MOVEMENT OF PHOSPHORUS THROUGH SOILS AS AFFECTED BY SOIL pH, TEXTURE, AND APPLICATION RATES OF MONOCALCIUM PHOSPHATE AND ORGANIC WASTE

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CHAPTER I

INTRODUCTION

Phosphorus (P) movement down through a soil profile is found to be slow or limited and, traditionally, P has been designated as an immobile plant nutrient. Generally, plant response to the addition of P to soils follows a Mitscherlich-type curve (immobile nutrient), unlike nitrogen (N), a mobile nutrient, which tends to follow a Liebig-type response curve, the amount to be added almost entirely dependent upon the yield goal or the yield produced for non-legume crops.

Available P in soils is often not sufficient to produce good crop growth and the deficiency must be eliminated or reduced by supplying P by fertilization. Soil P is not recycled via rainfall, and it is made available to plants from organic residues only after organic breakdown. When a water soluble P source is applied to soil it is often changed to P compounds with lower water solubility, progressively, and P may become less available to plants with elapsed time.

Recent investigations show that many factors can affect P mobility in soils. Movement of P in soils has been related to soil pH, soil texture, and whether it is present in the soil system as an organic or inorganic form.

Soil pH is important because it may bring about an increase in P reaction with Al and Fe at pH values below 5.5 or an increase in Ca-P reversion reactions above pH 7.5. In both cases, P compounds with low water solubility and low plant availability result.

Heavy-textured soils have been reported to "fix" or retain more P than light-textured soils. Mobility of P in light-textured soils is greater than in heavy-textured soils. The P mobility in soils with high OM contents has been reported to be higher than in comparable soils with low OM contents. Initial investigations indicated that movement of inorganic and organic P was increased by application of organic wastes (OW). However, factors affecting organic matter "mobilization" of P have not been investigated adequately.

Research to investigate the effect of OW loading rates and P fertilization /$\bar{C}a(H_2PO_4)_2$/ on soil P mobility for two Oklahoma soils was initiated. Movement of P through soils, hopefully, can be related to plant availability and potential for groundwater pollution. This information is especially needed as soils are used in increasing numbers and with increasing loading rates for ultimate disposal of OW.

CHAPTER II

REVIEW OF LITERATURE

Phosphorus Forms and Availability in Soils

Tisdale and Nelson (1975) in their soil fertility textbook report that P occurs in soils as two main forms, organic and inorganic. In normal soils, organic P exists mainly as phospholipids, and nucleic and inositol P compounds. These organic P forms can make up from 15 to 85% of the total soil P. The amount of organic P declines with increasing soil depth, with few exceptions. Few organic compounds are directly available to plants.

Spencer and Steward (1934) placed the P contained in soils into two categories, available and nonavailable P in respect to the likelihood of plant uptake. Available P is usually evaluated via the plant response or estimated by soil test and soil test calibrations. Unavailable P may fall into two classifications. The P compounds in soil may be of such low water solubility or have such a low potential chemical reactivity that the P is essentially "chemically unavailable" to plants. The placement of P in relation to plant roots or plant root growth, or the natural occurrence in a soil profile may be at such a depth that the P availability is very low or nil. This kind of unavailability is termed as "positional unavailability."

Ozanne (1980) reports that the ability of soils to resist changes in soil solution P may be dependent upon whether P is being added or removed from the soil system. This phenomenon to resist P change is called soil P buffering capacity. He states that the equilibrium soil solution P concentration level is very low, varying from 0.05 to 0.3 ppm. Ozanne (1980) pointed out that not only is soil solution P level low, but that P movement in soils is very slow and, hence, P tends to be accumulated near the soil surface since plant residues and manures containing P, P fertilizers, etc. are usually added at the soil surface. Small amounts of P may be transported down the soil profile by insects, fungi, and as a result of root growth, etc., however, the availability of P for plants will be greater at or near the soil surface in almost all soils. Buried profiles or severe surface erosion present possible exceptions, however.

Factors Affecting P Movement in Soils

Soil factors that affect P movement in the soil profile are soil pH, soil texture, aeration, and contents of OM and amorphous colloids.

Soil pH Effects

Soil pH has been singled out as the most important soil characteristic affecting P availability. Tisdale and Nelson (1975) show results of earlier works on the effect of pH on relative concentrations of the $H_2PO_4^-$ and $HPO_4^=$ ions in solutions, $H_2PO_4^-$ being favored below about 6.2 and $HPO_4^=$ being favored above 7.0, but with significant amounts of $PO_4^\equiv$ indicated at approximately 8.5 and above.

Donahue et al. (1977), Jenny et al. (1950), Wild (1959), Hsu and Jackson (1960), and Russell (1961) studied relative amounts of P "fixation" by Fe, Al, Mn, and Ca vs soil pH. Since amounts of reactive Al, Fe, and Mn ions are usually high in soils with pH values below 5.5 and low solubility P compounds are frequently formed in interactions with $H_2PO_4^=$, P availability and mobility are thereby restricted. The Ca-P reversion compounds tend to form at pH values above 7.5 and are low in water solubility rediced plant availability, and soil mobility. All of the above workers selected the pH range of 6.0 to 7.0 as being best for P availability to crops. Hernandez and Burhnam (1974) cautioned that P fixation may not be highly correlated with soil pH for a group of mixed soils, but for a group of soils pedalogically similar, P "fixation" is quite clearly related to soil pH.

Sanchez and Uehara (1980) and Sample et al. (1980) propose three mechanisms of P "fixation" in alkaline soils:

1. Reversion-precipitation of P from $Ca(H_2PO_4)_2$ via di-, octo-, and tri-Ca phosphates (P);

2. Surface precipitation of phosphate (P) on solid phase $CaCO_3$, with the higher the $CaCO_3$ specific surface and phosphate ions in solution the greater the amounts of precipitation;

3. Retention of phosphates by clays with high saturation percentages of Ca. Bridging compounds of clay-Ca-H_2PO_4 are reportedly formed. Montmorillonitic (2:1) clays often fix more P by this mechanism than kaolinitic (1:1) clays. At least part of this effect is attributed to higher CEC of 2:1 clays and, hence, increasing the opportunity for clay-Ca-H_2PO_4 linkages. Studies by Hemwall (1957), Thomas and Peaslee (1973) and Hilal (1973) support these general conclusions, also.

