0	238.8	398.2	465.0	445.6	99.2

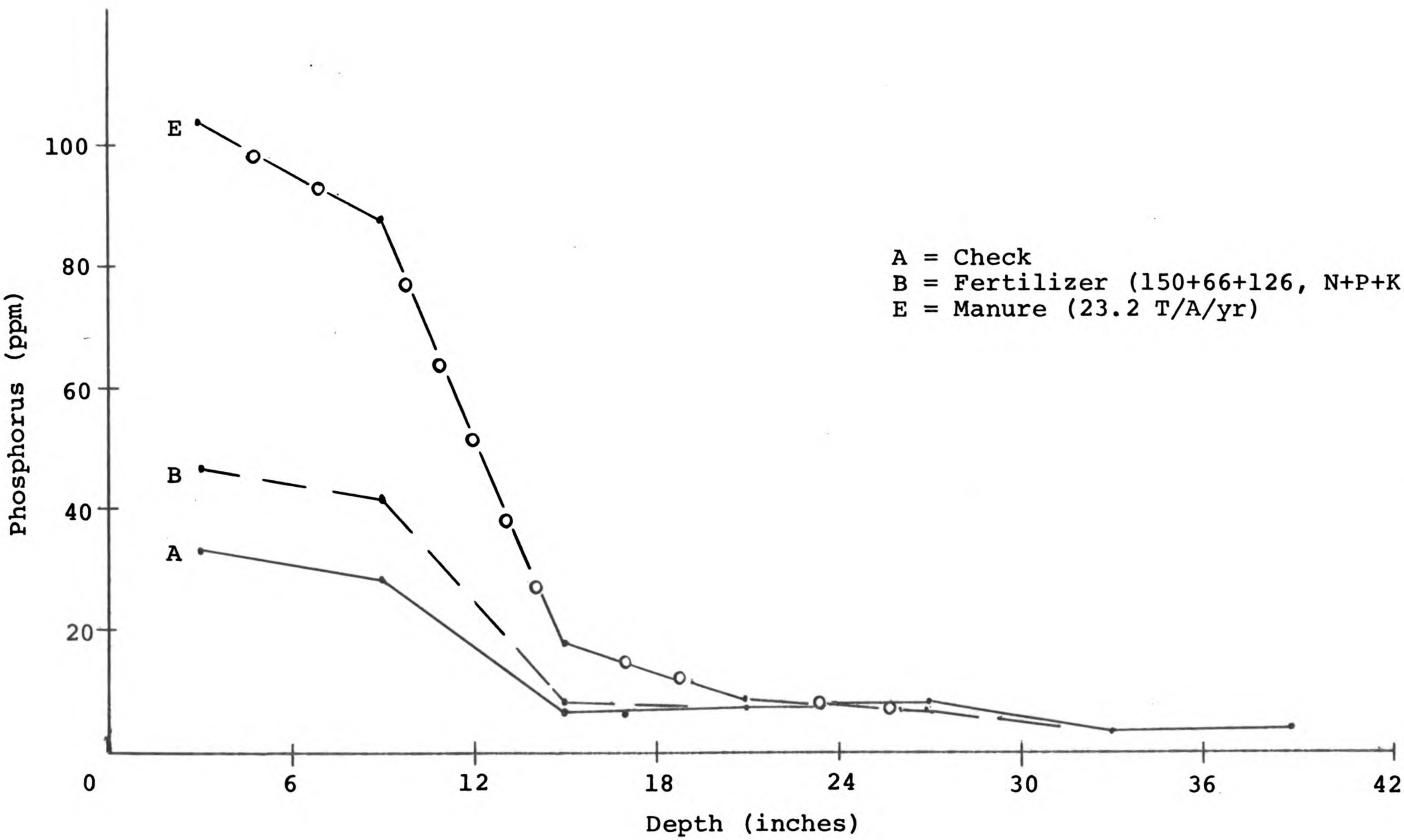

Figure 2.--Available phosphorus in the soil profiles as affected by fertilizer and chicken manure.

With increasing rates of manure, the soil tests for available phosphorus increased. This would be expected because the manure applied in the 5 years contained, depending upon the treatment, up to almost 2,600 pounds of phosphorus. Indirectly, the data in Table 5 illustrate the tremendous fixing power for phosphorus that the soil within the experimental area had.

The data in Table 6 have been calculated from the data in Table 5. The ppm values were changed to "pounds per acre." The appropriate numbers were added to show the total values for the 0 to 12 inch depth and for the 0 to 42 inch depth. This procedure was used for each of the plant nutrients considered in this project.

Considering the great effect that the higher rates of manure had upon the phosphorus soil test levels, poultry farmers should be using very little or possibly no phosphate in their fertilization programs if they use rates of manure similar to the high rates used in this experiment.

Available Potassium

The potassium soil test levels are shown in Tables 7 and 8 and in Figure 3. In general, the effects of both fertilizer and manure on these soils were very similar to that already described for phosphorus.

While the differences caused by fertilizer were not great or statistically significant, the fertilizer

TABLE 7.--Available potassium levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments						Prob.*	L.S.D. (.05)
	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A		
0"- 6"	133.8	157.5	169.5	321.2	371.3	446.3	0.001	144.3
6"-12"	108.1	140.6	161.1	257.5	348.8	417.5	0.002	142.8
12"-18"	70.6	66.9	65.3	65.6	101.9	135.0	0.035	45.3
18"-24"	61.9	66.9	56.0	64.4	56.3	111.3	N.S.	N.S.
24"-30"	51.0	57.5	53.9	60.6	51.7	104.4	N.S.	N.S.
30"-36"	35.1	33.5	47.8	32.9	45.5	80.9	N.S.	N.S.
36"-42"	39.9	36.8	54.6	34.5	37.4	65.6	N.S.	N.S.

*Significance probability of F statistics.

TABLE 8.--Pounds per acre of available potassium in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments						L.S.D. (.05)
	A	B	C	D	E	F	
0-12"	483.8	596.2	661.2	1157.4	1440.2	1727.6	548.0
0-42"	1000.8	1119.4	1216.4	1673.4	2025.8	2722.0	739.0

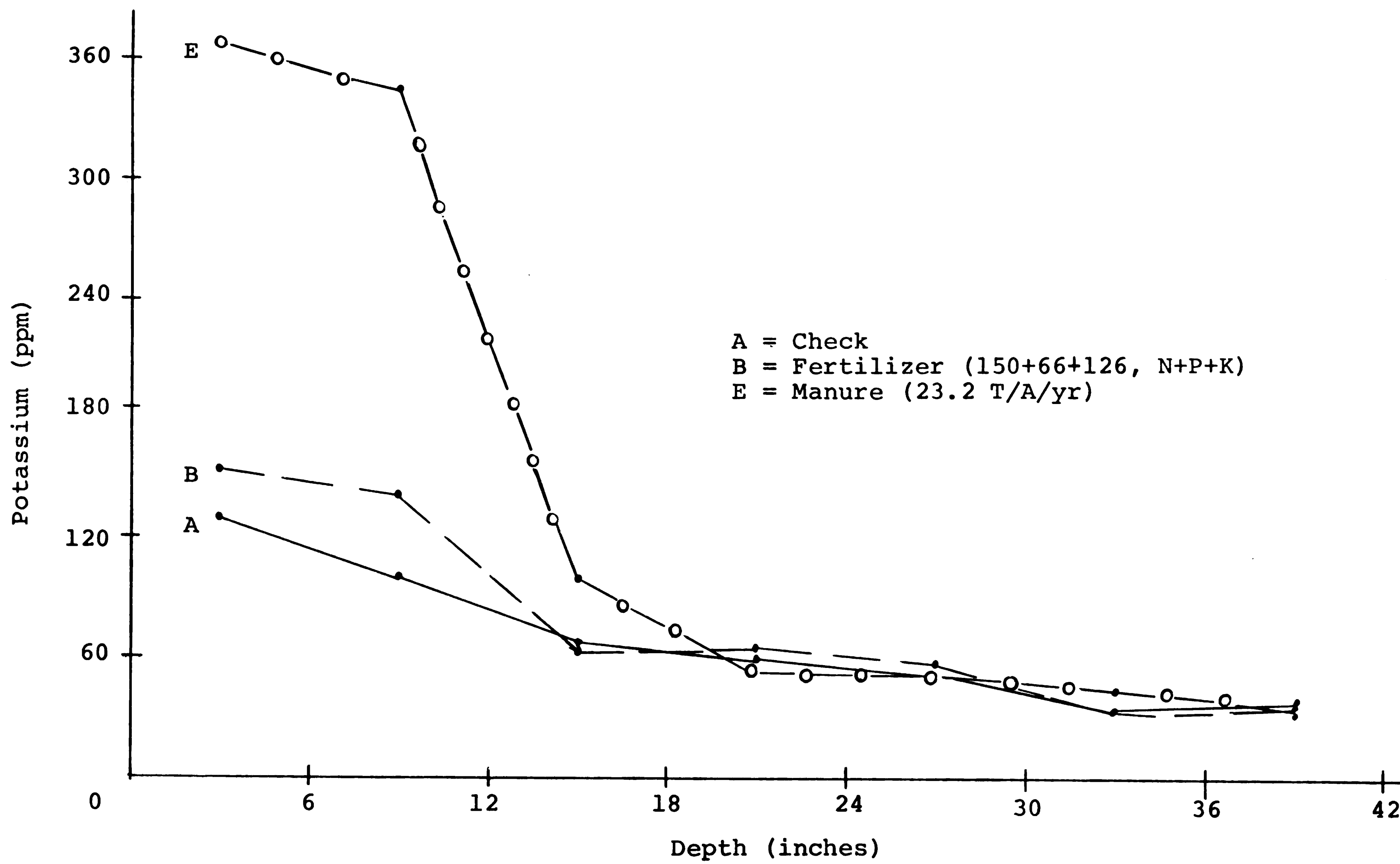

Figure 3.--Available potassium in the soil profiles as affected by fertilizer and chicken manure.

tended to increase the soil test levels in the surface soil down to a depth of 12 inches. Below this depth the test levels on the check plots and the fertilizer plots were remarkably similar and relatively low, less than 150 ppm. As on the check plots, the available potassium levels in the profile of the fertilized plots tended to decrease with depth.

The potassium in the manure applied during the 5 year period amounted to up to almost 2,700 pounds per acre. Such large amounts, as expected, significantly increased the soil test levels. The greatest increase occurred in the surface soil down to a depth of 12 inches.

There was little evidence to suggest that the potassium applied in the manure moved very much until the highest rate of manure was used. Increasing the rate from 23.2 to 46.4 T/A tended to result in higher soil test levels in the 18 to 42 inch depths, but the differences shown in Table 7 were not statistically significant. It is problematical as to what the results might be if the manure had been used at even higher rates or it had been used for a longer time.

The data strongly suggest that on these soils, potassium in the manure is not likely to leach and to cause pollution problems. At the rates used for the duration of the research, the potassium tended to collect in the surface soil and therefore was subject to loss primarily through erosion--either wind or water.

Furthermore, when poultry manure is used at rates similar to those used in this experiment, or for longer periods of time crop producers should be testing their soils at frequent and regular intervals so that proper adjustments can be made in a fertilizer use program. With the higher soil test levels reported in Table 8, the use of commercial fertilizer potassium is more likely to reduce crop yields than to improve them.

Available Calcium

Calcium availability levels for the seven depths of sampling as affected by chicken manure and fertilizer treatments are shown in Tables 9 and 10.

There were statistically significant differences within the 0 to 6 inch sampling depth. No other significant differences were observed.

The soils utilized for this project were naturally high in available calcium. Chicken manure is high in calcium. Both situations undoubtedly affect the pH of the soil by tending to keep the pH at a relatively high level.

The data presented in Figure 4 suggest that both fertilizer and manure might possibly reduce the amount of available calcium in the entire profile. With more time,

TABLE 9.--Available calcium levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	2,625	2,334	2,436	2,597	2,783	2,941	0.023	349
6"-12"	2,887	2,254	2,271	2,418	2,721	2,825	N.S.	N.S.
12"-18"	4,057	2,954	2,028	1,965	2,348	2,276	N.S.	N.S.
18"-24"	3,905	2,636	3,007	1,938	3,270	2,019	N.S.	N.S.
24"-30"	4,259	3,578	3,081	2,344	3,461	2,063	N.S.	N.S.
30"-36"	4,181	3,174	3,271	1,676	3,588	2,243	N.S.	N.S.
36"-42"	4,380	3,861	3,284	4,009	4,204	3,671	N.S.	N.S.

*Significance probability of F statistics.

TABLE 10.--Pounds per acre of available calcium in the soil profiles to depths of 12 and 42 inches.

Depth	A	B	C	D	E	F	L.S.D. (.05)
0-12"	11,024	9,176	9,414	10,030	11,008	11,532	1,688
0-42"	52,588	41,582	38,756	33,894	44,750	32,076	N.S.

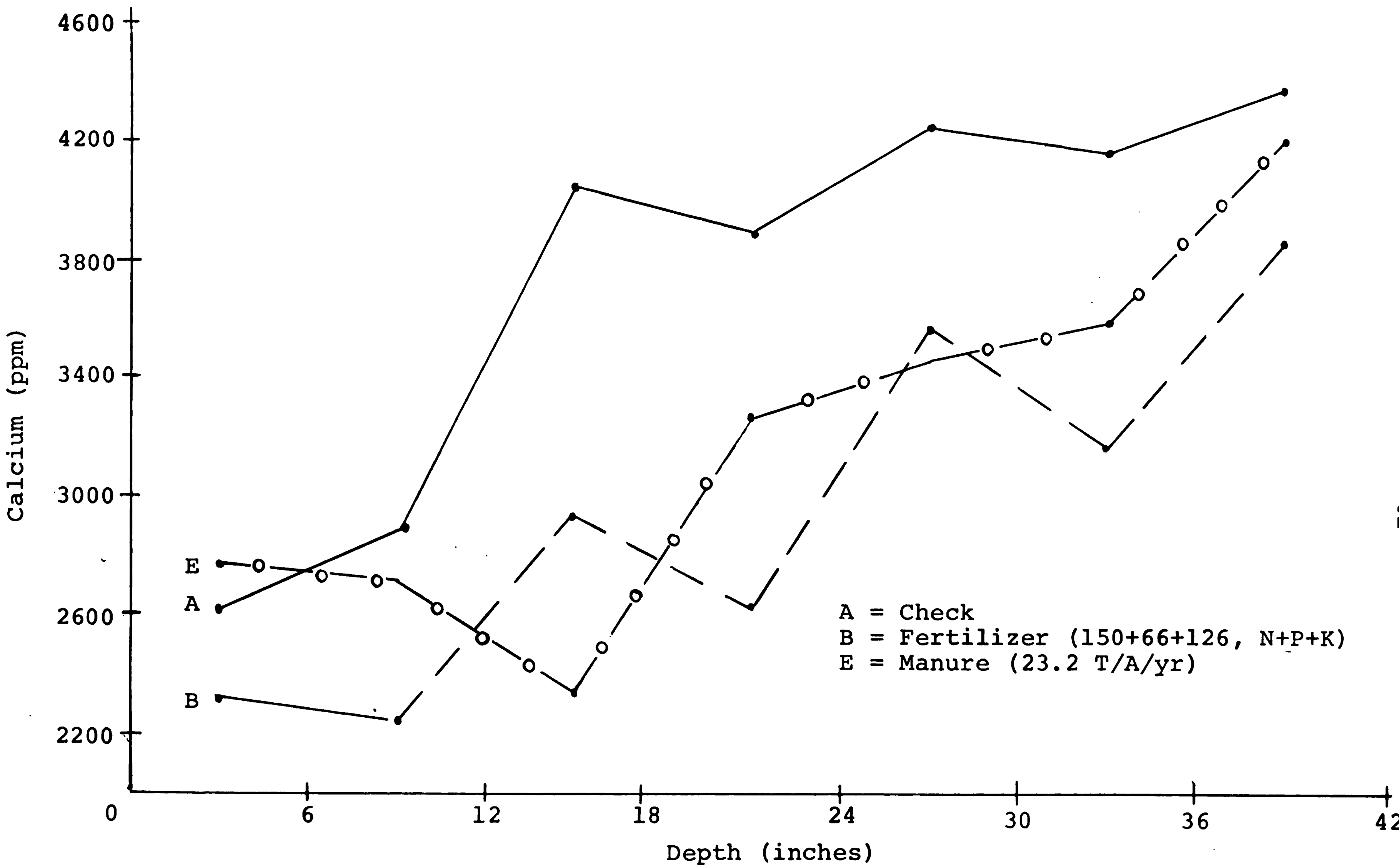

Figure 4.--Available calcium in the soil profiles as affected by fertilizer and chicken manure.

or with these materials used at higher rates the differences shown might become significant. Never the less, the only interpretation that is valid at this time is that while differences in available calcium levels within the subsurface horizons were measured, the differences probably represent natural soil variations as much as treatments.