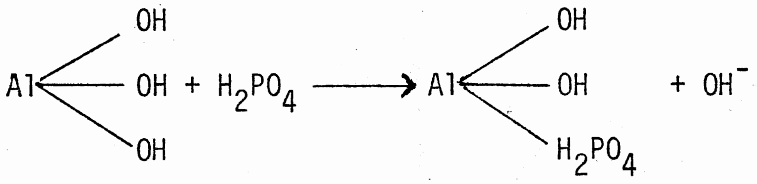
Sample et al. (1980), Sanchez and Uehara (1980) suggest three mechanisms of P "fixation" in acid soils:

1. Precipitation by Al, Fe, and Mn ions with phosphate (P) already mentioned, since the concentration of these cations is usually present in significant amounts in acid soils. The equation for such a reaction may be demonstrated as:

$$Al^{+++} + H_2PO_4^- + 2H_2O \longrightarrow 2H^+ + Al(OH)_3H_2PO_4$$

soluble available — insoluble non-available

2. "Fixation" by hydrous oxides: Al, Fe, and Mn such as limonite and geothite. "Fixation" by this means may exceed that precipitated. The reactions involved can be represented as follows:



soluble available — insoluble non-available

Sanchez and Uehara (1980) explain that phosphate ions in soil solution enter into legand exchange reactions with hydroxyls on the surfaces of sesquioxide particles or films.

3. Reaction with silicate clays. Phosphate ions may replace OH groups from Al of the clays. Sanchez and Uehara (1980) suggest that the anion exchange capacity of 1:1 clays exceeds that for 2:1 clays and will have a greater tendency to interact with phosphates.

The report of Wild (1959) in a review of P retention in soils shows that R. Warrington as early as 1866 found hydrous oxides of Al and Fe retained was dilute HCl-extractable.

Fordham and Norrish (1979) attempted to evaluate P sorbing properties of components in a "clay fraction" of acidic soils using radioactive arsenate-73 having sorption properties similar to $PO_4^{\equiv}$ ions. He states that P retention results from Fe-oxides. However, he found that kaolinite, illite, vermiculite, muscovite, a K-feldspar, illimenite, and quartz did not retain arsenite-73. These results seem to conflict with the majority of data reported if retention of $PO_4^{\equiv}$ and arsenate-73 are truly similar.

Soil Texture

Kamprath and Watson (1980) show P fixation increases with clay content. The type of clay affects P-fixation capacity, also. This confirms findings of Sanchez and Uehara (1980) given earlier, but Hemwall (1957) suggests that P fixation reported for clays is due to soluble Fe and Al originating with structural decomposition of clay minerals or that being held by the CEC. However, his finding that kaolinite clays fix more P than montmorillinite clays presents the question of greater Al-OH exposure not completely in agreement with his statement relating to decomposed sources or exchangeable Fe and Al reactions with P. Russell's (1944) report on P "fixation" by Al and Fe agrees with Hemwall (1957). He said that when Fe-and Al-oxides were removed from clay surfaces (both 1:1 and 2:1), little or no P was fixed. It should be noted that this condition will not be found often under field conditions, though Sanchez and Uehara's (1980) findings might so be interpreted by some. The amount of Al or Fe on the 1:1 and 2:1 clays of a Hapinstoll soil would be orders of magnitude less than for gibbsite, geothite, or hematite.

Amorphous Colloidal Content

Sanchez and Uehara(1980) found P fixation in acid soils positively correlated with X-ray determined colloidal content and measured specific surface. In this case, texture and clay contents were not the only factors to be considered. The Eutrandept soil (Andepts) with 11% clay fixed more P than a Haplustox soil (oxisols) with 38% clay because the first contained higher contents of amorphous colloidal materials. The amorphous materials exhibited a dominate effect.

Organic Matter Content

Struthers and Sieling (1950) reported that P availability was increased with increased OM contents. This might be attributed to the following factors:

1. OM may form a protective or inhibiting coating over clays or Al and Fe oxides.

2. Greater microbial activity in soils with high OM will produce CO_2 partial pressures ($CO_2 + H_2CO_3 \longrightarrow H^+ + HCO_3^-$) will tend to solubilize some soil P compounds and interact with and reduce Fe activity.

3. Organic P compounds will be formed via microbial action that are less firmly fixed by soil components, and

4. The mineralization of P contained in OM will increase P in available forms or will be continually releasing available P to the soil systems.

Work of Dalton et al. (1952) and Stanford and Pierre (1953) supports the conclusions of Struthers and Sieling (1950). Work by

Doughty (1935) indicated that natural and synthetic humus did not "fix" P and oxidation of OM with H_2O_2 decreased the power of soils to fix P. Addition of water soluble P to soils resulted in little, if any, P fixation by OM. These conclusions were supported by Wild (1959) and Fox and Kamprath (1971).

Experimental investigations of soils with high OM and sesquioxides by Sanchez and Uehara (1980) show "fixation" of P by Fe and Al oxides by high OM is blocked, resulting in greater availability and mobility of P. Microbial synthesis of simple organic P and inorganic poly-P compounds could result in higher P mobility as OW application rates are increased. Bacillus magatherium var. phosphobacterins was reported by Saber et al. (1977) to produce such an effect on soil P. He found that applications of Mn increased the activity of the phosphate mobilizing bacteria also. Miller's (1973) work reminds us that plant uptake of P must be considered under field conditions when P mobility is being studied and when laboratory vs. field work are compared. Without doubt, some discrepancies in the literature could be reconciled by evaluating the experimental consequences in greater detail.

Aeration

Patrick et al. (1974) showed poor aeration decreased P fixation because of ferric iron reduction. The work of Shiga (1976) and Dhua and Chattopadhyay (1973) produced similar conclusions. Work of Singlachar and Samaniegos (1973) in greenhouse experiments was supportive also, but made note of the fact the measured Fe-P fraction was increased by addition of P under flooded conditions. The changes were greater when the flooded soils were cropped. Krivonosova (1975) studied an uncropped soil with additions of ordinary superphosphate (OSP) under high moisture conditions. The added P increased the content of loosely bound Al-, Ca-, and Fe-P compounds. Prolonged wet conditions without added OSP decreased insoluble and reductant insoluble P. Prolonged drying decreased P availability. Work of Chang and Lin (1970) supports the conclusions that P availability and mobility are increased by poor aeration.

Phosphate Mobility Under Both Lab and Field Conditions

Lab Experiment

Soil penetration studies of organic and inorganic P compounds by Spencer and Steward (1934) with soil columns demonstrated P movement was faster in columns treated with organic P compounds. A range of 75 to 95% of added organic P moved by comparison with 0.7 to 11.5% of the added inorganic P.

Hannaple et al.(1964a) studied movement of P in soils via collected leachates and P^{32} when treatments of plant residues of bean and barley plants and sucrose + NH_4NO_3 were mixed into 300 g soil and incubated for 30 days. Ten displaced soil solution samples were analyzed for total, organic, and inorganic P. High organic level treatments increased movement of organic and inorganic P. The results obtained by comparison with the sucrose treatment indicate that a readily available energy source effects P movement through mocrobial synthesis of organic forms (Hannaple et al. 1964b).

A study by Lance et al. (1978) attempted to evaluate the effect of plants on P movement in soil columns. The P mobility was reduced by growing plants, root uptake of P the evident cause for the difference.

Logan and McLean (1973) used P^{32} in a soil column study in an attempt to evaluate P application rate, soil properties, and leaching mode. Leaching of P^{32} was inversely proportional to free Fe content of the soils and was increased with increasing P rate and intensity of leaching. They also found that constant head leaching resulted in greater movement of P than intermittent leaching.

Field Experiments

Olsen and Barber (1977) reviewed approximately 117 years of work done by Hoosfield and Broadbalk plots at Rothamsted Experiment station. The effect of annual manure or superphosphate applications on P availability in the Hoosfield plots reveal that soluble and available P levels were increased beyond crop requirement. They reported that the manure produced more available or soluble P than superphosphate.

Anderson et al. (1974) showed that inositol pentaphosphates were adsorbed on the same sites as orthophosphates. Organic P application reduced inorganic P retention, but high inorganic P did not produce reciprocal effects on organic P retention. He further postulated that the organic part of the manures tended to reduce P "fixation" by "mechanically" separating soluble P from the soil minerals.

Sommers and Sutton (1980) studied the influence of so-l textures on the movement of P. A clay loam cropped with corn and treated with sewage effluents for nine to eleven years had less than one percent of the added P leached to the 120 cm (48") depth. For a sandy loam, by comparison, a large amount of P moved to the 120 cm depth or below.

The work of Beek et al. (1977) who intermittently flooded 100 ha (approximately 250 acres) of sandy soil covered with permanent pasture, with raw sewage effluent, on the other hand, seemed to obtain a different result. After application of 2.5 m (98") of the effluents for 45 years, the P was accumulated in the upper 50 cm (20") of soil. The high nutrient requirements of good pastures may be the cause for the difference in results. This treatment raised the soil pH, and they stated that adsorption and precipitation reactions played roles in the P retention. Works of Prummel and Sissing (1976) and Pratt et al. (1956) support the results obtained by Beek et al. (1977). Under good crop management, waste applications did not produce appreciable P movement below the upper 50-60 cm (20-24") depths.

CHAPTER III

MATERIALS AND METHODS

Materials

Two soils were selected for the study of P mobility as affected by P fertilization ($Ca(H_2PO_4)_2$) and application of organic waste (OW).

1. Carey silt loam (fine-silty, mixed, thermic Typic Arginstolls), and
2. Taloka silt loam (fine, mixed, thermic Mollic Albaqualfs).

Textural information is given in Table I. Tables II and III present the initial contents of available, inorganic, organic, and total P; and available $N(NO_3^=-N)$, Ca, Mg, K, soil pH, and percent organic matter (OM), respectively, for the surface and subsurface layers used in this study.

The surface 0-6" (0-15 cm) and subsurface 6-12" (15-30 cm) soil samples were collected in the summer of 1980. The samples were air dried, ground, passed through a 20-mesh sieve, sampled for the analyses, and stored in tight plastic bags until the experiment was begun.

Eight glass columns 3 x 15" (7.6 cm x 38 cm) were constructed for each soil, fitted with a fritted glass filter and a built-on glass funnel. A vacuum regulator was prepared to allow a maximum of 38 cm H_2O vacuum by use of a saturated NaCl solution (1.20 density). These details are shown in Fig. 1. The function of the vacuum "system" was to pull water slowly through the prepared soil columns. It was used if the water had not percolated through the columns after 24 hours.

TABLE I

SOIL TEXTURE ANALYSES FOR CAREY AND TALOKA SOIL SAMPLES

Soil Type	Soil Depth (inches)	Composition		
		% Sand	% Silt	% Clay
Taloka SiL	0- 6	32.5	45.5	22.0
Taloka SiL	6-12	14.5	41.0	44.5
Carey SiL	0- 6	28.5	47.0	24.5
Carey SiL	6-12	24.5	45.5	30.0

TABLE II

INITIAL SOIL ANALYSES FOR TOTAL, INORGANIC, ORGANIC, AND AVAILABLE P

	Depth (inches)	Total P (lbs/A)*	Inorganic P (lbs/A)	Organic P (lbs/A)	Available P (lbs/A)
Taloka SiL	0- 6	240	128	112	8
Taloka SiL	6-12	200	112	88	5
Carey SiL	0- 6	650	384	266	147
Carey SiL	6-12	470	336	134	51

*Pounds/Acre furrow slice (afs) equivalent (for conversion to μg/g soil, divide lbs/A by 2)

TABLE III

INITIAL SOIL ANALYSES FOR NO_3-N, Ca, Mg, K, SOIL pH, AND ORGANIC MATTER

	Depth (inches)	Available Ca (lbs/A)*	Available Mg (lbs/A)	Available K (lbs/A)	NO_3-N (lbs/A)	Soil pH	Organic Matter (%)
Taloka SiL	0- 6	1191	507	202	1.0	5.2	1.2
Taloka SiL	6-12	2291	999	227	1.0	6.1	1.1
Carey SiL	0- 6	3041	2851	747	11.0	6.6	1.3
Carey SiL	6-12	4170	2962	556	10.0	7.1	1.2

*Pounds/Acre furrow slice (afs) equivalents (for conversion to µg/g soil, divide lbs/A by 2).

Methods of Analysis

Initial Soil and Organic Waste Analysis

Samples of the prepared soils were used for determining soil pH, % OM, total, inorganic, organic, and available P, and available N(NO_3^--N), Ca, Mg, and K (see Tables II and III). The P contents were measured according to Mehta et al. (1954) involving sequential extractions with cold and hot concentrated HCl and cold and hot 0.5 N NaOH. Organic P was determined as a difference between total P and inorganic P. Available P was determined by a modified Bray No. 1 procedure (20:1 solution to soil ratio). Respective P contents were quantified with a Turner spectrophotometer (Model 330) with a Fisher concentration computer (Model CDR) attached, after standardization. The spectrophotometer wave length setting was 650 nm. Concentrations of available Ca, Mg, and K extracts were measured via atomic absorption. Soil pH was determined