Available Magnesium

Magnesium availability in the soil profile as affected by chicken manure and fertilizer are shown in Tables 11 and 12.

The soils in this project were well supplied with magnesium in an available form. Generally speaking, the available magnesium levels tended to decrease with depth.

The fertilizer used in the experiment did not cause any statistical difference in magnesium levels to develop.

The use of high rates of chicken manure had a tendency to increase the available magnesium levels in the plow layers as is shown in Figure 5. As with calcium, the small differences are difficult to interpret. With the use of more manure or with more time the trend could become more distinct.

There is about 10 times as much calcium as magnesium in poultry manure and approximately 2.5 times as much potassium. As has been discussed, such a situation affects

TABLE 11.--Available magnesium levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	281	278	258	328	347	381	N.S.	N.S.
6"-12"	236	219	216	252	282	299	0.041	19.3
12"-18"	225	238	183	235	237	286	N.S.	N.S.
18"-24"	193	201	156	197	177	297	N.S.	N.S.
24"-30"	202	205	158	224	185	338	N.S.	N.S.
30"-36"	128	138	167	134	156	266	N.S.	N.S.
36"-42"	148	144	211	136	142	219	N.S.	N.S.

*Significance probability of F statistics.

TABLE 12.--Pounds per acre of available magnesium in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	1,034	994	948	1,160	1,258	1,360	299.0
0-42"	2,826	2,846	2,698	3,012	3,052	4,172	N.S.

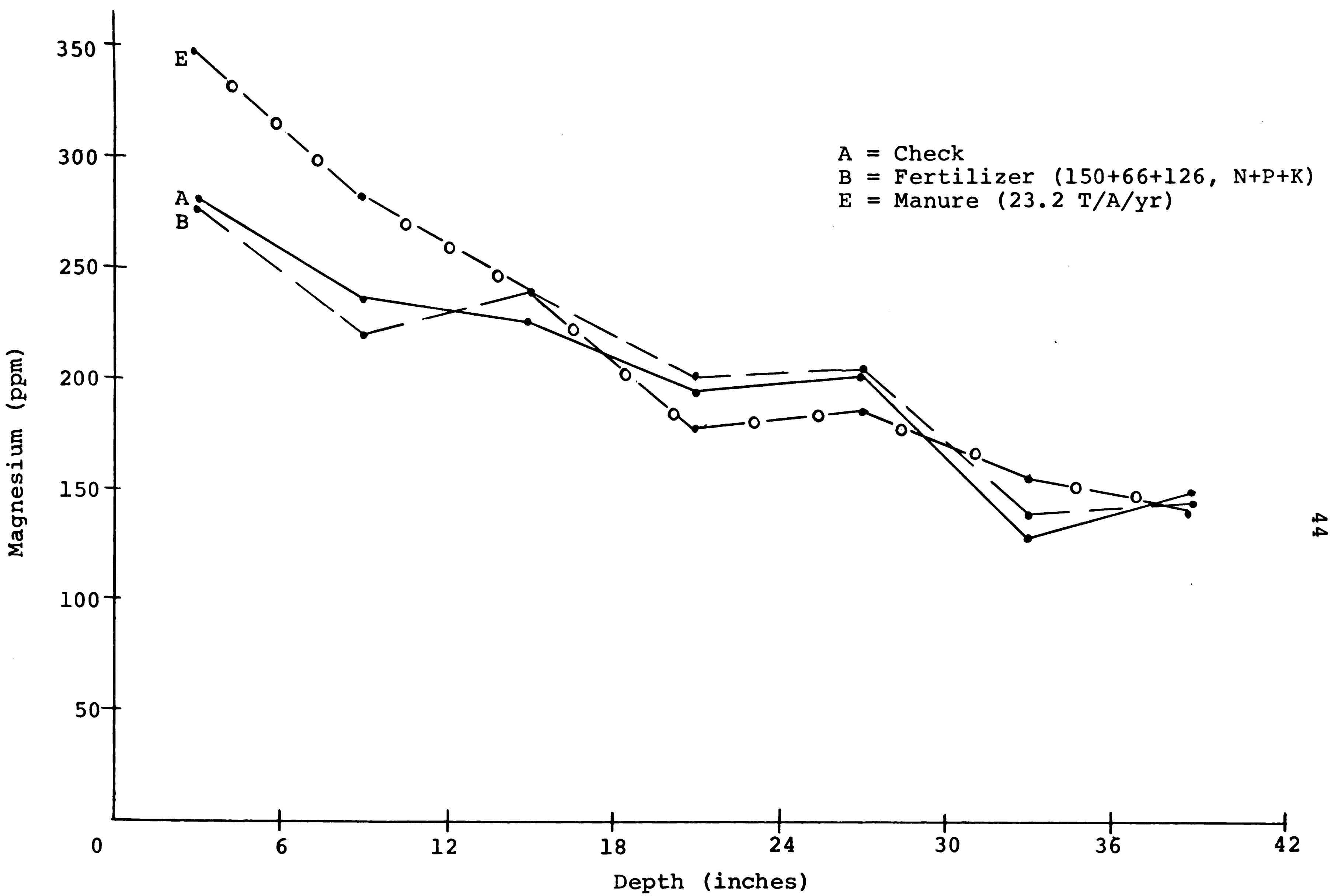

Figure 5.--Available magnesium in the soil profiles as affected by fertilizer and chicken manure.

the soil test levels. It also affects several of the cation ratios that, when extreme, become important in crop production.

The K:Mg ratio for the surface soil of the check plots and for the other treatments were 0.48, 0.57, 0.66, 0.98, 1.07, and 1.17 for treatments A, B, C, D, E, and F respectively. At the second depth (6-12 inches) the K:Mg ratio changed even more and ranged from 0.46 in treatment A to 1.36 in treatment F.

The increasing K:Mg ratio obtained with increased rates of poultry manure suggest that heavy and/or prolonged applications of manure could theoretically produce magnesium deficiencies. This would be likely on the more sandy soils which naturally contain less available magnesium than reported for the soils in this experiment.

Available Sodium

Available sodium levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 13 and 14.

Poultry manure contains significant quantities of sodium, but commercial fertilizer contains little or no sodium. This is shown in Figure 6, where the curves for the check plots and the fertilizer plots are similar.

The available sodium content of the soil profile tended to increase slightly with depth. The level in

TABLE 13.--Available sodium levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	50.8	50.1	66.1	80.3	87.5	96.0	<0.0005	19.2
6"-12"	66.9	64.4	75.2	118.8	154.4	128.1	<0.0005	34.2
12"-18"	68.1	75.0	72.5	107.5	155.0	126.2	0.007	47.1
18"-24"	69.1	73.1	75.9	82.5	112.5	116.2	<0.0005	19.3
24"-30"	76.9	71.6	73.1	83.1	89.4	100.3	0.010	15.5
30"-36"	79.1	68.4	74.7	68.4	81.9	101.3	N.S.	N.S.
36"-42"	63.8	59.1	62.9	67.9	69.7	70.1	N.S.	N.S.

*Significance probability of F statistics.

TABLE 14.--Pounds per acre of available sodium in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	235.4	229.0	282.6	398.2	483.8	448.2	96.4
0-42"	959.4	923.4	1000.8	1217.0	1500.8	1476.4	220.2

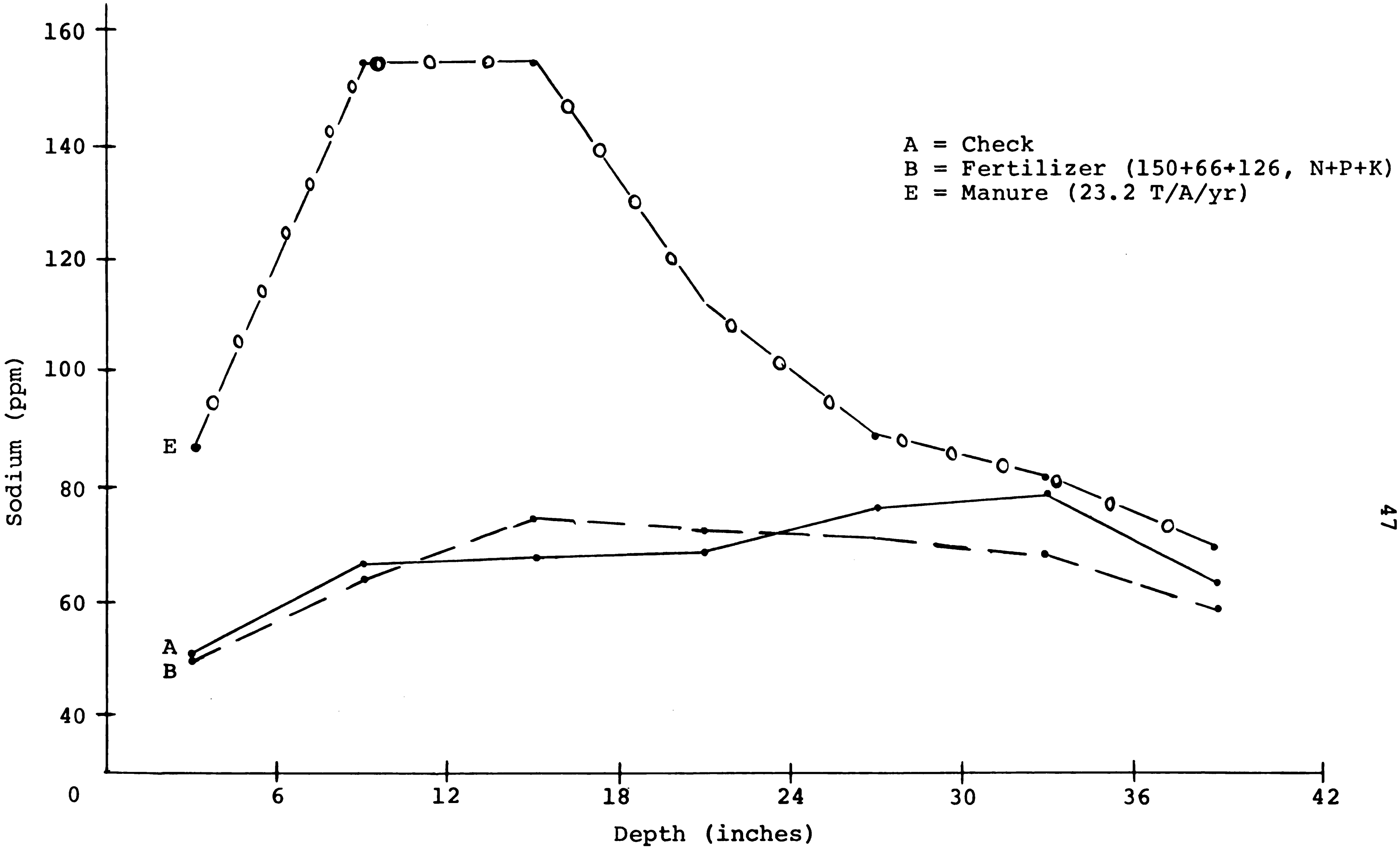

Figure 6.--Available sodium in the soil profiles as affected by fertilizer and chicken manure.

close proximity to tile lines tended to decrease, probably because of leaching.

The use of poultry manure tended to increase the available sodium levels not only in the surface soil but even more so in the subsurface horizons. The increase in general was proportional to the amount of manure used.

The data suggest that some sodium was leached from the surface soil down into the profile. The sodium reached deeper depths with increasing rates of manure. The amount of sodium decreased in the seventh depth (36-42 inches) in all treatments. This can be attributed to the effect of the tile drains in the field.

In spite of the significant accumulation of sodium in the areas above 36 inches, the concentration did not reach levels that are considered to be toxic to crops. It cannot be concluded that with the rates of manure used in the field experiment, that accumulations of soluble salts would not reach detrimental levels at some future date.

Available Iron

Iron availability levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 15 and 16. and in figure 7

Poultry manure contains relatively small amounts of iron so that great differences from the use of manure

TABLE 15.--Available iron levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

	Treatments							
Depth in Soil	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	26.7	41.8	45.8	41.9	43.7	40.3	N.S.	N.S.
6"-12"	23.4	37.1	42.2	44.4	40.9	37.3	N.S.	N.S.
12"-18"	34.0	73.5	58.7	67.2	58.0	85.1	N.S.	N.S.
18"-24"	23.2	101.5	54.6	81.9	57.1	143.3	N.S.	N.S.
24"-30"	12.0	37.3	54.4	82.1	27.8	143.2	0.008	20.7
30"-36"	1.9	5.9	59.7	102.2	33.8	140.2	N.S.	N.S.
36"-42"	3.8	2.2	60.1	1.6	1.7	9.7	N.S.	N.S.

*Significance probability of F statistics.

TABLE 16.--Pounds per acre of available iron in the soil profiles to depths of 12 and 42 inches.

	Treatments						
Depth	A	B	C	D	E	F	L.S.D. (.05)
0-12"	100.2	157.8	176.0	172.6	169.2	155.2	N.S.
0-42"	250.0	598.6	751.0	842.6	526.0	1198.2	N.S.

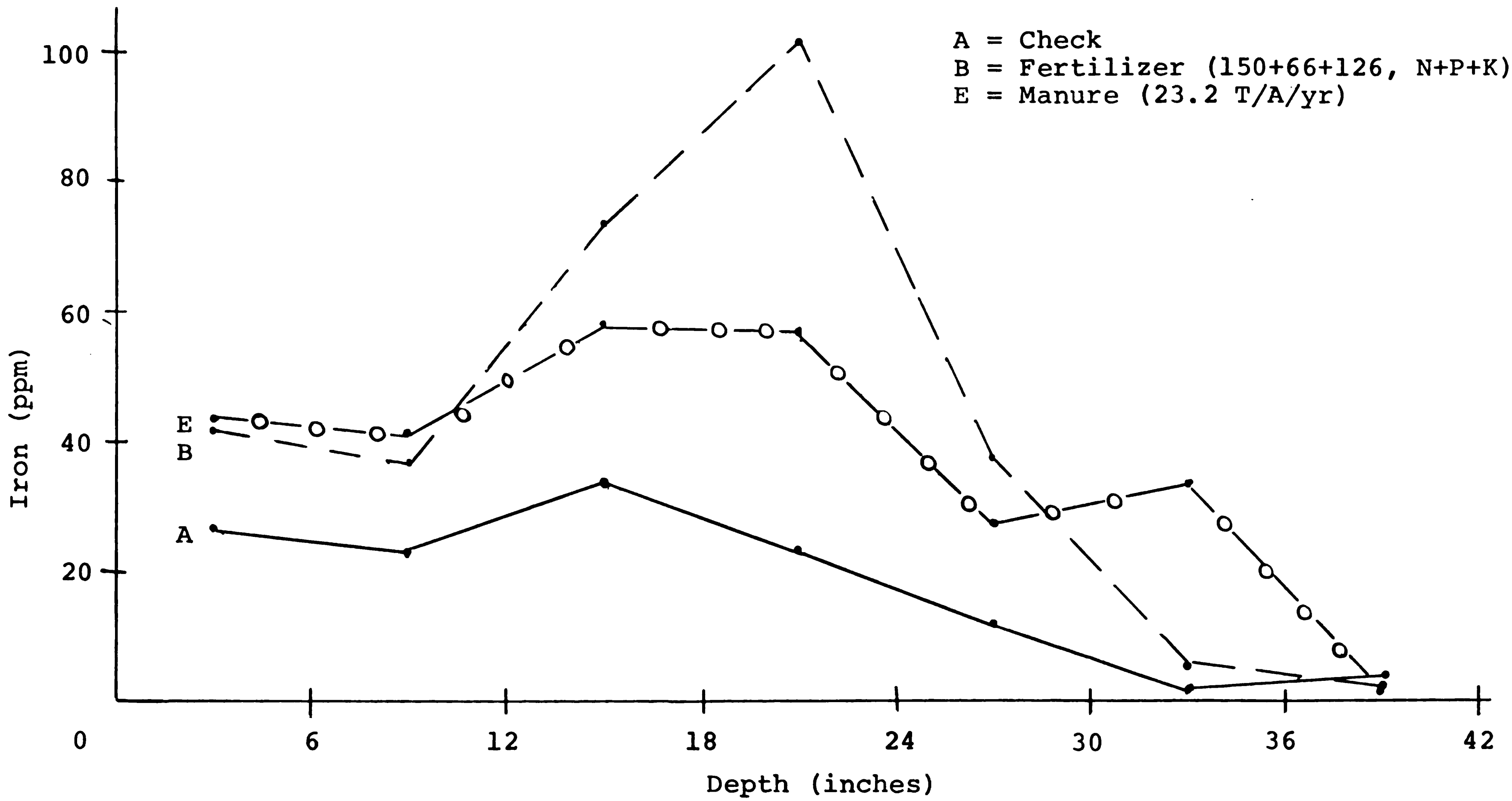

Figure 7.--Available iron in the soil profiles as affected by fertilizer and chicken manure.

would not be expected. Commercial fertilizer also contains little or no iron.