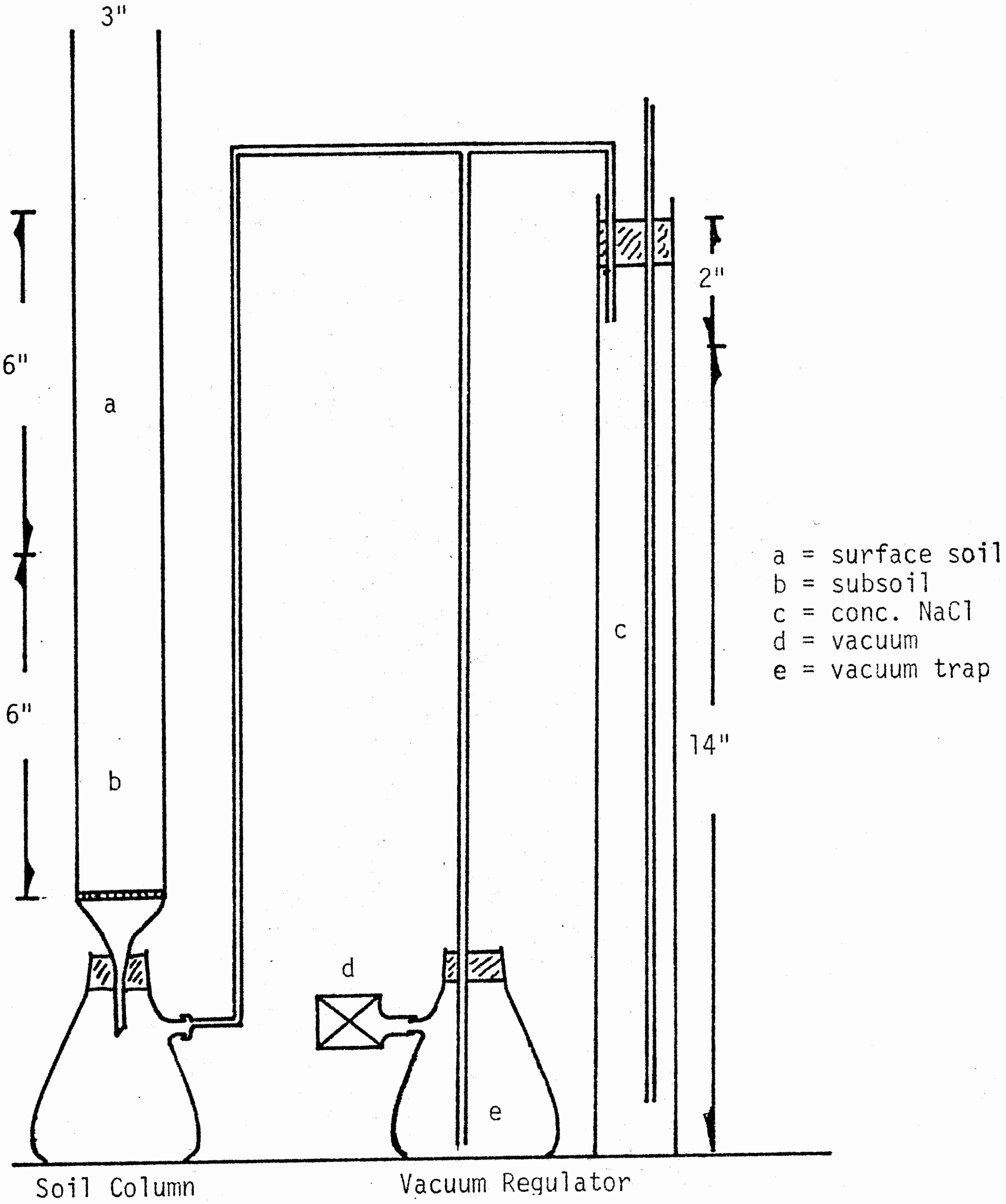


Figure 1. Soil Column With Vacuum Regulator for Removal of Free Water From the Soil Column After 24 Hours

in a 1:1 solution to soil mix with a glass electrode.

Total organic matter (OM) in soils was determined by the Walkeley and Black method according to Jackson (1973). Soil NO_3^--N extractions were made as described by Roller and McKaig (1939), and the contents measured using a NO_3^--N electrode. The composition of dried sewage used as the source of organic waste is given in Table IV. The dried sludge was obtained from the Stillwater municipal sewage treatment plant. Total N was determined according to Bremner (1965). An extract after the perchloric-nitric digestion procedure of Shelton and Harper (1941) was used to quantitate the element content by atomic absorption, the Ca and Mg were measured after addition of 5% $LaCl_3$.

TABLE IV

AVERAGE CONTENT OF SELECTED ELEMENTS IN DRIED SEWAGE SLUDGE

Element	Percent	Element	PPM
N	1.45	Fe	2.43
P	1.55	Zn	12.03
K	0.32	Mn	34.40
Ca	3.10		
Mg	0.40		

Column Preparation

Soil subsurface samples were placed in the prepared columns to a depth of 6" (15 cm). The surface soil samples received their prescribed treatments and placed on (over) their respective subsurface counterparts, randomly, to a 6" (15 cm) depth, the composite to represent treated and untreated layers of soil. The surface soil treatments are presented in Table V. The weights of soil in the packed columns were surface and subsurface, respectively, 830 g and 800 g for the Carey soil, and 830 g and 820 g for the Taloka soil.

TABLE V

TREATMENT RATES (lbs P/A equivalent and Ton OW/A)

Treatment	OW*	P**
I	0	0
II	0	52
III	20	52
IV	60	52

*OW = Dried sewage sludge.
**P = Added as $Ca(H_2PO_4)_2$ lbs P/afs equivalent.

Leaching Method

Approximately 400 ml of water was required initially to bring the packed soil columns to a moisture level approximating capillary water holding capacity. Two hundred ml leaching volumes were added subsequently at 4-day intervals (Table VI). Applied water was left 24 hours for free percolation; the low "vacuum" was attached on the second day to increase water movement and collect the leachates in 250 ml

Erlenmeyer flasks. After collection of the leachate from the fourth treatment (water) the soils were left for exactly 57 days at laboratory temperature (controlled at $20^{o} \pm 1^{o}C$) to allow continued microbiological decomposition. No measurement of CO_2 evolution or microbial activity for this period was made excepting inferences from subsequent leachate and soil analyses.

TABLE VI

DATES OF WATER APPLICATION FOR LEACHING

Leaching Number	Date	Leaching Volume (ml)
1	06-12-81	200
2	06-16-81	200
3	06-20-81	200
4	06-24-81	200
5	08-20-81	200
6	08-24-81	200
7	08-28-81	200
8	09- 2-81	200

Methods for Chemical Analyses in Leachates

In the methods for chemical analyses (according to Mehta et al., 1954), the leachate was collected, measured, and analyzed for total, inorganic, and organic P, and organic matter content, by the method of Carolan (1948). After the eighth leachate was collected, the soil columns were sampled for the 0-3" (0-7.5 cm), 3-6" (7.5-15 cm), 6-9"

(15-22.5 cm), and 9-12" (22.5-30 cm) depths to see if concentration changes within surface and subsurface layers, as well as between them could be noted. All analyses were converted to lbs/afs equivalent to simplify direct comparisons with the initial analyses and the applied fertilizer rates.*

Experimental Design

A completely randomized design with two replications was used. All soil columns were placed on the same laboratory bench.

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*For conversion to μg/g soil, divide lbs/afs by 2.

CHAPTER IV

RESULTS AND DISCUSSION

Initial and Final Soil Analyses Comparisons

Changes in the initial vs. final soil analyses were examined for evaluation of induced soil changes or processes involved over the experimental period. Initial analyses are found in Tables II and III, final analyses in Tables VII and VIII. A summary of the analysis of variance for evaluating changes found between initial and final soil analyses is given in Table IX. The interactions of soil type X treatment X soil depth is highly significant for all factors except inorganic P (OSL = 0.244). Effects of treatments and treatments X depth interactions were highly significant in all cases. Soil type effects did not show a significant effect for changes in total (OSL = 0.256), inorganic (OSL = 0.256), and organic (OSL = 0.387) P. Soil type X depth effect for available P and soil type X treatment interaction for inorganic P do not show significance at the 10% level (OSL values of 0.122 and 0.147, respectively). Soil type X soil depth interaction was significant with an OSL = 0.025; all other unmentioned treatment and interaction effects were highly significant. Measured OM content differences were found to be significantly affected in this experiment, a result of OW loading and leaching. Organic matter changes were very highly significant with depth and soil type factors, and for the interactions of soil type X depth, treatment X depth, soil

TABLE VII

FINAL SOIL ANALYSES FOR TOTAL, INORGANIC, ORGANIC, AND AVAILABLE P

Soil Type	Trt	Depth (inches)	P Total (lb/A)*	P Inorganic (lb/A)	P Organic (lb/A)	P Available (lb/A)
Carey	I	0- 3	615.0**	377.0	238.0	124.0
		3- 6	595.0	468.0	127.0	122.5
		6- 9	505.0	267.5	237.5	29.5
		9-12	500.0	410.0	90.0	20.0
	II	0- 3	650.0	388.0	262.0	153.5
		3- 6	690.0	430.0	260.0	162.5
		6- 9	535.0	250.5	284.5	45.0
		9-12	515.5	284.0	228.5	20.0
	III	0- 3	1210.0	576.0	684.0	308.0
		3- 6	1260.0	773.5	486.5	325.5
		6- 9	532.5	232.0	300.5	48.5
		9-12	516.0	240.0	276.0	23.0
	IV	0- 3	2270.0	1410.0	860.0	467.0
		3- 6	2150.0	1258.0	892.0	463.5
		6- 9	1230.0	616.0	614.0	204.0
		9-12	550.0	208.0	342.0	46.5
Taloka	I	0- 3	210.0	104.0	106.0	5.0
		3- 6	215.0	112.0	103.0	3.5
		6- 9	180.0	120.0	60.0	3.7
		9-12	175.0	96.0	79.0	2.0
	II	0- 3	325.0	202.5	122.5	47.0
		3- 6	190.0	80.0	110.0	7.0
		6- 9	170.0	112.0	58.0	2.5
		9-12	202.5	80.0	122.5	2.0
	III	0- 3	900.0	648.0	252.0	155.0
		3- 6	825.0	413.0	412.0	167.0
		6- 9	260.0	98.0	162.0	9.5
		9-12	210.0	67.5	142.5	4.0
	IV	0- 3	2160.0	1165.0	995.0	384.0
		3- 6	2080.0	850.0	1230.0	450.0
		6- 9	775.0	442.0	333.0	103.0
		9-12	230.0	104.0	126.0	7.5

*Data given in lbs/afs equivalent. (To convert to μg/g soil, divide by 2).

**Numbers are averages of two replicates.

TABLE VIII

FINAL SOIL ANALYSES FOR Ca, Mg, K, NO_3-N, SOIL pH, AND ORGANIC MATTER

Soil Type	Trt	Depth (inches)	Available Ca (lb/A)*	Available Mg (lb/A)	Available K (lb/A)	NO_3-N (lb/A)	pH	Organic Matter (%)
Carey	I	0- 3	3460.0 **	1459.5	315.0	14.1	6.55	1.09
		3- 6	2854.0	957.5	527.0	8.5	6.55	0.79
		6- 9	3863.0	1716.0	465.5	21.7	6.65	0.87
		9-12	4087.5	1752.0	412.0	31.5	6.60	0.97
	II	0- 3	3974.0	1754.5	436.0	7.5	6.50	0.71
		3- 6	2281.0	682.5	389.0	12.0	6.50	0.83
		6- 9	4215.0	1678.5	555.5	37.5	6.55	1.44
		9-12	4141.5	1724.0	379.5	40.1	6.45	0.78
	III	0- 3	3406.0	955.0	467.5	30.5	6.35	1.01
		3- 6	3198.0	922.0	506.0	81.1	6.10	1.01
		6- 9	4634.5	811.0	368.5	48.7	6.10	1.58
		9-12	4155.5	1788.0	372.5	48.8	6.55	0.98
	IV	0- 3	3818.0	793.5	421.5	36.5	6.55	1.39
		3- 6	3687.5	849.5	481.5	91.0	6.35	1.50
		6- 9	3205.5	472.0	432.0	102.0	6.10	1.34
		9-12	4684.5	185.0	465.0	56.8	6.45	1.27
Taloka	I	0- 3	1301.0	466.0	191.0	1.0	5.55	0.60
		3- 6	1250.5	441.0	189.0	2.2	5.40	1.12
		6- 9	1886.0	358.0	250.5	0.0	5.55	0.86
		9-12	2432.5	144.0	257.5	2.5	6.05	1.00
	II	0- 3	1386.0	475.0	173.0	1.5	5.20	1.21
		3- 6	1326.0	468.0	177.0	1.5	5.30	1.23
		6- 9	2142.0	587.0	241.5	0.0	5.65	1.26
		9-12	2362.5	137.5	252.5	0.0	6.00	0.75
	III	0- 3	2073.5	486.0	155.5	3.2	5.65	0.81
		3- 6	1868.0	475.0	171.5	2.2	5.45	2.13
		6- 9	3085.5	150.5	280.0	1.7	5.85	1.00
		9-12	2550.0	173.0	251.5	0.0	5.80	0.90
	IV	0- 3	2974.0	507.5	180.0	5.5	6.35	1.46
		3- 6	2992.5	420.0	191.0	5.5	6.35	1.59
		6- 9	3565.0	178.5	322.0	2.0	6.25	1.25
		9-12	3000.5	140.5	282.5	0.0	5.95	0.86

*Available Ca, Mg, K, and NO_3^--N given in lbs/afs equivalent (to convert to μg/g soil, divide by 2).