Any great change in availability of iron within the soil profiles would have to be caused by a change in solubility of the iron already present.

The data are variable and difficult to interpret. Even though differences in availability were measured, the differences were not statistically significant except at depth 5 (24-30 inches).

Differences in availability of iron were not expected because of the naturally high pH level of the soils within the experimental areas. At such levels, iron normally is relatively insoluble.

Available Manganese

Available manganese levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 17 and 18.

Statistically significant differences in available manganese were measured only at depths 4 and 5. As in the case of iron the data are difficult to interpret. Most of the differences are considered to reflect variations in soil within the plot area, and not necessarily the treatments despite the fact that there is a tendency for the values to increase with increasing rates of manure.

TABLE 17.--Available manganese levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	46.6	45.1	44.0	62.2	58.5	49.9	N.S.	N.S.
6"-12"	39.4	40.9	38.7	51.9	53.5	45.2	N.S.	N.S.
12"-18"	21.1	17.5	23.3	25.4	27.3	32.2	N.S.	N.S.
18"-24"	18.2	24.4	20.3	21.1	21.6	43.3	0.020	14.3
24"-30"	16.7	17.4	21.5	14.6	28.1	43.4	0.002	12.6
30"-36"	14.8	19.4	27.0	14.2	23.4	45.6	N.S.	N.S.
36"-42"	13.2	14.8	25.9	15.1	18.4	17.6	N.S.	N.S.

*Significance probability of F statistics.

TABLE 18.--Pounds per acre of available manganese in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	172.0	172.0	165.4	228.2	224.0	190.2	N.S.
0-42"	340.0	359.0	401.4	409.0	461.6	554.4	122.2

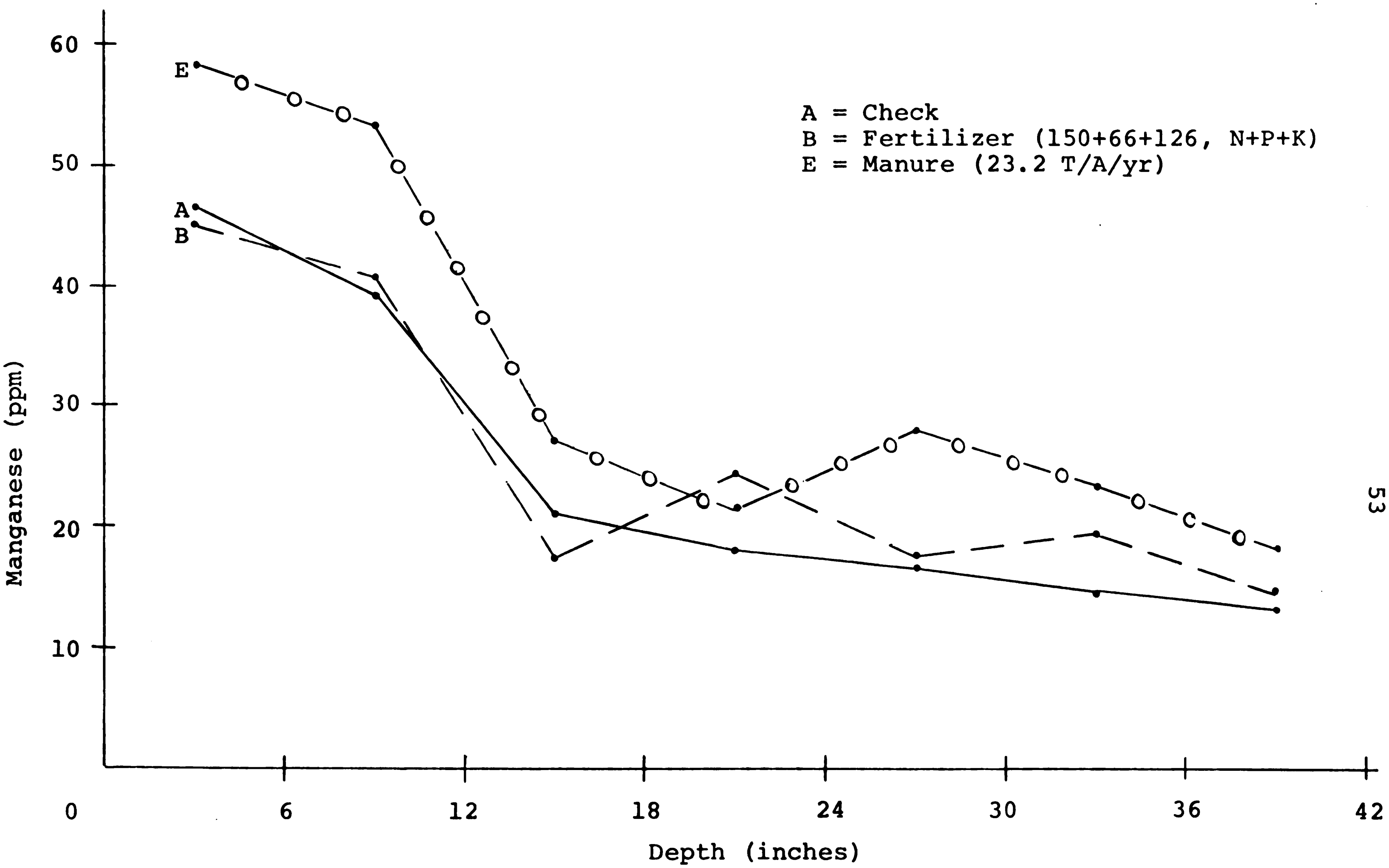

Figure 8.--Available manganese in the soil profiles as affected by fertilizer and chicken manure.

The amount of manganese added to the soil with the manure was not high. With high pH levels in the soil, differences in available manganese were not expected.

Available Zinc

Zinc availability in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 19 and 20.

The availability of zinc in general decreased with depth. This was closely associated with an increase in pH.

While fertilizer tended to increase the availability of zinc, the differences were not statistically significant. If in the long run zinc availability could be increased on these soils, the change in availability would probably be associated with decrease in pH levels of the soil.

The use of the higher rates of manure increased the availability of zinc only in the surface soil. The increase in zinc availability in treatments D, E, and F can be attributed to (1) a decrease in soil pH associated with the treatments, (2) and zinc added to the soil with the manure, and (3) the effect of the chelating agents in the manure.

TABLE 19.--Available zinc levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	7.6	8.3	10.5	16.9	21.6	18.3	0.003	7.0
6"-12"	6.2	6.7	7.9	13.4	17.5	14.5	0.002	5.6
12"-18"	2.6	3.4	4.2	5.1	4.5	5.4	N.S.	N.S.
18"-24"	1.6	4.8	3.1	3.5	2.8	5.1	N.S.	N.S.
24"-30"	1.7	2.4	3.3	3.8	2.0	4.6	N.S.	N.S.
30"-36"	0.5	1.1	2.6	3.4	1.6	4.7	N.S.	N.S.
36"-42"	0.4	1.0	2.2	0.6	0.5	1.7	N.S.	N.S.

*Significance probability of F statistics.

TABLE 20.--Pounds per acre of available zinc in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	27.6	30.0	36.8	60.6	78.2	65.6	21.2
0-42"	41.2	55.4	67.6	93.4	101.0	108.6	32.6

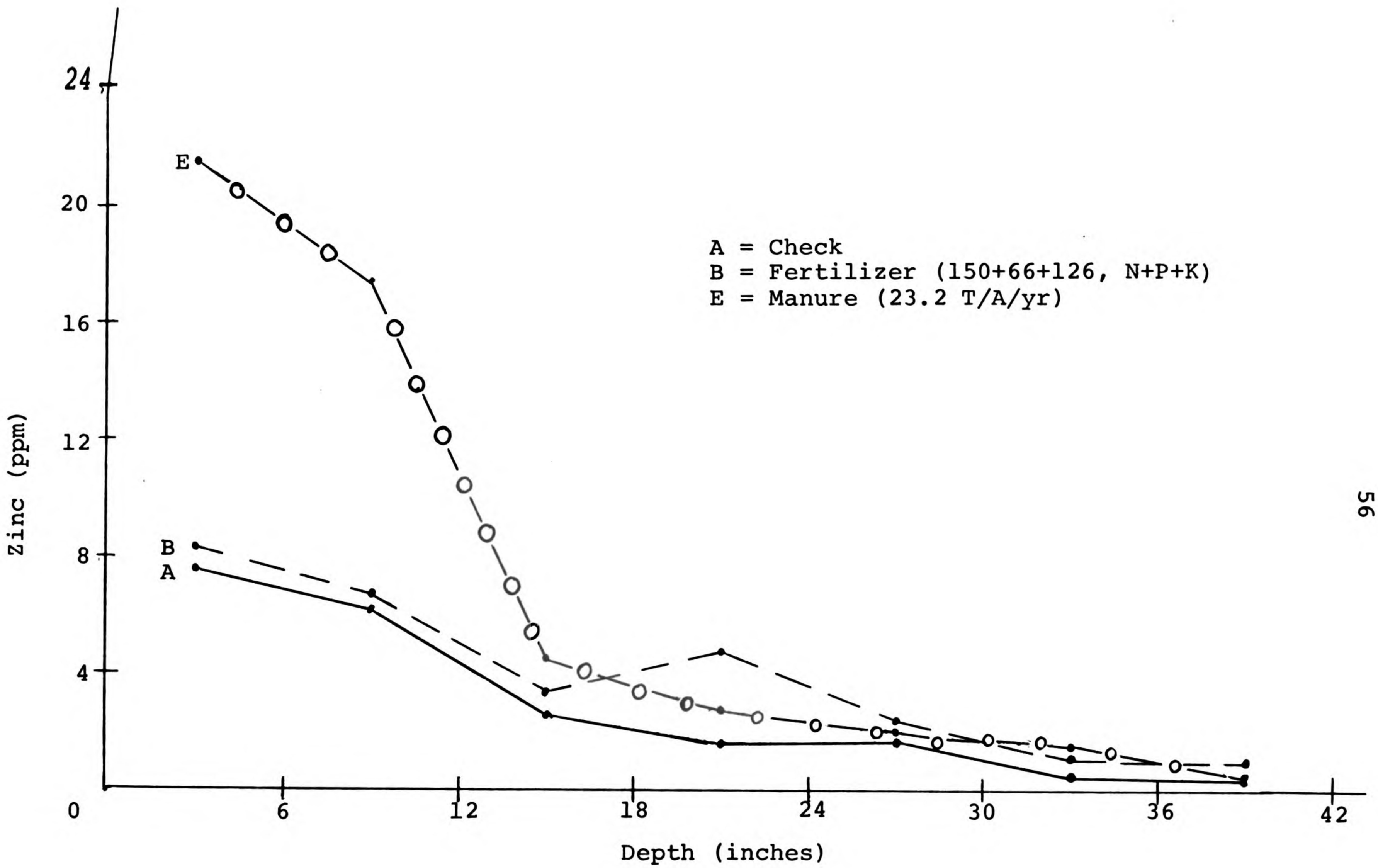

Figure 9.--Available zinc in the soil profiles as affected by fertilizer and chicken manure.

Available Copper

Available copper levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 21 and 22.

The copper contents of the soil profiles did not vary as much as did the other cations. There was a general tendency for the available copper content of the soil profiles to decrease with depth. This is probably associated with the changes in soil reaction.

The amount of copper added to the soil in the manure was very small, even where the highest rate of manure was used. The increase in copper availability of the surface soil was probably due to decrease in soil pH as already discussed.

Total Carbon

Total carbon levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 23 and 24.

Total carbon is present in the soil in relatively large amounts and occurs in both inorganic and organic forms. Poultry manure contains significant amounts of organic carbon, so that the use of poultry manure should increase the amount of total carbon in the surface soil rather significantly.

TABLE 21.--Available copper levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	7.2	6.9	7.7	8.2	8.2	11.7	0.001	1.9
6"-12"	7.2	7.0	7.1	7.3	8.0	10.9	0.008	2.1
12"-18"	7.1	6.3	6.7	7.1	5.9	7.9	N.S.	N.S.
18"-24"	6.2	5.3	5.7	5.4	5.5	6.7	N.S.	N.S.
24"-30"	5.5	4.8	4.4	4.9	3.9	6.2	N.S.	N.S.
30"-36"	5.1	4.9	5.0	4.4	4.8	6.2	N.S.	N.S.
36"-42"	5.0	5.4	5.3	4.9	5.3	6.1	N.S.	N.S.

*Significance probability of F statistics.

TABLE 22.--Pounds per acre of available copper in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	28.8	27.8	29.6	31.0	32.4	45.2	7.4
0-42"	86.6	81.2	83.8	84.4	83.2	111.4	N.S.

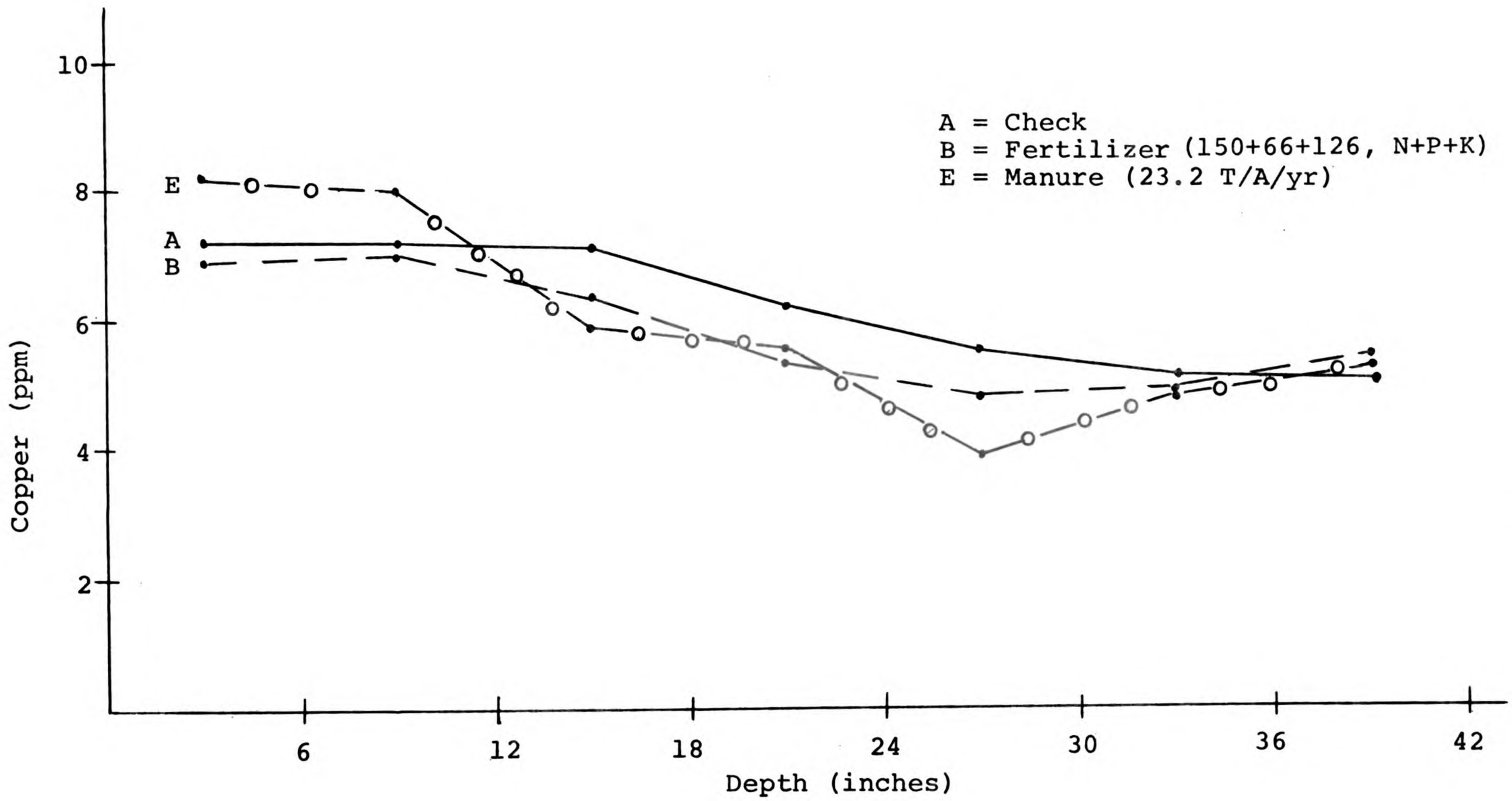

Figure 10.--Available copper in the soil profiles as affected by fertilizer and chicken manure.