**Numbers are averages of two replicates.

TABLE IX

SUMMARY OF THE ANALYSES OF VARIANCE FOR THE DIFFERENCE BETWEEN FINAL AND INITIAL ANALYSES IN CAREY AND TALOKA SOILS

	D		ST		ST x D		Trt		Trt x D		ST x Trt		ST x Trt x D			
	F	OSL*	F	OSL	F	OSL	F	OSL	F	OSL	F	OSL	F	OSL	E.M.S.	d.F.
Total P	598.5	0.0001	1.54	0.256	17.56	0.0016	1844	0.0001	303.0	0.0001	7.11	0.0009	6.92	0.0001	2082.7	32
Inorganic P	102.6	0.0001	1.34	0.256	6.40	0.0016	173.2	0.0001	38.12	0.0001	1.91	0.147	1.36	0.244	5578.7	32
Organic P	60.78	0.0001	0.77	0.387	35.19	0.0001	414.3	0.0001	54.29	0.0001	11.83	0.0001	12.05	0.0001	2324.5	32
Available P	188.9	0.0001	9.96	0.0035	2.08	0.122	375.2	0.0001	62.26	0.0001	1.77	0.173	4.28	0.0010	34074.5	32
NO_3-N	195.4	0.0001	4110.4	0.0001	233.7	0.0001	735.2	0.0001	96.9	0.0001	620.4	0.0001	92.5	0.0001	1296.6	32
Soil pH	166.3	0.0001	409.9	0.0001	3.56	0.025	27.3	0.0001	7.04	0.0001	53.05	0.0001	8.12	0.0001	0.01141	32
Organic Matter	28.19	0.0001	22.65	0.0001	33.07	0.0001	45.37	0.0001	12.53	0.0001	4.62	0.008	12.08	0.0001	0.01171	32

D = soil depth
ST = soil type
Trt = treatment
E.M.S. = error mean square
d.F. = degree of freedom

*OSL = observed statistical level

type X treatment, and soil type X treatment X depth. The statistical evaluation indicates that soil OM effects are of definite interest in determining movement of organic components and P mobility. Some of the above effects can best be evaluated from graphical representations of soil content changes.

Carey Soil

Changes in total, inorganic, organic, and available P with treatments and soil depth are given in Table X and shown graphically in Figures 2, 3, 4, and 5. In all cases, note a significant effect for P movement into the subsoil for the highest OW treatment (treatment IV). Though not significant from treatments I and II, the low OW treatment (treatment III) is graphically intermediate. The effect of OW loading on increasing P movement is clearly indicated but additional treatments would be required for computing a scaling factor since significant effects were not found in the subsoil from the low OW treatment. Figure 6 and Table XI show that some microbial activity is stimulated by the addition of OW, decomposition such that nitrification is increased. Changes in NO_3^--N content were greater in the sequence of treatments IV, III, II, and I, respectively. The highest OW loading produced the highest OM content of the 9-12" (12.5-15 cm) depth (see Figure 7 and Table XI). This seemingly would require some breakdown of the added waste. Movement of OM is also indicated for treatments I and II, where no OW was applied, though not consistent (see Table XI) are difficult to explain. However, the effect of pH lowering shown in Figure 8 and Table XI is best explained by increases in microbial activity, but removal of basic cations by leaching and

TABLE X

DIFFERENCE BETWEEN THE FINAL AND INITIAL ANALYSES FOR TOTAL, INORGANIC, ORGANIC, AND AVAILABLE P

Soil Type	Trt	Depth (inches)	P Total (lb/A)*	P Inorganic (lb/A)	P Organic (lb/A)	P Available (lb/A)
Carey	I	0- 3	-35.0**	-7.0	-28.0	-23.0
		3- 6	-55.0	84.0	-139.0	-24.5
		6- 9	35.0	-68.5	103.5	-21.5
		9-12	30.0	74.0	-44.0	-31.0
	II	0- 3	0.0	4.0	-4.0	6.5
		3- 6	40.0	46.0	-6.0	15.5
		6- 9	65.0	-85.0	150.5	-6.0
		9-12	42.5	-52.0	54.5	-31.0
	III	0- 3	560.0	192.0	418.0	161.0
		3- 6	610.0	389.5	220.5	178.5
		6- 9	62.5	-104.0	166.5	-2.5
		9-12	46.0	-96.0	142.0	-28.0
	IV	0- 3	1620.0	1026.0	594.0	320.0
		3- 6	1500.0	874.0	626.0	316.5
		6- 9	760.0	280.0	480.0	153.0
		9-12	80.0	-128.0	208.0	-4.5
Taloka	I	0- 3	-30.0	-24.0	-6.0	3.0
		3- 6	-25.0	-16.0	-9.0	-4.5
		6- 9	-20.0	8.0	-28.0	-1.25
		9-12	-25.0	-18.0	-9.0	-3.0
	II	0- 3	85.0	74.5	10.5	39.0
		3- 6	-50.0	-48.0	-2.0	-1.0
		6- 9	-30.0	0.0	-30.0	-2.5
		9-12	2.5	-32.0	34.5	-3.0
	III	0- 3	660.0	520.0	140.0	147.0
		3- 6	585.0	285.0	300.0	159.0
		6- 9	60.0	-14.0	74.0	4.5
		9-12	10.0	-44.5	54.5	-1.0
	IV	0- 3	1920.0	1037.0	823.0	376.0
		3- 6	1840.0	722.0	1118.0	442.0
		6- 9	575.0	330.0	245.0	98.0
		9-12	30.0	-8.0	38.0	2.5

*Data given in lbs/afs equivalent. (To convert to µg/g soil, divide by 2).

**Numbers are averages of two replicates.

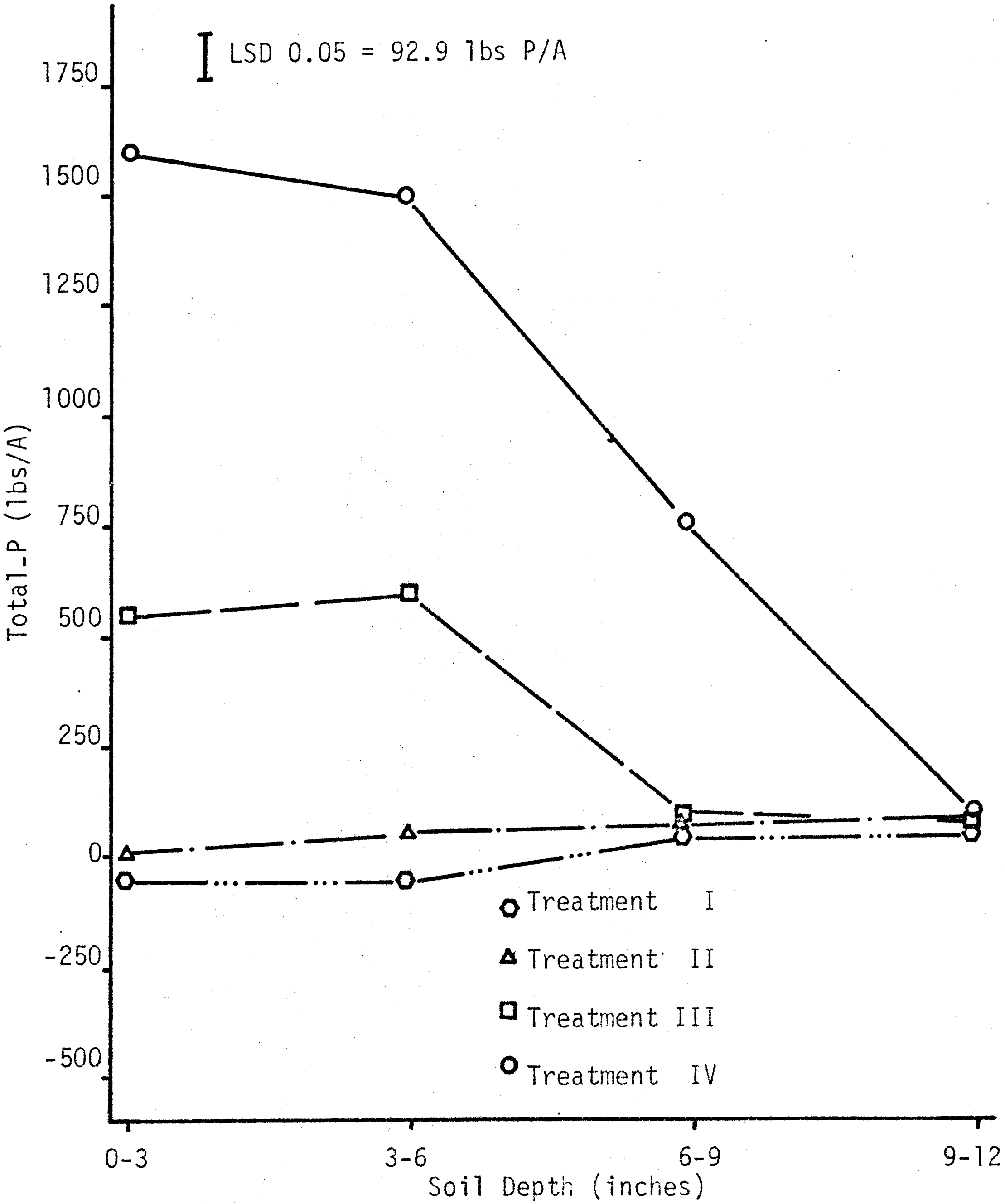

Figure 2. Difference Between the Final and Initial Analyses for Total P in Carey Soil With Soil Depth

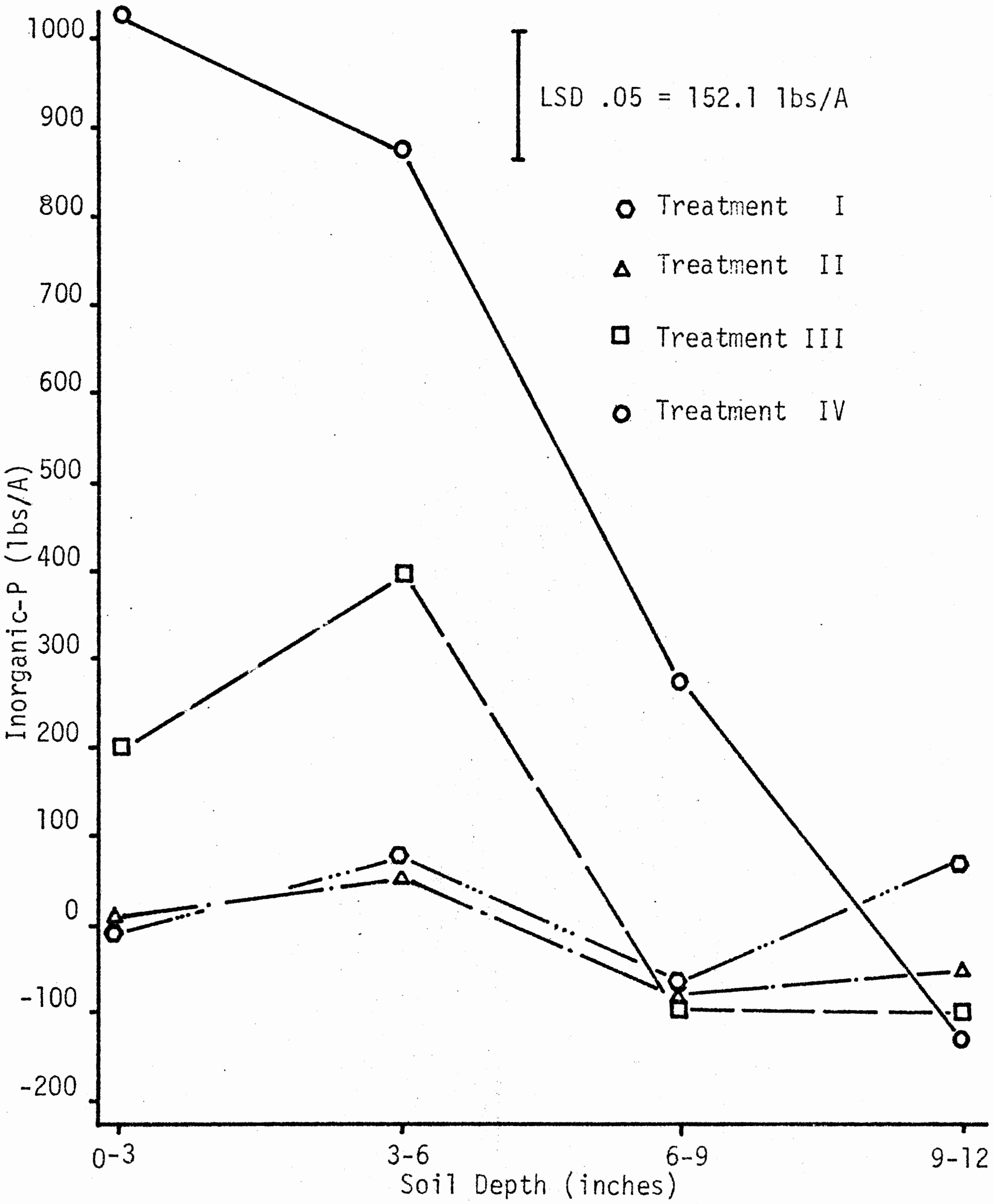

Figure 3. Difference Between the Final and Initial Analyses for Inorganic P in Carey Soil With Soil Depth