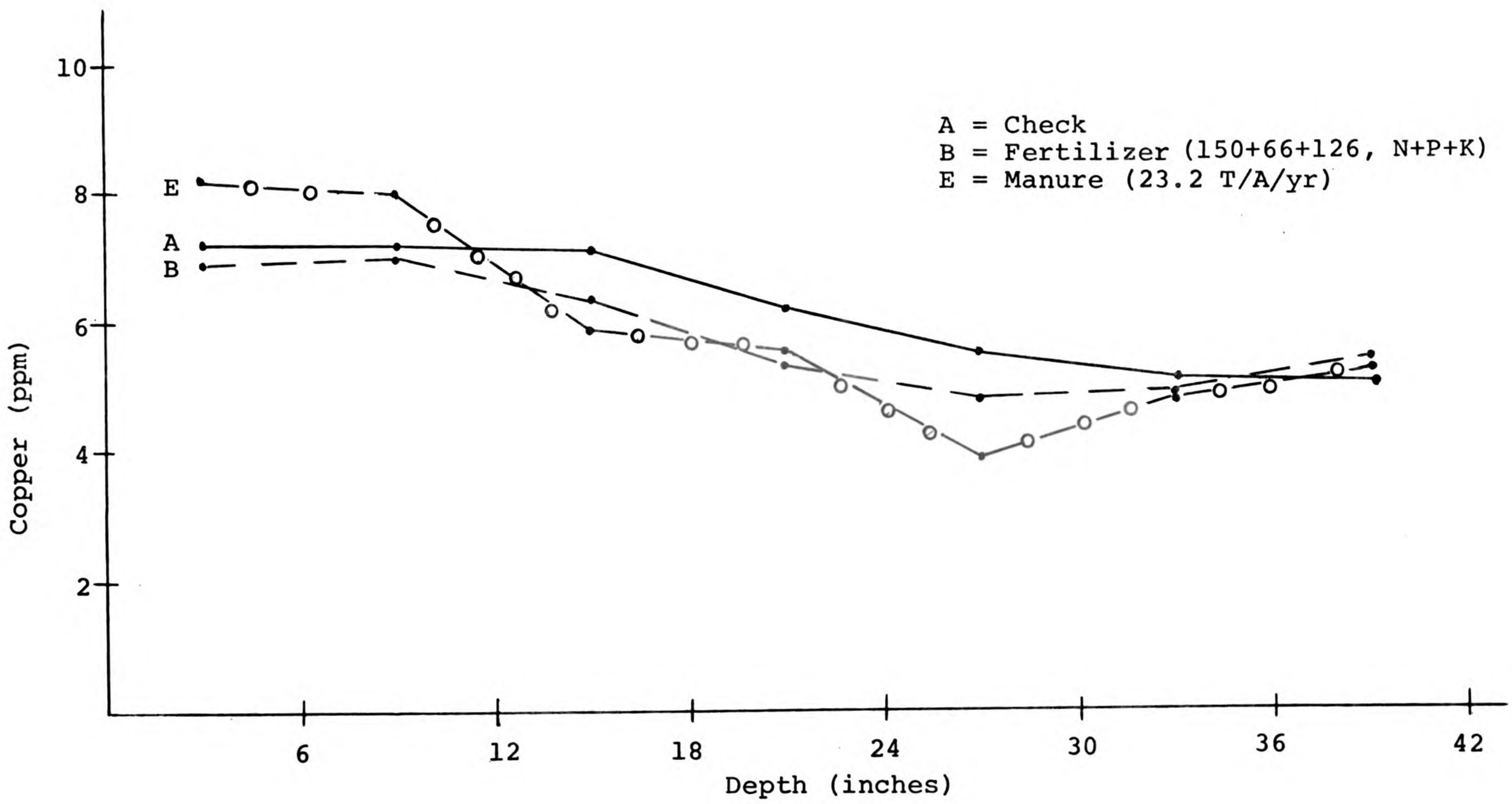

Figure 10.--Available copper in the soil profiles as affected by fertilizer and chicken manure.

TABLE 23.--Total carbon levels (%) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	1.90	2.20	2.23	2.33	2.41	2.80	0.029	0.48
6"-12"	2.36	2.35	2.23	2.31	2.44	2.91	N.S.	N.S.
12"-18"	2.73	1.97	1.36	1.40	1.30	1.31	N.S.	N.S.
18"-24"	2.63	1.70	1.64	1.01	1.99	0.89	N.S.	N.S.
24"-30"	2.79	1.80	1.72	1.53	2.00	0.68	N.S.	N.S.
30"-36"	3.01	2.20	2.32	1.32	2.51	1.05	N.S.	N.S.
36"-42"	3.93	3.17	2.74	3.39	3.55	2.44	N.S.	N.S.

*Significance probability of F statistics.

TABLE 24.--Pounds per acre of total carbon in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	85,200	91,000	89,200	92,800	97,000	114.200	17,016
0-42"	387,000	307,800	284,800	265,800	324,000	241,600	N.S.

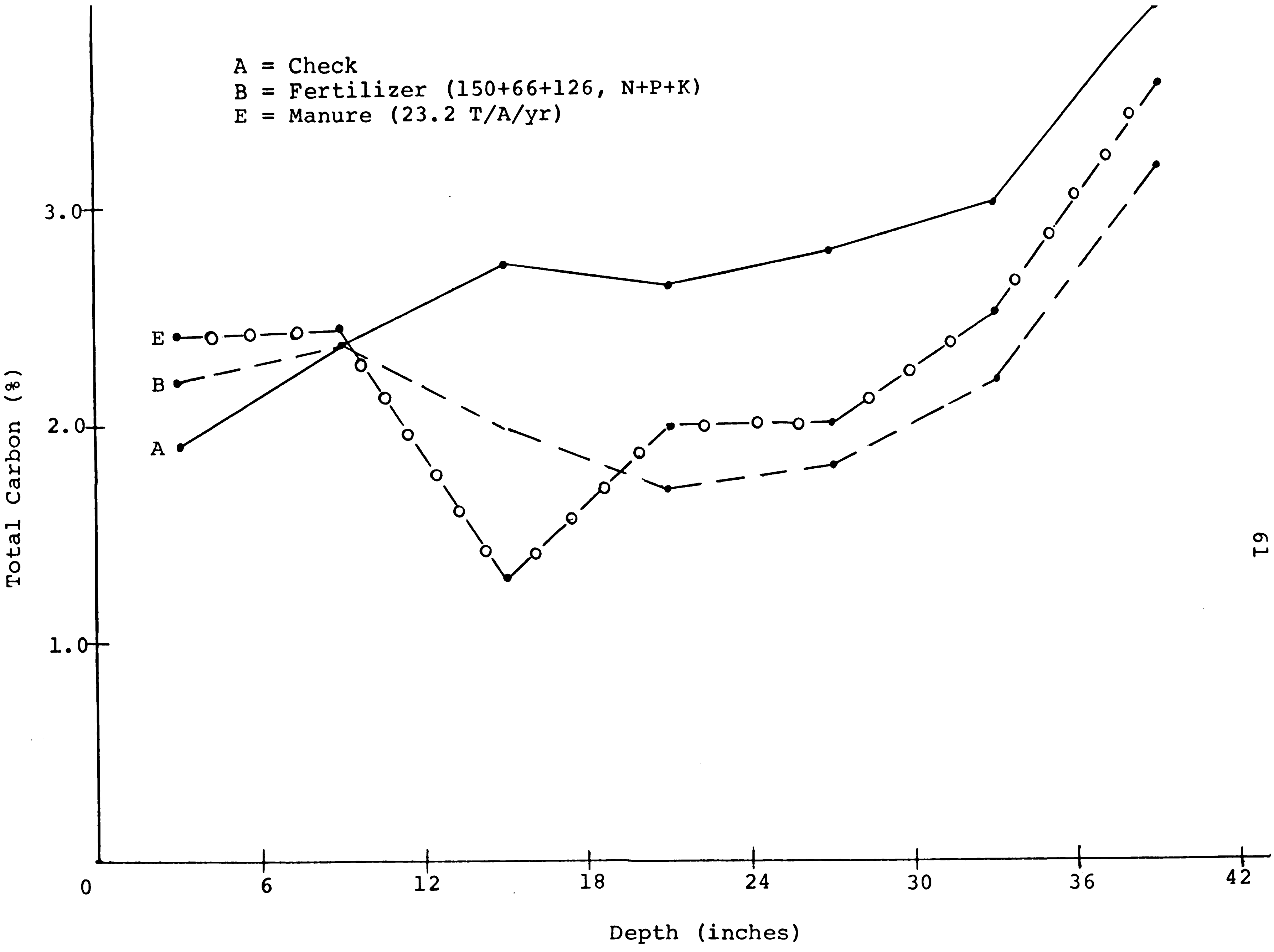

Figure 11.--Total carbon in the soil profiles as affected by fertilizer and chicken manure.

High analysis mixed fertilizers are not likely to contain very much carbon. No statistically significant differences were found to be caused by the fertilizer that was used in this experiment.

As predicted, the use of large amount of poultry manure increased the total carbon content of the surface soils. While rather large differences in carbon content were observed in the subsurface horizons the differences could not be attributed to the treatments. They were more closely associated with the natural variations in carbonate contents of the subsoil.

Carbonate

The carbonate levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 25 and 26. The values are considerably lower than anticipated especially when one takes into consideration the values reported for total carbon.

The soils used in this experiment were derived from calcareous materials. Much of the calcium is in the carbonate form. The soils are relatively young as is shown by the high values for both calcium and carbonates.

The fertilizer and manure treatments, from a statistical viewpoint, did not affect the carbonate content of the soil profiles. The variation in carbonate contents

TABLE 25.--Carbonate levels (%) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	0.112	0.061	0.054	0.082	0.141	0.047	N.S.	N.S.
6"-12"	0.385	0.048	0.049	0.079	0.129	0.030	N.S.	N.S.
12"-18"	0.857	0.622	0.141	0.046	0.159	0.010	N.S.	N.S.
18"-24"	1.350	0.637	0.685	0.119	0.895	0.008	N.S.	N.S.
24"-30"	1.545	1.041	0.930	0.419	1.177	0.007	N.S.	N.S.
30"-36"	1.797	1.333	1.366	0.615	1.579	0.356	N.S.	N.S.
36"-42"	2.191	1.669	1.303	1.967	1.921	1.511	N.S.	N.S.

*Significance probability of F statistics.

TABLE 26.--Pounds per acre of carbonate in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	9,940	2,180	2,060	3,220	5,400	1,540	N.S.
0-42"	164,740	108,220	90,560	68,140	120,020	39,380	N.S.

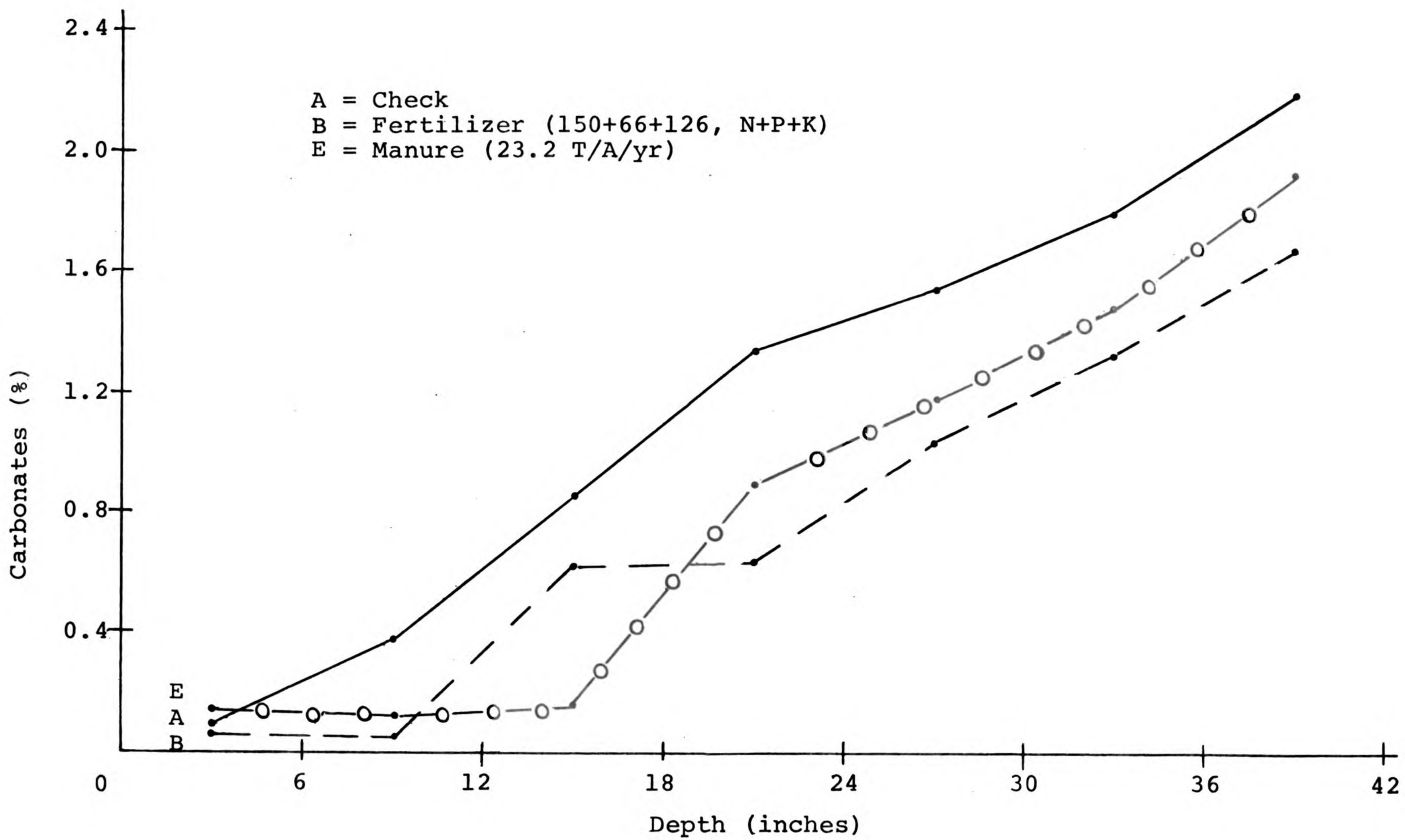

Figure 12.--Carbonate in the soil profiles as affected by fertilizer and chicken manure.

are apparently due to natural variations that occurred within the plot area.

Total Nitrogen

Total nitrogen levels for the seven depths of sampling as affected by chicken manure and fertilizer treatments are in Tables 27 and 28.

Nitrogen in soils is closely associated with the organic matter content. Since the organic matter is located primarily in the surface horizons it is natural that this is also the case for nitrogen.

Nitrogen was present in all parts of the profile. It was concentrated in the surface horizons and decreased with depth.

The fertilizer that was used had no practical effect upon the content or distribution of nitrogen in the profiles.

As would be expected, considering the nitrogen content of chicken manure, the more manure the greater the nitrogen. The data suggest that there was some movement of nitrogen down through the soil especially where the highest rate of manure had been used. This is a significant point because there are some people who are concerned about water pollution. The data in Figure 13 suggest that the movement of nitrogen may not be significant in these soils if rates of application of

TABLE 27.--Total nitrogen levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	1,702	1,729	1,857	1,937	2,057	2,550	0.015	466
6"-12"	1,714	1,641	1,708	1,848	1,978	2,474	0.003	377
12"-18"	725	695	716	739	733	971	N.S.	N.S.
18"-24"	399	448	425	432	442	681	N.S.	N.S.
24"-30"	350	408	343	418	318	604	0.019	159
30"-36"	230	215	291	296	231	476	0.015	144
36"-42"	178	281	203	196	191	366	N.S.	N.S.

*Significance probability of F statistics.

TABLE 28.--Pounds per acre of total nitrogen in the soil profiles to depths 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	6,832	6,740	7,130	7,570	8,070	10,048	1,504
0-42"	10,596	10,834	11,086	11,732	11,900	16,243	2,885

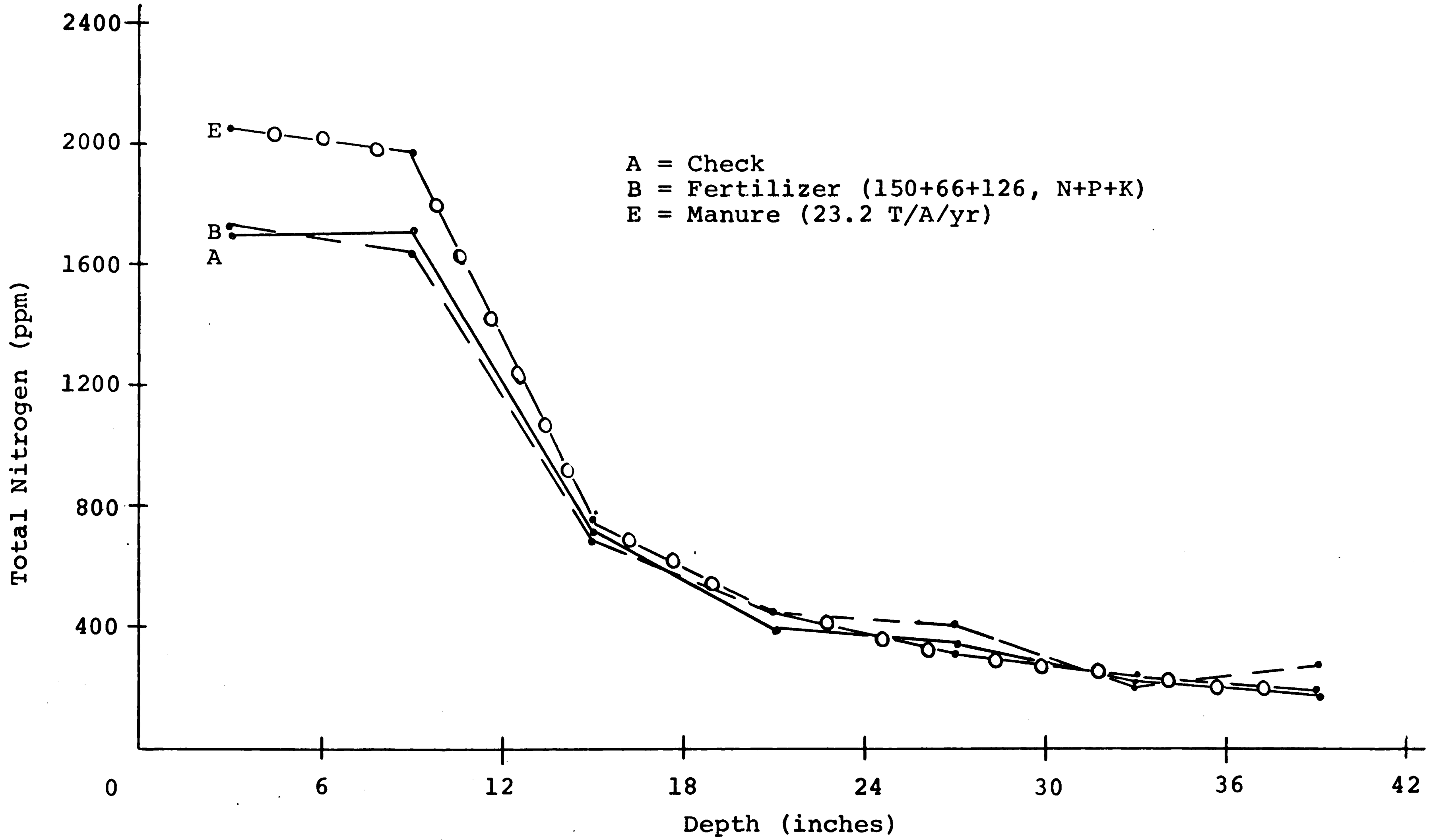

Figure 13.--Total nitrogen in the soil profiles as affected by fertilizer and chicken manure.

manure are restricted to less than that received in treatment E (23.2 T/A).

The C:N ratio for the first depth (0-6 inches) was approximately 11:1 with small variation in all treatments.

Exchangeable Ammonium

Exchangeable ammonium levels for the seven depths of sampling as affected by chicken manure and fertilizer treatments are shown in Tables 29 and 30.

The ammonium levels within the soil profiles generally decreased with depth except that at the greatest depth, the zone in which most of the tile were located, the amount increased very greatly. Undoubtedly many of the samples collected from the 36-42 inch depth contained significant amounts of soil material from below the depth of the tile. At this location, with relative moist conditions existing most of the year, it would be possible for nitrate nitrogen to be reduced to the ammonium form.

Fertilizer had very little effect upon the ammonium content of the soil in samples collected in the fall. The values obtained from the fertilizer plots were very similar to those obtained from the check plots.

The use of high rates of manure, as would be expected, increased the ammonium levels in the surface soil and in the zone where the tile were located.

TABLE 29.--Exchangeable ammonium levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	Treatments A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	0.66	0.56	0.60	0.77	0.70	1.00	0.042	0.27
6"-12"	0.64	0.73	0.68	0.87	0.79	1.17	N.S.	N.S.
12"-18"	0.13	0.12	0.11	0.10	0.15	0.14	N.S.	N.S.
18"-24"	0.13	0.12	0.12	0.12	0.08	0.22	N.S.	N.S.
24"-30"	0.15	0.12	0.07	0.10	0.07	0.18	N.S.	N.S.
30"-36"	0.00	0.00	0.02	0.00	0.03	0.02	N.S.	N.S.
36"-42"	0.55	0.73	0.46	1.00	0.27	2.37	0.027	1.23

*Significance probability of F statistics.

TABLE 30.--Pounds per acre of exchangeable ammonium in the soil profiles to depths of 12 and 42 inches.

Depth	Treatments A	B	C	D	E	F	L.S.D. (.05)
0-12"	2.60	2.58	2.56	3.28	2.98	4.34	1.12
0-42"	4.52	4.76	4.12	5.92	4.18	10.18	2.14

As is shown in Figure 14, there was very little difference in ammonium levels in the zone from the bottom of the plow layer down to near tile depth.

Nitrate

Nitrate levels for the seven depths of sampling as affected by chicken manure and fertilizer are shown in Tables 31 and 32.

Nitrate levels in soils reflect several conditions including treatment of the soil, vegetative cover, recent climatic conditions, and sampling time.

While the values for nitrate were higher on the fertilized plots, at all depths, the difference was small enough that little significance can be attributed to this fact.

The values for nitrates, where 5.8 T/A of manure had been used were similar to those obtained in the profiles from the check plots.

The nitrates levels had a tendency to increase in the subsurface soil where the higher rates of manure had been used. This strongly suggests a downward movement of nitrate nitrogen.

Because it is not possible to account for all of the nitrogen that was added in the manure, one naturally wonders about how much of the nitrogen applied in the manure was converted to nitrate nitrogen and was lost

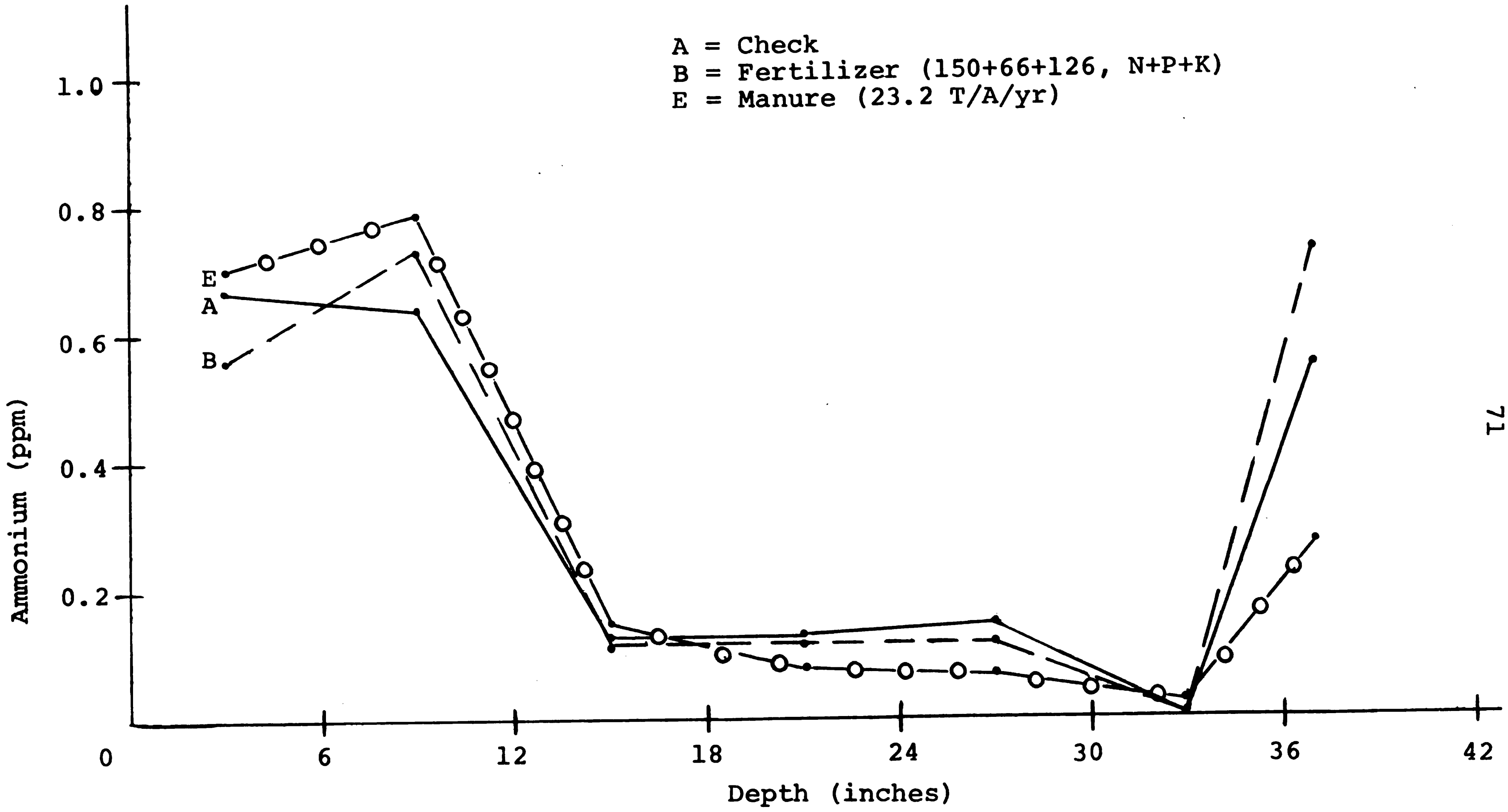

Figure 14.--Exchangeable ammonium in the soil profiles as affected by fertilizer and chicken manure.

TABLE 31.--Nitrate levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
0"- 6"	5.8	10.2	9.8	27.5	42.3	38.3	0.001	17.6
6"-12"	6.6	20.4	9.3	49.1	96.1	62.1	0.001	39.9
12"-18"	3.0	21.9	3.8	28.2	75.3	34.6	0.032	43.8
18"-24"	2.1	20.6	3.2	25.4	49.5	33.0	0.012	26.1
24"-30"	2.7	13.2	3.5	22.4	25.1	40.3	0.004	18.1
30"-36"	2.0	7.7	4.4	10.7	18.5	33.3	0.001	12.6
36"-42"	3.0	11.3	5.0	12.5	14.1	24.1	<0.0005	7.3

*Significance probability of F statistics.

TABLE 32.--Pounds per acre of nitrate in the soil profiles to depths of 12 and 42 inches.

Depth	A	B	C	D	E	F	L.S.D. (.05)
0-12"	24.8	61.2	38.2	153.2	276.8	200.8	111.9
0-42"	50.4	210.6	78.0	351.6	641.8	531.4	252.2

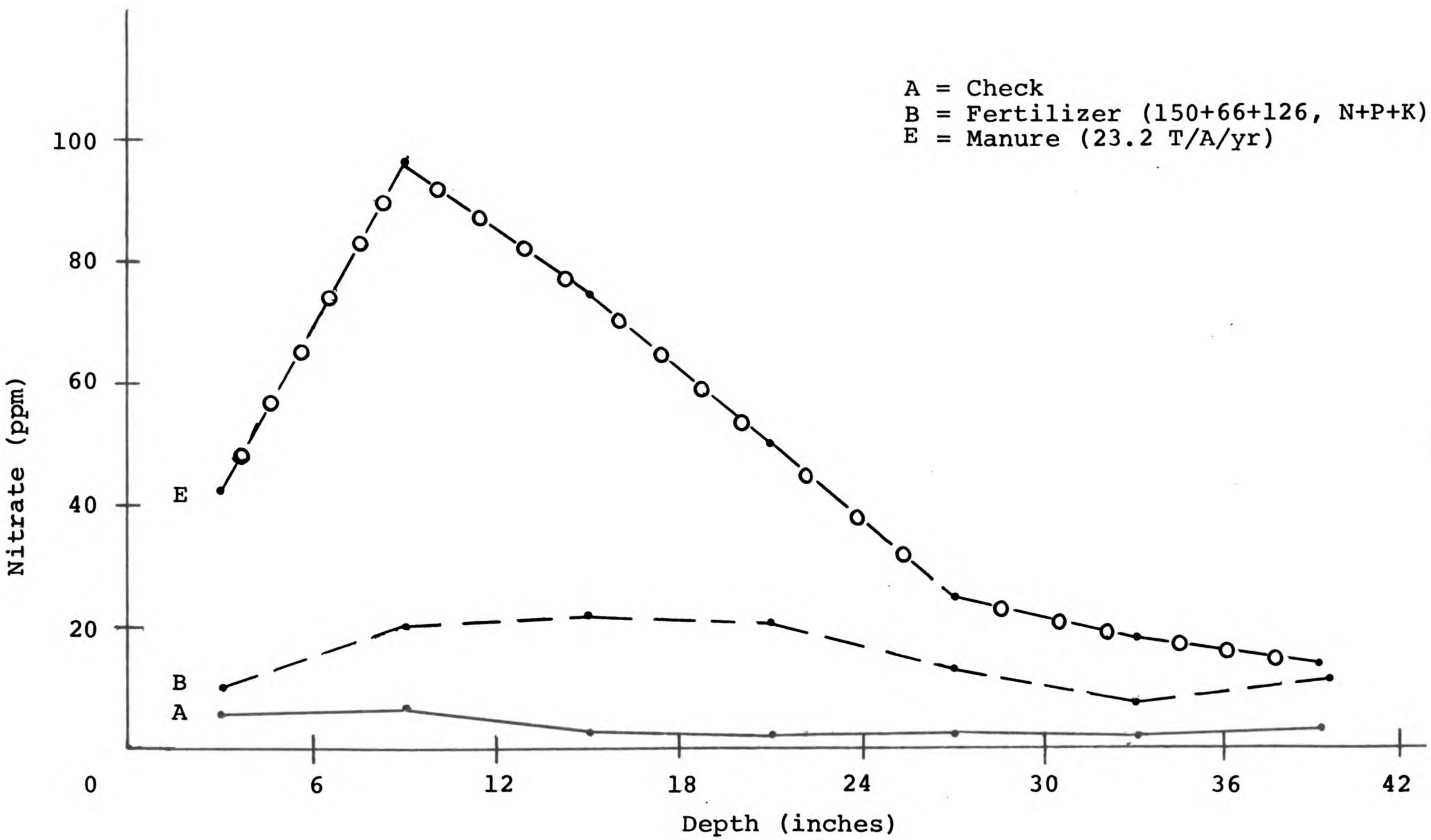

Figure 15.--Nitrate in the soil profiles as affected by fertilizer and chicken manure.

through the tile drainage system. The data suggest that those who have expressed concern about polluting water as a result of using high rates of manure undoubtedly have a basis for the concerns.

Chloride

Chloride levels in the soil profiles as affected by chicken manure and fertilizer are shown in Tables 33 and 34.

The tests for chloride did not show any easily observable trends as related to treatments. Chlorides are very mobile anions and therefore had probably moved out of the soil profile before samples were collected. If soil samples had been collected soon after the treatments were made, it is assumed that differences would have been measured because the fertilizer contained significant amounts of chloride. Poultry manure also contains measurable amounts of chloride.

TABLE 33.--Chloride levels (ppm) in the soil profiles as affected by fertilizer and chicken manure.

Depth in Soil	A Check	B Fertilizer 150+66+126	C Manure 5.8 T/A	D Manure 11.6 T/A	E Manure 23.2 T/A	F Manure 46.4 T/A	Prob.*	L.S.D. (.05)
	Treatments							
0"- 6"	39.5	43.2	37.2	32.7	29.3	17.5	N.S.	N.S.
6"-12"	0.0	12.8	8.2	16.2	43.2	9.2	N.S.	N.S.
12"-18"	0.0	35.2	0.0	0.0	38.5	8.2	N.S.	N.S.
18"-24"	17.5	26.8	34.0	24.5	63.2	44.5	N.S.	N.S.
24"-30"	29.5	17.5	15.2	14.0	16.2	21.0	N.S.	N.S.
30"-36"	10.5	29.2	1.2	5.8	70.0	39.8	0.001	27.7
36"-42"	4.5	18.5	6.0	21.2	16.5	13.0	N.S.	N.S.

*Significance probability of F statistics.

TABLE 34.--Pounds per acre of chloride in the soil profiles to depths of 12 and 42 inches.

Depth	A	B	C	D	E	F	L.S.D. (.05)
	Treatments						
0-12"	70.0	112.0	90.8	97.6	145.0	53.4	N.S.
0-42"	194.0	366.4	203.6	228.6	553.8	306.4	195.7

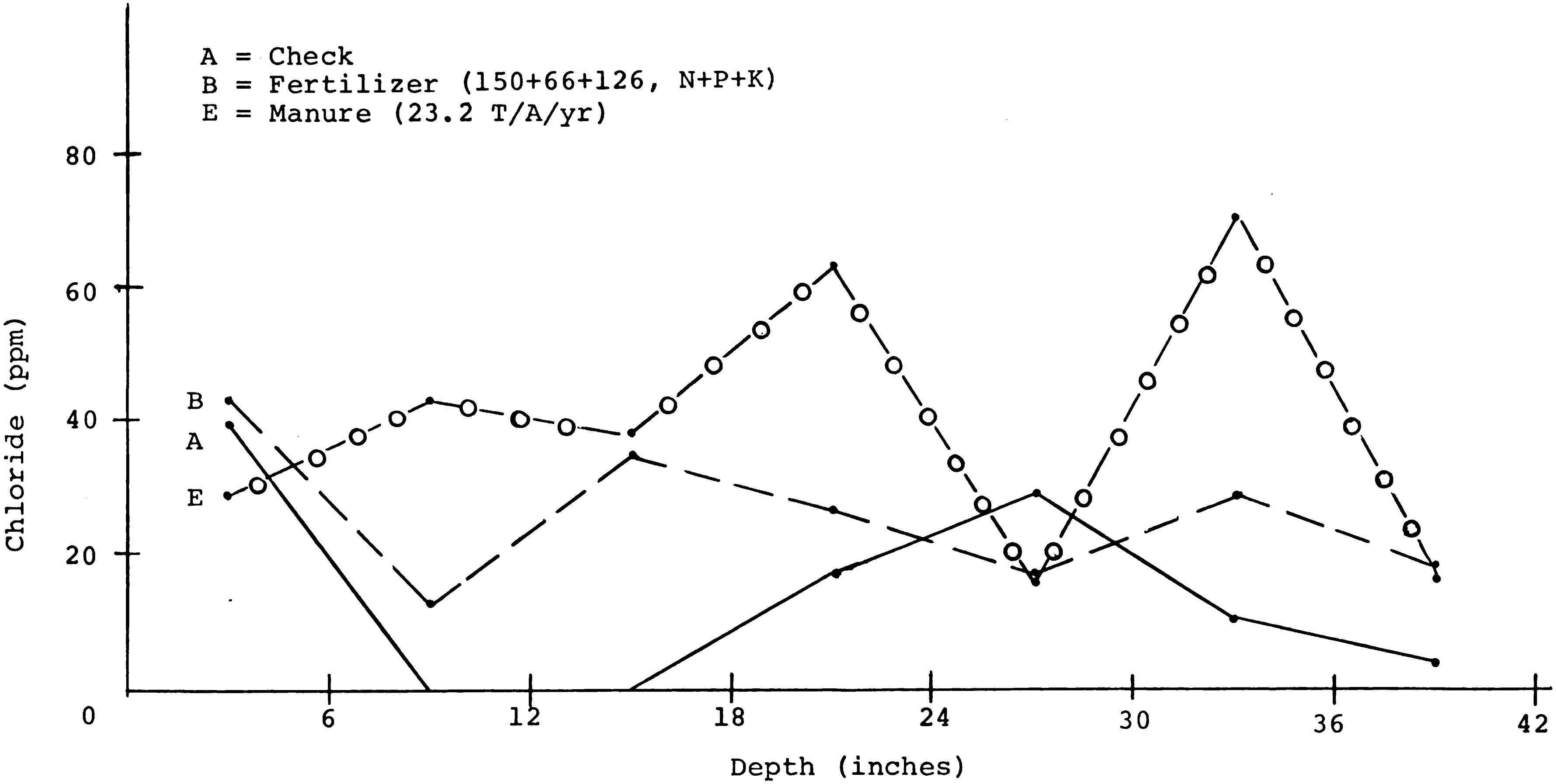

Figure 16.--Chloride in the soil profiles as affected by fertilizer and chicken manure.

SUMMARY AND CONCLUSIONS

Corn was grown in a monoculture system in Huron County, on field experimental plots which involved the use of one rate, 150+66+126 lbs/A (N+P+K), of fertilizer and four rates (5.8, 11.6, 23.2, and 46.4 T/A) of manure from egg producing cage chickens.

Soil profile samples were collected at six inch intervals from each plot. They were analyzed by standard soil testing procedures for pH, nitrates, total nitrogen, total carbon, carbonates, chlorides, exchangeable ammonium and available calcium, potassium, magnesium, sodium, iron, manganese, zinc, copper and phosphorus. The distribution of these chemicals in the soil profile were plotted in graph form to suggest movement and distribution as related to fertilizer needs for future crop production and possible pollution of the water flowing into tile drainage systems.

Analysis of variance procedures were used to assist in the interpretation of the effects of fertilizer and poultry manure on some of the chemical characteristics of the soil profiles.

In general, the use of moderate rates of commercial fertilizer for the production of high yielding corn crops had little effect upon the chemical characteristics of the soil, either surface or subsurface. The greatest effect the fertilizer had was on the pH which was lowered significantly on the alkaline soils used for this research.

The chicken manure, especially when used at the higher rates (up to 46.4 T/A) had the greatest effect upon the chemical conditions within the soil profiles. High rates of chicken manure contains many times the nutrients that are frequently used in fertilizer for a given crop. In addition the manure contains many chemical elements not frequently found in commercial fertilizers.

Of the several chemicals considered in this study only nitrogen and phosphorus have received very much attention from the standpoint of water pollution. The data showed that there is little need for great concern about phosphorus in either fertilizer or manure being able to move down through the soil into drainage waters. The phosphorus from both sources was retained in the surface horizons of the profile.

This was not the case in regard to nitrogen. Chicken manure used at rates of 46.4 T/A annually increased the nitrate content of the soil profile at all depths. There was an increase in both nitrate and ammonium levels near the tile drains, suggesting

that nitrogen was moving through the soil profile into the tile drains.

Other observations are summarized as follows:

1. The greatest effect of both fertilizer and manure was in the surface soil down to a depth of 12 inches.
2. The changes in the chemical condition of the soil caused by the manure was approximately proportional to the amount of manure used.
3. A 5.8 T/A annual application of chicken manure did not produce any significant changes in the chemical characteristics of the soil.
4. The use of either fertilizer or manure did not cause any great changes in the available calcium, magnesium, iron, manganese, carbonate, or chloride levels within the soil profile.
5. The use of the higher rates of chicken manure caused the pH levels to decrease significantly.
6. Also, the available quantities of phosphorus, zinc and copper were increased in the surface 12 inches of soil.
7. Available potassium levels were increased in the surface 18 inches of soil.

8. Sodium levels were increased significantly in the surface 30 inches of soil.

9. The use of chicken manure significantly increased the total carbon content of the surface soil. This was associated without a change in C:N ratio.

10. Increases in total nitrogen levels were observed at the 0-6, 6-12, 24-30 and 30-36 inch depths which proves that nitrogen from manure used at high rates moves downward through the soil and that water pollution from manure is a real possibility.

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LITERATURE CITED

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APPENDIX

TABLE 35.--pH levels in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	7.45	7.73	7.47	7.66	7.58
	2	7.49	7.71	7.48	7.70	7.59
	3	7.72	8.18	7.40	8.02	7.83
	4	7.62	8.39	7.96	8.31	8.07
	5	7.76	8.28	8.09	8.43	8.14
	6	8.08	8.45	8.25	8.46	8.31
	7	8.01	8.42	8.38	8.35	8.29
150 + 66 + 126 N + P + K	1	7.35	7.46	7.31	7.58	7.42
	2	7.37	7.44	7.13	7.42	7.34
	3	7.54	7.75	7.43	7.61	7.58
	4	7.56	7.73	7.57	7.89	7.69
	5	7.78	7.84	7.98	8.02	7.91
	6	7.81	8.15	8.33	8.19	8.12
	7	7.72	8.17	8.21	8.10	8.05
5.8 T/A	1	7.39	7.69	7.39	7.64	7.53
	2	7.32	7.75	7.39	7.58	7.51
	3	7.63	8.01	7.42	7.89	7.74
	4	7.56	8.08	7.52	8.29	7.86
	5	7.74	8.44	7.84	8.35	8.09
	6	8.04	8.30	7.79	8.26	8.10
	7	7.90	8.21	7.89	8.27	8.07
11.6 T/A	1	7.58	7.35	7.21	7.37	7.38
	2	7.54	7.37	7.31	7.28	7.38
	3	7.65	7.59	7.43	7.50	7.54
	4	7.66	7.64	7.63	7.64	7.64
	5	7.66	7.69	7.95	7.69	7.75
	6	7.73	8.00	8.36	7.71	7.95
	7	8.13	8.02	8.26	8.16	8.14
23.2 T/A	1	7.28	7.19	7.61	7.41	7.37
	2	7.20	7.30	7.37	7.21	7.27
	3	7.32	7.53	7.59	7.54	7.50
	4	7.37	7.85	8.14	7.63	7.75
	5	7.71	8.14	8.39	7.93	8.04
	6	7.67	8.22	8.39	8.03	8.08
	7	7.78	8.45	8.26	8.26	8.19
46.4 T/A	1	6.88	6.86	7.19	7.19	7.03
	2	6.61	6.90	7.09	7.04	6.91
	3	7.17	7.11	7.25	7.28	7.20
	4	7.14	7.03	7.34	7.57	7.27
	5	7.25	7.15	7.46	7.59	7.36
	6	7.44	7.77	7.55	7.67	7.61
	7	7.67	7.86	8.05	7.83	7.85

*See page 28 for key.

TABLE 36.--Available phosphorus levels in soil (ppm) in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	36.8	34.2	30.9	31.7	33.4
	2	32.1	32.1	26.0	24.7	28.7
	3	10.6	2.5	7.4	5.1	6.4
	4	9.2	6.6	8.4	6.0	7.6
	5	8.3	5.6	8.6	9.3	8.0
	6	4.9	2.2	3.2	1.9	3.1
	7	5.8	3.1	3.1	3.1	3.8
150 x 66 x 126 N + P + K	1	47.5	45.6	53.2	41.1	46.9
	2	45.3	36.5	36.5	48.4	41.7
	3	6.8	7.9	12.5	5.7	8.2
	4	7.7	8.6	6.0	6.7	7.3
	5	7.3	7.3	6.6	6.6	7.0
	6	4.9	3.4	2.2	3.1	3.4
	7	4.9	4.0	3.4	3.1	3.9
5.8 T/A	1	63.4	34.2	40.2	53.2	47.8
	2	59.6	38.2	30.0	41.9	42.4
	3	15.5	6.5	7.4	9.1	9.6
	4	6.9	6.3	6.7	3.9	6.0
	5	6.2	4.4	7.3	4.3	5.6
	6	4.9	3.1	4.8	2.2	3.8
	7	4.8	1.9	6.3	3.7	4.2
11.6 T/A	1	57.2	79.4	117.9	112.9	91.9
	2	72.2	54.3	60.0	96.8	70.8
	3	7.9	9.7	13.2	25.0	14.0
	4	7.1	8.3	7.5	7.9	7.7
	5	5.6	7.9	7.1	8.3	7.2
	6	3.4	3.6	1.6	5.3	3.5
	7	3.4	5.6	2.4	4.6	4.0
23.2 T/A	1	88.2	148.4	73.4	105.1	103.8
	2	63.4	61.5	99.6	128.2	88.2
	3	11.3	18.3	33.7	8.2	17.9
	4	13.4	6.9	6.7	7.7	8.7
	5	9.1	5.0	7.0	7.6	7.2
	6	6.0	3.1	1.0	2.7	3.2
	7	6.3	2.4	2.2	3.1	3.5
46.4 T/A	1	146.2	90.9	65.6	103.6	101.6
	2	84.5	84.5	53.5	101.1	80.9
	3	10.0	11.0	6.8	12.2	10.0
	4	8.3	10.5	7.5	9.2	8.9
	5	8.3	10.0	8.6	10.0	9.2
	6	5.6	6.6	3.7	6.3	5.6
	7	6.1	7.4	5.6	7.4	6.6

*See page 28 for key.

TABLE 37.--Available potassium levels in soil (ppm) in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	162.5	120.0	122.5	130.0	133.8
	2	120.0	112.5	105.0	95.0	108.1
	3	80.0	37.5	92.5	72.5	70.6
	4	95.0	22.5	91.3	38.8	61.9
	5	85.0	31.3	58.8	28.8	51.0
	6	63.0	20.0	36.3	21.0	35.1
	7	57.5	27.2	40.0	35.0	39.9
150 + 66 + 126 N + P + K	1	162.5	167.5	170.0	130.0	157.5
	2	140.0	140.0	185.0	97.5	140.6
	3	75.0	72.5	55.0	65.0	66.9
	4	90.0	72.5	70.0	35.0	66.9
	5	73.8	63.8	58.8	33.8	57.5
	6	60.0	28.0	27.5	18.5	33.5
	7	60.0	31.0	27.0	29.0	36.8
5.8 T/A	1	227.5	118.0	162.5	170.0	169.5
	2	250.0	127.5	115.0	152.0	161.1
	3	85.0	32.0	81.5	62.5	65.3
	4	71.3	36.3	93.8	22.5	56.0
	5	70.0	23.3	92.5	30.0	53.9
	6	61.5	25.0	86.0	18.5	47.8
	7	66.3	39.2	85.5	27.2	54.6
11.6 T/A	1	177.5	260.0	415.0	432.5	321.2
	2	152.5	162.5	350.0	365.0	257.5
	3	45.0	80.0	85.0	152.5	65.6
	4	42.5	75.0	62.5	77.5	64.4
	5	41.3	75.0	58.8	67.5	60.6
	6	28.0	25.3	28.0	50.5	32.9
	7	24.0	45.5	34.0	34.5	34.5
23.2 T/A	1	350.3	495.0	260.0	380.0	371.3
	2	267.5	325.0	347.5	455.0	348.8
	3	107.5	80.0	152.5	67.5	101.9
	4	103.8	32.5	27.5	61.3	56.3
	5	113.0	26.3	26.3	41.3	51.7
	6	118.0	19.5	18.0	26.6	45.5
	7	82.0	12.0	29.0	26.5	37.4
46.4 T/A	1	600.0	537.5	302.5	345.0	446.3
	2	568.8	506.3	250.0	345.0	417.5
	3	155.0	140.0	105.0	140.0	135.0
	4	122.5	131.3	110.0	81.3	111.3
	5	122.5	141.3	106.3	47.5	104.4
	6	107.0	108.8	51.0	57.0	80.9
	7	51.0	111.3	47.0	53.0	65.6

*See page 28 for key.

TABLE 38.--Available calcium levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	2611	2493	2493	2904	2625
	2	2679	2444	2414	4010	2887
	3	4435	3947	2382	5462	4057
	4	2189	4476	4283	4672	3905
	5	2638	4483	5327	4586	4259
	6	4767	3724	4442	3790	4181
	7	4737	3870	4427	4485	4380
150 + 66 + 126 N + P + K	1	2556	2484	2008	2289	2334
	2	2245	2689	1979	2102	2254
	3	2382	1610	1917	5905	2954
	4	2014	1630	2174	4726	2636
	5	2298	1972	5394	4646	3578
	6	2223	2443	4199	3830	3174
	7	3202	4157	3830	4256	3861
5.8 T/A	1	2639	2271	2648	2185	2436
	2	2484	2246	2404	1951	2271
	3	2296	2099	2131	1586	2028
	4	1849	4317	1768	4093	3007
	5	1767	4498	1760	4297	3081
	6	3239	4398	1682	3763	3271
	7	2703	4647	1602	4185	3284
11.6 T/A	1	2538	2845	2520	2484	2597
	2	2484	2188	2494	2504	2418
	3	1172	1929	2672	2085	1965
	4	1097	1653	3640	1360	1938
	5	1120	1615	5161	1481	2344
	6	832	786	3883	1201	1676
	7	3080	4514	4199	4241	4009
23.2 T/A	1	3202	2448	2770	2713	2783
	2	3077	2344	2669	2794	2721
	3	2657	2850	2468	1418	2348
	4	2394	4708	4564	1415	3270
	5	2955	4616	4368	1903	3461
	6	2443	3992	3910	4005	3588
	7	4951	3477	4312	4074	4204
46.4 T/A	1	3157	2676	2750	3180	2941
	2	2710	2848	2710	3033	2825
	3	2569	2325	2093	2118	2276
	4	2050	2349	2002	1676	2019
	5	2110	2149	1910	2081	2063
	6	1763	4199	1165	1844	2243
	7	2566	5139	4312	2668	3671

*See page 28 for key.

TABLE 39.--Available magnesium levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	322	221	281	299	281
	2	247	209	240	249	236
	3	250	82	304	264	225
	4	246	61	328	137	193
	5	315	130	260	101	202
	6	200	76	157	77	128
	7	171	103	174	145	148
150 + 66 + 126 N + P + K	1	252	287	218	354	278
	2	192	272	202	211	219
	3	236	186	184	345	238
	4	217	236	213	139	201
	5	260	262	193	106	205
	6	252	122	107	70	138
	7	225	121	115	114	144
5.8 T/A	1	292	168	344	229	258
	2	222	164	280	198	216
	3	219	106	251	155	183
	4	201	96	270	56	156
	5	210	64	295	62	158
	6	233	96	276	63	167
	7	284	166	282	110	211
11.6 T/A	1	233	396	364	317	328
	2	210	271	265	263	252
	3	129	261	297	253	235
	4	119	235	230	203	197
	5	136	262	275	221	224
	6	109	148	102	176	134
	7	96	173	138	136	136
23.2 T/A	1	453	333	268	335	347
	2	321	226	260	322	292
	3	303	208	235	200	237
	4	255	107	94	253	175
	5	401	84	77	177	185
	6	371	68	80	105	156
	7	306	37	110	115	142
46.4 T/A	1	433	419	337	366	381
	2	268	329	294	303	299
	3	303	343	267	230	286
	4	297	372	310	209	297
	5	331	389	303	328	338
	6	272	309	174	307	266
	7	191	306	146	233	219

*See page 28 for key.

TABLE 40.--Available sodium levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	51.5	51.5	45.0	55.0	50.8
	2	65.0	67.5	62.5	72.5	66.9
	3	65.0	65.0	57.5	85.0	68.1
	4	66.3	73.8	71.3	65.0	69.1
	5	80.0	65.0	90.0	72.5	76.9
	6	83.8	70.0	97.5	65.0	79.1
	7	67.5	58.0	68.5	61.3	63.8
150 + 66 + 126 N + P + K	1	47.5	50.0	51.5	51.5	50.1
	2	70.0	70.0	52.5	65.0	64.4
	3	60.0	75.0	70.0	95.0	75.0
	4	76.3	68.8	72.5	75.0	73.1
	5	70.0	65.0	76.3	75.0	71.6
	6	63.8	62.5	80.0	67.5	68.4
	7	58.0	56.5	63.0	59.0	59.1
5.8 T/A	1	61.0	61.0	57.5	85.0	66.1
	2	75.0	77.5	75.0	73.5	75.2
	3	77.5	60.0	80.0	72.5	72.5
	4	77.5	86.3	72.5	67.5	75.9
	5	71.3	76.3	72.5	72.5	73.1
	6	78.8	68.8	68.8	82.5	74.7
	7	56.5	56.5	75.8	63.0	62.9
11.6 T/A	1	67.5	88.0	77.5	88.0	80.3
	2	110.0	122.5	132.5	110.0	118.8
	3	85.0	100.0	130.0	115.0	107.5
	4	75.0	75.0	88.8	91.3	82.5
	5	60.0	86.3	96.3	90.0	83.1
	6	60.0	62.5	70.0	81.3	68.4
	7	55.0	77.5	64.3	75.0	67.9
23.2 T/A	1	92.5	90.0	85.0	82.5	87.5
	2	145.0	195.0	150.0	127.5	154.4
	3	122.5	192.5	195.0	110.0	155.0
	4	112.5	121.3	98.8	117.5	112.5
	5	95.0	90.0	90.0	82.5	89.4
	6	82.5	75.0	82.5	87.5	81.9
	7	80.8	48.0	75.0	75.0	69.7
46.4 T/A	1	130.0	92.5	65.0	96.5	96.0
	2	182.5	107.5	87.5	135.0	128.1
	3	175.0	82.5	90.0	157.5	126.2
	4	140.0	96.3	91.3	137.5	116.2
	5	93.8	102.5	87.5	117.5	100.3
	6	80.0	135.0	76.3	113.8	101.3
	7	60.8	88.8	59.0	71.8	70.1

*See page 28 for key.

TABLE 41.--Available iron levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	34.0	29.2	22.6	21.0	26.7
	2	29.0	28.4	27.6	8.7	23.4
	3	55.6	2.9	73.9	3.5	34.0
	4	85.0	2.6	2.6	2.6	23.2
	5	40.1	2.0	3.1	2.8	12.0
	6	3.3	1.0	1.2	1.9	1.9
	7	1.0	2.0	1.5	10.8	3.8
150 + 66 + 126 N + P + K	1	34.8	30.4	56.6	45.3	41.8
	2	31.5	29.3	42.8	44.6	37.1
	3	110.0	123.3	57.0	3.6	73.5
	4	159.2	155.5	87.5	3.9	101.5
	5	65.5	79.0	2.0	2.8	37.3
	6	14.8	3.5	3.3	1.9	5.9
	7	3.7	2.0	1.2	2.0	2.2
5.8 T/A	1	38.0	69.2	30.8	45.3	45.8
	2	35.2	57.3	30.2	46.0	42.2
	3	48.4	34.7	72.9	78.6	58.7
	4	80.0	3.4	132.0	3.1	54.6
	5	91.0	4.2	119.1	3.4	54.4
	6	22.2	5.1	210.2	1.4	59.7
	7	1.4	1.8	235.0	2.0	60.1
11.6 T/A	1	40.8	36.0	37.6	53.2	41.9
	2	43.4	41.2	42.5	50.6	44.4
	3	35.7	123.8	33.8	75.4	67.2
	4	54.4	145.9	2.6	124.6	81.9
	5	77.0	128.0	2.0	121.3	82.1
	6	111.3	127.9	3.0	166.6	102.2
	7	1.5	1.8	1.2	1.8	1.6
23.2 T/A	1	32.0	49.0	34.0	57.9	43.7
	2	29.0	45.7	29.9	59.0	40.9
	3	100.6	25.9	41.6	63.8	58.0
	4	87.0	4.2	3.1	134.2	57.1
	5	45.4	2.0	3.4	60.3	27.8
	6	130.5	1.0	1.5	2.0	33.8
	7	0.5	2.4	2.0	1.8	1.7
46.4 T/A	1	42.0	40.4	40.0	38.8	40.3
	2	42.8	39.6	34.9	31.8	37.3
	3	82.2	77.2	107.2	73.9	85.1
	4	156.7	115.3	162.2	138.9	143.3
	5	153.1	104.0	158.5	157.3	143.2
	6	218.9	2.3	200.0	139.7	140.2
	7	30.0	1.8	1.0	5.8	9.7

*See page 28 for key.

TABLE 42.--Available manganese levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	32.1	42.5	55.0	56.7	46.6
	2	28.3	38.3	43.4	47.7	39.4
	3	14.9	27.9	35.9	5.8	21.1
	4	15.8	24.5	19.4	12.9	18.2
	5	28.0	14.7	8.3	15.8	16.7
	6	14.1	12.4	8.5	24.2	14.8
	7	14.5	15.2	10.8	12.3	13.2
150 + 66 + 126 N + P + K	1	30.6	37.6	66.5	45.7	45.1
	2	30.1	31.2	54.8	47.5	40.9
	3	11.9	19.4	33.1	5.7	17.5
	4	16.6	28.0	38.7	14.3	24.4
	5	22.3	14.5	12.4	20.5	17.4
	6	27.8	11.6	13.2	24.8	19.4
	7	15.9	17.5	12.0	13.6	14.8
5.8 T/A	1	34.2	45.2	37.3	59.2	44.0
	2	34.6	48.0	24.0	48.2	38.7
	3	14.0	40.0	17.5	21.8	23.3
	4	8.6	21.9	28.0	22.8	20.3
	5	11.6	22.6	27.3	24.6	21.5
	6	33.2	14.6	38.3	21.7	27.0
	7	36.2	8.0	40.5	19.0	25.9
11.6 T/A	1	35.9	37.1	88.3	87.7	62.2
	2	35.6	27.2	68.5	76.1	51.9
	3	4.8	31.6	15.7	49.4	25.4
	4	4.1	15.5	33.9	30.9	21.1
	5	6.0	23.5	3.9	24.9	14.6
	6	13.7	7.7	16.4	19.2	14.2
	7	16.2	14.7	13.4	15.9	15.1
23.2 T/A	1	43.2	62.1	57.0	71.6	58.5
	2	30.4	47.7	58.5	77.2	53.5
	3	23.7	45.3	22.5	17.8	27.3
	4	20.9	23.7	18.0	23.9	21.6
	5	31.1	26.1	20.6	34.7	28.1
	6	32.9	20.2	17.0	22.6	23.4
	7	13.4	25.9	14.3	19.8	18.4
46.4 T/A	1	58.7	44.5	44.1	52.3	49.9
	2	45.0	47.3	37.7	50.8	45.2
	3	39.1	23.0	37.6	28.9	32.2
	4	57.3	28.8	45.8	41.2	43.3
	5	45.7	27.4	51.7	48.9	43.4
	6	37.7	19.7	28.7	96.2	45.6
	7	19.8	11.6	20.4	18.7	17.6

*See page 28 for key.

TABLE 43.--Available zinc levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	9.1	6.9	7.1	7.4	7.6
	2	7.6	7.0	6.0	4.1	6.2
	3	5.4	0.7	3.6	0.5	2.6
	4	4.5	0.7	0.7	0.5	1.6
	5	4.8	0.7	0.5	0.6	1.7
	6	0.5	0.6	0.1	0.6	0.5
	7	0.4	0.5	0.2	0.4	0.4
150 + 66 + 126 N + P + K	1	9.7	8.0	8.5	7.0	8.3
	2	7.9	6.1	6.4	6.4	6.7
	3	4.8	4.3	3.9	0.7	3.4
	4	6.0	4.7	7.7	0.7	4.8
	5	4.1	3.6	0.9	0.8	2.4
	6	2.3	0.8	0.6	0.8	1.1
	7	1.8	0.6	1.2	0.2	1.0
5.8 T/A	1	14.3	6.9	11.2	9.6	10.5
	2	11.4	6.1	7.0	7.1	7.9
	3	6.2	2.0	5.3	3.1	4.2
	4	6.1	0.5	5.2	0.7	3.1
	5	5.7	0.9	5.5	1.1	3.3
	6	2.2	0.3	7.1	0.6	2.6
	7	1.9	0.3	6.0	0.5	2.2
11.6 T/A	1	10.8	14.2	21.9	20.6	16.9
	2	14.2	10.0	12.1	17.2	13.4
	3	3.3	6.7	3.5	6.9	5.1
	4	4.4	4.1	1.6	3.7	3.5
	5	5.1	4.0	0.6	5.3	3.8
	6	4.1	4.5	0.6	4.2	3.4
	7	0.8	0.4	0.2	0.8	0.6
23.2 T/A	1	21.0	22.3	12.9	30.0	21.6
	2	12.8	11.5	16.2	28.1	17.5
	3	5.2	3.6	6.3	3.0	4.5
	4	5.7	1.0	0.6	4.0	2.8
	5	3.6	0.8	0.7	3.0	2.0
	6	4.8	0.7	0.3	0.7	1.6
	7	0.4	0.9	0.3	0.4	0.5
46.4 T/A	1	26.8	15.6	12.0	18.9	18.3
	2	14.1	14.5	9.1	20.1	14.5
	3	5.9	5.9	5.0	4.8	5.4
	4	5.2	5.3	4.9	5.0	5.1
	5	4.8	4.6	4.4	4.7	4.6
	6	5.2	0.6	5.1	7.8	4.7
	7	3.3	0.5	1.3	1.5	1.7

*See page 28 for key.

TABLE 44.--Available copper levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	10.1	6.2	6.3	6.3	7.2
	2	10.2	7.3	5.6	5.6	7.2
	3	9.9	4.5	7.8	6.3	7.1
	4	8.5	4.0	7.9	4.5	6.2
	5	6.9	3.7	7.8	3.6	5.5
	6	7.4	4.0	4.9	4.0	5.1
	7	6.0	4.3	5.1	4.4	5.0
150 + 66 + 126 N + P + K	1	8.9	7.7	5.7	5.1	6.9
	2	8.8	7.7	5.8	5.6	7.0
	3	7.8	5.8	5.4	6.2	6.3
	4	7.1	4.5	4.9	4.5	5.3
	5	7.0	3.7	4.4	3.6	4.8
	6	7.7	4.0	3.8	4.1	4.9
	7	7.0	4.4	4.5	5.7	5.4
5.8 T/A	1	9.8	5.5	9.0	6.6	7.7
	2	9.6	5.1	8.2	5.5	7.1
	3	9.8	5.3	7.0	4.5	6.7
	4	7.8	5.0	5.3	4.5	5.7
	5	6.1	3.2	4.4	3.8	4.4
	6	6.3	4.1	5.0	4.4	5.0
	7	6.3	5.1	5.2	4.6	5.3
11.6 T/A	1	9.0	9.0	7.0	7.7	8.2
	2	8.1	7.2	6.1	7.6	7.3
	3	7.4	5.5	9.1	6.2	7.1
	4	6.3	4.9	5.3	5.0	5.4
	5	4.9	4.2	5.7	4.6	4.9
	6	5.3	3.8	3.7	4.6	4.4
	7	4.5	5.7	4.7	4.5	4.9
23.2 T/A	1	11.5	6.9	6.3	8.1	8.2
	2	10.3	6.4	6.9	8.5	8.0
	3	8.3	4.9	5.6	4.9	5.9
	4	8.5	3.8	3.6	6.1	5.5
	5	4.5	3.7	3.8	3.7	3.9
	6	7.1	4.0	4.0	4.1	4.8
	7	8.4	3.9	4.4	4.4	5.3
46.4 T/A	1	13.1	13.0	9.8	10.8	11.7
	2	10.5	12.7	9.4	10.8	10.9
	3	7.4	10.6	6.3	7.1	7.9
	4	5.5	8.6	6.7	6.1	6.7
	5	5.1	7.7	6.5	5.5	6.2
	6	5.8	7.3	4.5	7.3	6.2
	7	6.4	7.2	4.5	6.3	6.1

*See page 28 for key.

TABLE 45.--Total carbon levels (%) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	2.06	1.98	1.16	2.40	1.90
	2	2.32	2.22	2.14	2.76	2.36
	3	1.75	3.39	1.20	4.59	2.73
	4	1.19	3.43	1.98	3.94	2.63
	5	1.32	2.68	3.46	3.69	2.79
	6	2.67	2.20	4.04	3.13	3.01
	7	3.47	2.67	4.80	4.76	3.93
150 + 66 + 126 N + P + K	1	2.04	2.55	2.12	2.08	2.20
	2	2.33	2.43	2.31	2.32	2.35
	3	0.90	0.86	1.41	4.69	1.97
	4	0.90	0.78	1.12	3.99	1.70
	5	1.11	0.94	2.24	2.92	1.80
	6	1.27	1.98	2.91	2.64	2.20
	7	2.08	3.23	3.35	4.03	3.17
5.8 T/A	1	2.28	1.83	2.60	2.20	2.23
	2	2.49	1.92	2.32	2.17	2.23
	3	1.72	1.41	1.32	0.99	1.36
	4	0.96	3.03	0.86	1.69	1.64
	5	0.78	2.87	0.58	2.64	1.72
	6	1.74	3.53	0.62	3.40	2.32
	7	1.54	4.59	0.88	3.94	2.74
11.6 T/A	1	1.94	2.36	2.31	2.72	2.33
	2	2.20	1.78	2.49	2.75	2.31
	3	1.03	1.08	1.79	1.69	1.40
	4	0.95	0.98	1.43	0.67	1.01
	5	0.74	0.85	3.85	0.68	1.53
	6	0.74	0.98	2.93	0.62	1.32
	7	2.10	3.94	4.83	2.69	3.39
23.2 T/A	1	2.36	2.28	2.27	2.73	2.41
	2	2.48	2.04	2.34	2.90	2.44
	3	1.09	1.88	1.28	0.94	1.30
	4	1.24	2.92	3.13	0.66	1.99
	5	1.14	2.74	2.94	1.16	2.00
	6	0.82	3.31	3.02	2.89	2.51
	7	3.31	2.64	4.37	3.89	3.55
46.4 T/A	1	2.60	3.11	2.48	3.02	2.80
	2	2.82	3.31	2.35	3.15	2.91
	3	1.74	1.18	0.92	1.41	1.31
	4	1.04	0.96	0.77	0.77	0.89
	5	0.74	0.70	0.55	0.72	0.68
	6	0.64	2.11	0.63	0.82	1.05
	7	1.66	3.24	2.69	2.17	2.44

*See page 28 for key.

TABLE 46.--Carbonate levels (%) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	0.044	0.072	0.110	0.221	0.112
	2	0.033	0.112	0.120	1.275	0.385
	3	0.013	0.475	0.008	2.930	0.857
	4	0.002	2.035	1.142	2.222	1.350
	5	0.420	1.554	1.701	2.504	1.545
	6	1.954	1.266	1.788	2.179	1.797
	7	1.802	1.652	2.029	3.281	2.191
150 + 66 + 126 N + P + K	1	0.064	0.053	0.030	0.095	0.061
	2	0.044	0.090	0.020	0.038	0.048
	3	0.005	0.015	0.023	2.446	0.622
	4	0.019	0.045	0.172	2.312	0.637
	5	0.247	0.309	1.520	2.087	1.041
	6	0.501	1.220	1.851	1.759	1.333
	7	0.751	1.854	1.799	2.271	1.669
5.8 T/A	1	0.053	0.089	0.017	0.057	0.054
	2	0.028	0.116	0.014	0.038	0.049
	3	0.007	0.498	0.005	0.054	0.141
	4	0.000	1.393	0.005	1.341	0.685
	5	0.016	1.960	0.000	1.744	0.930
	6	1.131	2.261	0.002	2.070	1.366
	7	0.756	2.093	0.008	2.355	1.303
11.6 T/A	1	0.083	0.017	0.121	0.108	0.082
	2	0.083	0.079	0.064	0.089	0.079
	3	0.000	0.126	0.031	0.025	0.046
	4	0.000	0.013	0.765	0.019	0.199
	5	0.000	0.057	0.586	0.031	0.419
	6	0.013	0.310	2.122	0.016	0.615
	7	1.081	2.107	3.037	1.641	1.967
23.2 T/A	1	0.080	0.154	0.230	0.100	0.141
	2	0.050	0.184	0.169	0.112	0.129
	3	0.011	0.479	0.126	0.022	0.159
	4	0.025	1.684	1.805	0.065	0.895
	5	0.394	1.788	1.992	0.532	1.177
	6	0.166	2.104	1.995	2.050	1.579
	7	1.721	1.425	1.992	2.544	1.921
46.4 T/A	1	0.063	0.028	0.025	0.069	0.047
	2	0.013	0.020	0.011	0.074	0.030
	3	0.013	0.004	0.008	0.016	0.010
	4	0.005	0.003	0.008	0.016	0.008
	5	0.005	0.000	0.011	0.011	0.007
	6	0.000	1.174	0.045	0.206	0.356
	7	1.751	1.871	1.615	0.805	1.511

*See page 28 for key.

TABLE 47.--Total nitrogen levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	1955	1554	1551	1747	1702
	2	1987	1663	1441	1765	1714
	3	1307	433	575	586	725
	4	688	149	473	287	399
	5	644	262	309	185	350
	6	347	178	251	142	230
	7	270	118	153	170	178
150 + 66 + 126 N + P + K	1	1926	2228	1336	1427	1729
	2	1842	1398	1638	1685	1641
	3	655	444	732	950	695
	4	553	448	477	313	448
	5	659	360	357	254	408
	6	294	189	175	200	215
	7	650	153	204	117	281
5.8 T/A	1	2184	1405	2104	1733	1857
	2	2046	1416	1773	1598	1708
	3	1099	404	834	528	716
	4	659	295	542	204	425
	5	535	234	426	175	343
	6	375	204	433	153	291
	7	270	153	259	129	203
11.6 T/A	1	1649	2002	1977	2118	1937
	2	1558	1915	1809	2111	1848
	3	411	477	942	1125	739
	4	426	440	459	404	432
	5	382	433	360	495	418
	6	353	207	207	415	296
	7	188	253	153	188	196
23.2 T/A	1	2457	1980	1605	2184	2057
	2	2202	1572	1813	2326	1978
	3	775	863	721	571	733
	4	659	389	226	495	442
	5	484	291	193	302	318
	6	488	164	94	178	231
	7	423	123	76	141	191
46.4 T/A	1	2528	2872	2231	2570	2550
	2	2522	2781	2009	2584	2474
	3	1366	892	655	972	971
	4	819	797	553	553	681
	5	702	622	477	615	604
	6	546	353	415	590	476
	7	482	323	182	476	366

*See page 28 for key.

TABLE 48.--Exchangeable ammonium levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	.69	.47	.73	.73	0.66
	2	.51	.80	.87	.36	0.64
	3	.11	.15	.11	.15	0.13
	4	.22	.11	.18	.00	0.13
	5	.07	.15	.18	.18	0.15
	6	.00	.00	.00	.00	0.00
	7	1.46	.00	.73	.00	0.55
150 + 66 + 126 N + P + K	1	.44	.73	.69	.44	0.58
	2	.44	.76	.91	.80	0.73
	3	.04	.07	.18	.18	0.12
	4	.22	.04	.22	.00	0.12
	5	.00	.18	.18	.11	0.12
	6	.00	.00	.00	.00	0.00
	7	1.46	.00	.00	1.46	0.73
5.8 T/A	1	.62	.36	.66	.76	0.60
	2	.22	.69	.91	.91	0.68
	3	.15	.07	.07	.15	0.11
	4	.18	.00	.29	.00	0.12
	5	.00	.00	.18	.11	0.07
	6	.07	.00	.00	.00	0.02
	7	1.46	.00	.36	.00	0.46
11.6 T/A	1	.51	1.06	.91	.58	0.77
	2	.51	.55	1.09	1.31	0.87
	3	.04	.11	.11	.15	0.10
	4	.04	.22	.18	.04	0.12
	5	.00	.18	.11	.11	0.10
	6	.00	.00	.00	.00	0.00
	7	.36	1.09	1.46	1.09	1.00
23.2 T/A	1	.69	.55	.76	.80	0.70
	2	.40	.66	.87	1.24	0.79
	3	.07	.11	.33	.07	0.15
	4	.04	.18	.07	.04	0.08
	5	.00	.00	.11	.18	0.07
	6	.11	.00	.00	.00	0.03
	7	1.09	.00	.00	.00	0.27
46.4 T/A	1	.95	1.24	.91	.91	1.00
	2	1.20	1.57	.58	1.31	1.17
	3	.15	.15	.15	.11	0.14
	4	.33	.36	.07	.11	0.22
	5	.00	.29	.18	.25	0.18
	6	.04	.00	.00	.04	0.02
	7	2.91	1.46	.73	4.37	2.37

*See page 28 for key.

TABLE 49.--Nitrate levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	5.9	4.8	7.3	5.2	5.8
	2	5.1	6.8	8.1	6.5	6.6
	3	3.0	3.0	2.7	3.2	3.0
	4	1.5	2.3	1.5	3.1	2.1
	5	1.6	2.9	2.2	3.9	2.7
	6	1.2	1.8	2.7	2.4	2.0
	7	2.1	2.6	3.3	4.0	3.0
150 + 66 + 126 N + P + K	1	5.8	10.4	17.7	7.0	10.2
	2	6.2	17.4	33.5	24.6	20.4
	3	2.9	5.0	17.4	62.4	21.9
	4	1.7	9.3	32.3	38.9	20.6
	5	2.7	8.7	22.2	19.1	13.2
	6	3.2	5.5	12.0	9.9	7.7
	7	5.5	6.0	15.2	18.5	11.3
5.8 T/A	1	13.0	10.3	8.7	7.0	9.8
	2	11.6	11.2	7.9	6.5	9.3
	3	4.8	4.0	3.2	3.1	3.8
	4	2.0	5.7	2.6	2.4	3.2
	5	2.0	4.7	3.6	3.5	3.5
	6	2.5	5.5	3.7	5.7	4.4
	7	3.2	6.4	4.2	6.0	5.0
11.6 T/A	1	12.8	36.6	32.7	28.0	27.5
	2	18.7	43.3	69.7	64.7	49.1
	3	10.4	18.0	60.2	24.1	28.2
	4	17.0	17.7	52.6	14.4	25.4
	5	13.1	23.0	33.5	19.8	22.4
	6	9.1	10.3	8.8	14.6	10.7
	7	9.1	18.5	8.8	13.5	12.5
23.2 T/A	1	44.4	60.3	25.0	39.6	42.3
	2	80.6	139.5	86.7	77.7	96.1
	3	37.4	129.7	96.8	37.4	75.3
	4	31.1	85.8	37.5	43.6	49.5
	5	27.8	27.8	19.1	25.8	25.1
	6	24.3	19.2	14.6	15.8	18.5
	7	19.2	7.0	17.8	12.5	14.1
46.2 T/A	1	60.3	33.9	12.8	46.1	38.3
	2	122.7	38.8	19.8	67.2	62.1
	3	74.9	11.6	8.4	43.3	34.6
	4	36.1	10.1	26.7	58.9	33.0
	5	23.0	14.6	47.0	76.7	40.3
	6	24.3	13.5	35.9	59.5	33.3
	7	24.3	17.1	21.6	33.2	24.1

*See page 28 for key.

TABLE 50.--Chloride levels (ppm) in soil in individual plots.

Treatment	Depth*	Block I	Block II	Block III	Block IV	Average
Check Plot	1	112	0	18	28	39.5
	2	0	0	0	0	0.0
	3	0	0	0	0	0.0
	4	0	61	0	9	17.5
	5	19	5	14	80	29.5
	6	0	0	23	19	10.5
	7	0	0	9	9	4.5
150 + 66 + 126 N + P + K	1	108	14	37	14	43.2
	2	0	0	42	9	12.8
	3	0	0	47	94	35.2
	4	9	28	14	56	26.8
	5	0	9	14	47	17.5
	6	23	5	42	47	29.2
	7	9	28	0	37	18.5
5.8 T/A	1	23	84	23	19	37.2
	2	0	0	0	33	8.2
	3	0	0	0	0	0.0
	4	52	23	61	0	34.0
	5	0	23	19	19	15.2
	6	5	0	0	0	1.2
	7	0	0	19	5	6.0
11.6 T/A	1	98	9	19	5	32.7
	2	0	9	47	9	16.2
	3	0	0	0	0	0.0
	4	0	70	28	0	24.5
	5	14	0	42	0	14.0
	6	9	14	0	0	5.8
	7	5	19	42	19	21.2
23.2 T/A	1	33	37	28	19	29.2
	2	0	84	70	19	43.2
	3	0	84	70	0	38.5
	4	80	103	47	23	63.2
	5	33	0	23	9	16.2
	6	61	37	56	126	70.0
	7	14	5	19	28	16.5
46.4 T/A	1	33	28	0	9	17.5
	2	23	9	0	5	9.2
	3	0	0	0	33	8.2
	4	42	14	42	80	44.5
	5	23	14	28	19	21.0
	6	61	14	23	61	39.8
	7	19	14	14	5	13.0

*See page 28 for key.

PARKHILL SERIES

Soil Profile:		Parkhill Loam
Ap	0-8"	LOAM: very dark gray (10YR3/1) to very dark brown (10YR2/2); weak, fine to medium, granular structure; friable; slightly acid to neutral; abrupt smooth boundary. 6 to 10 inches thick.
A2g	8-12"	LOAM: grayish brown (10YR5/2) to brown (10YR5/3), mottled with yellowish brown (10YR5/4 -5/6), mottles are common, medium, and distinct; weak, medium, platy structure; friable; slightly acid to neutral; clear wavy boundary. 3 to 6 inches thick.
Bg21	12-23"	LOAM OR CLAY LOAM: gray (10YR5/1) mottled with yellowish brown (10YR5/4 - 5/8), mottles are common, medium, and distinct; moderate, medium, subangular blocky structure; slightly firm; slightly acid to neutral; gradual wavy boundary. 6 to 16 inches thick.
Bg22	23-36"	CLAY LOAM OR SILTY CLAY LOAM: grayish brown (10YR5/2) mottled with yellowish brown (10YR5/4 - 5/6) and pale olive (5Y6/3), mottles are many, coarse, and distinct; moderate to strong, coarse, subangular or blocky structure; firm; slightly acid to neutral; abrupt irregular boundary. 10 to 20 inches thick.
C	36"+	LOAM OR SILT LOAM: olive brown (2.5YR4/4) mottled with yellowish brown (10YR5/4 - 5/6) and gray (10YR5/1); massive, to weak, coarse, angular blocky structure; slightly firm; calareous till.

Range in Characteristics: Loam and silt loam types have been mapped. The A2g and Bg21 horizons are dominantly gray in the more poorly drained areas. The textures of the Bg21 and Bg22 horizons range from clay loam, silty clay loam, or fine, loam. Depth to calcareous till ranges from 20 to over 42 inches. Colors and consistence refer to moist conditions.

Topography: Nearly level to depressional areas in till and lake plains.

Drainage and Permeability: Poorly to very poorly drained. Runoff is very slow to ponded. Permeability is moderately slow.

Natural Vegetation: Chiefly elm, soft maple, ash, hickory, basswood, and swamp white oak.

BRECKENRIDGE SERIES

Soil Profile:		Breckenridge fine sandy loam
Ap	0-8"	Fine Sandy Loam: black (10YR 2/1) very dark gray (10YR 3/1) or very dark brown (10YR 2/2) weak, fine to medium, granular structure; friable; high organic matter content; slightly acid to mildly alkaline; abrupt smooth boundary. 6 to 12 inches thick.
A2g	8-12"	Fine Sandy Loam: dark, grayish brown (10YR 4/2) with few, fine distinct yellowish brown (10YR 5/6-5/8) mottles; weak; fine subangular blocky structures friable; slightly acid to mildly alkaline; clear wavy boundary. 0 to 8 inches thick.
B21tg	12-24"	Sandy Loam or Sandy Clay Loam: gray (10YR 5/1) to grayish brown (2.5Y 5/2) mottled with dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/6-5/8) and brownish yellow (10YR 6/6), mottles are common, medium and distinct; weak, medium to coarse, sub-angular blocky structure; friable; slightly acid to mildly alkaline; clear wavy boundary. 8 to 28 inches thick.
B22tg	24-30"	Sandy Loam: light bownish gray (10YR 6/2-2.5Y 6/2) mottled with dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6-5/8), mottles are common, medium, slightly acid to mildly alkaline; abrupt irregular boundary. 0 to 12 inches thick. Subangular structures very friable.
II C	30" +	Loam or Silty Clay Loam: gray (10YR 5/1) to light brownish gray (10YR 6/2) mottled with yellowish brown (10YR 5/6-5/8) and dark yellowish brown (10YR 4/4) mottles, mottles are common to many, fine to medium, distinct, massive to very weak, coarse angular blocky structure; firm; calcareous.

Range in Characteristics: Fine sandy loam, loam, and loamy fine sand types have been recognized. A thin layer of muck or peat 2 to 12 inches thick occurs as 01 and 02 horizons on some profiles. The depth to the IIC horizon ranges from 20 to 40 inches. The B22tg horizon is not present in all profiles. The reaction of the upper 2 to 6 inches of the IIC horizon is mildly alkaline in some profiles. Color notations refer to most conditions. The depth to the IIC horizon varies from 20 to 40 inches.

Topography: Nearly level and depressional areas in lake plains.

Drainage and Permeability: Poorly to very poorly drained. Surface runoff is very slow to ponded. Permeability is moderate in the solum and slow in the IIC horizon.

Natural Vegetation: Dominantly lowland hardwood forest of elm, ash, and red maple with some white cedar.