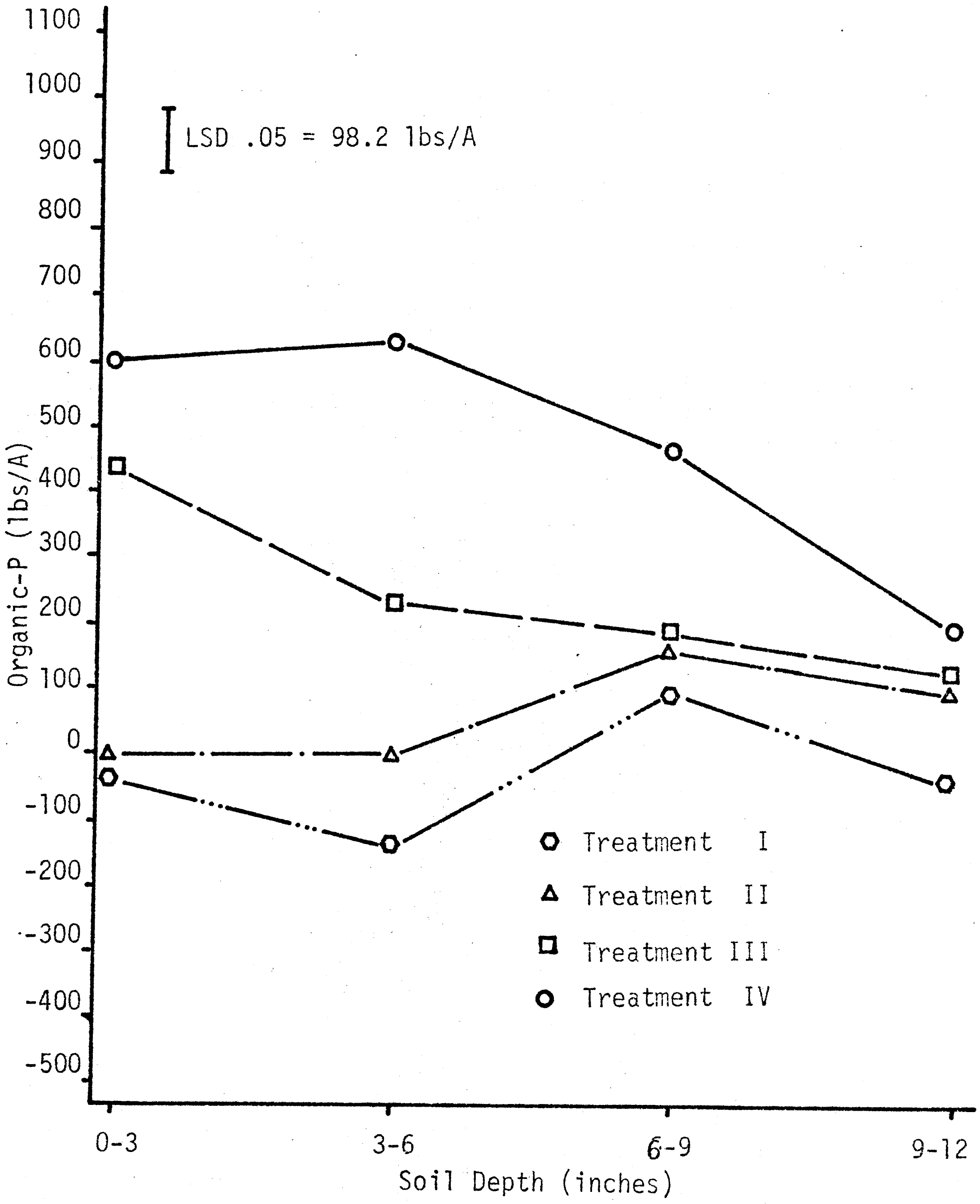

Figure 4. Difference Between Final and Initial Analyses for Organic-P in Carey Soil With Soil Depth

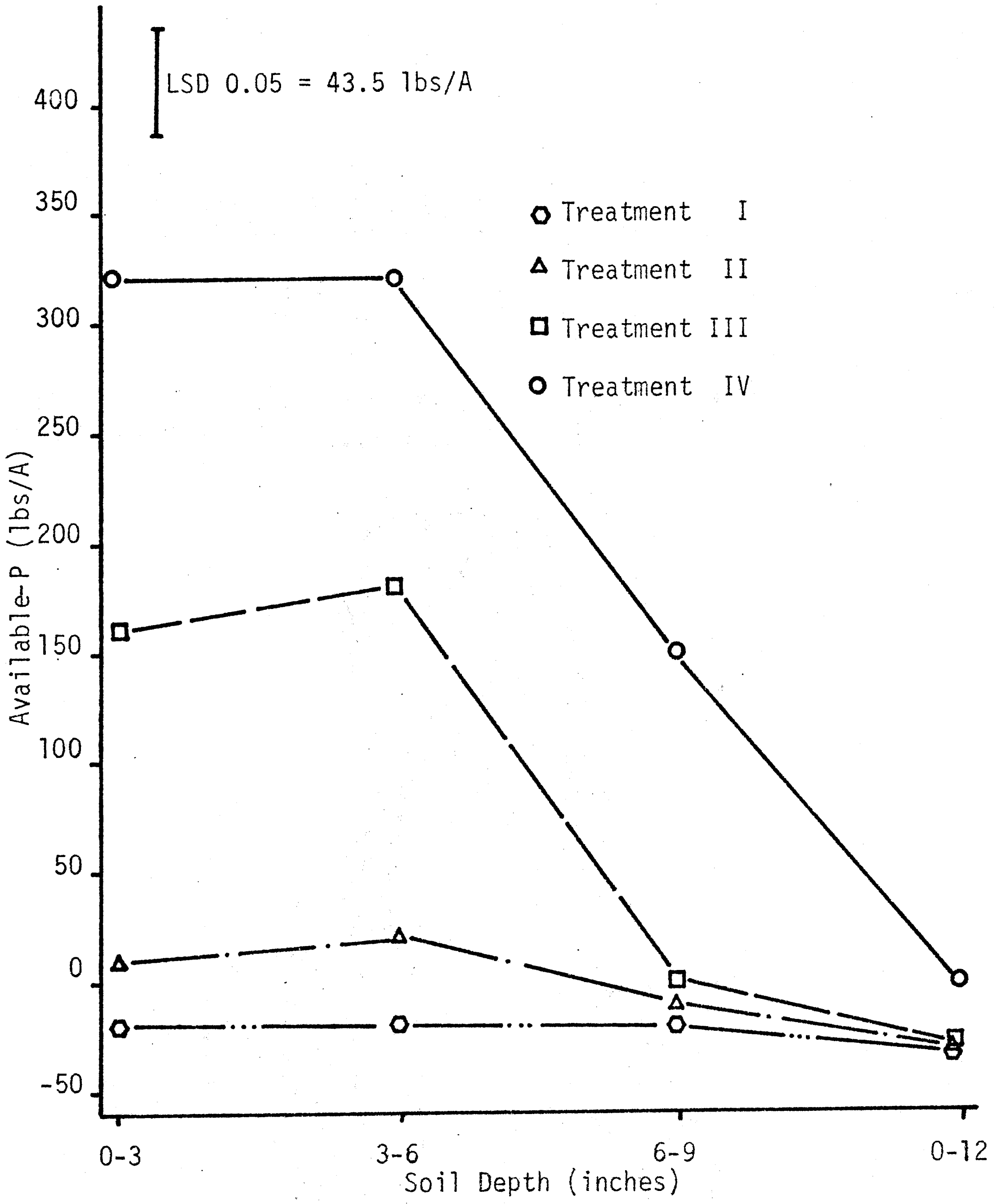

Figure 5. Difference Between the Final and Initial Analyses for Available P in Carey Soil With Soil Depth

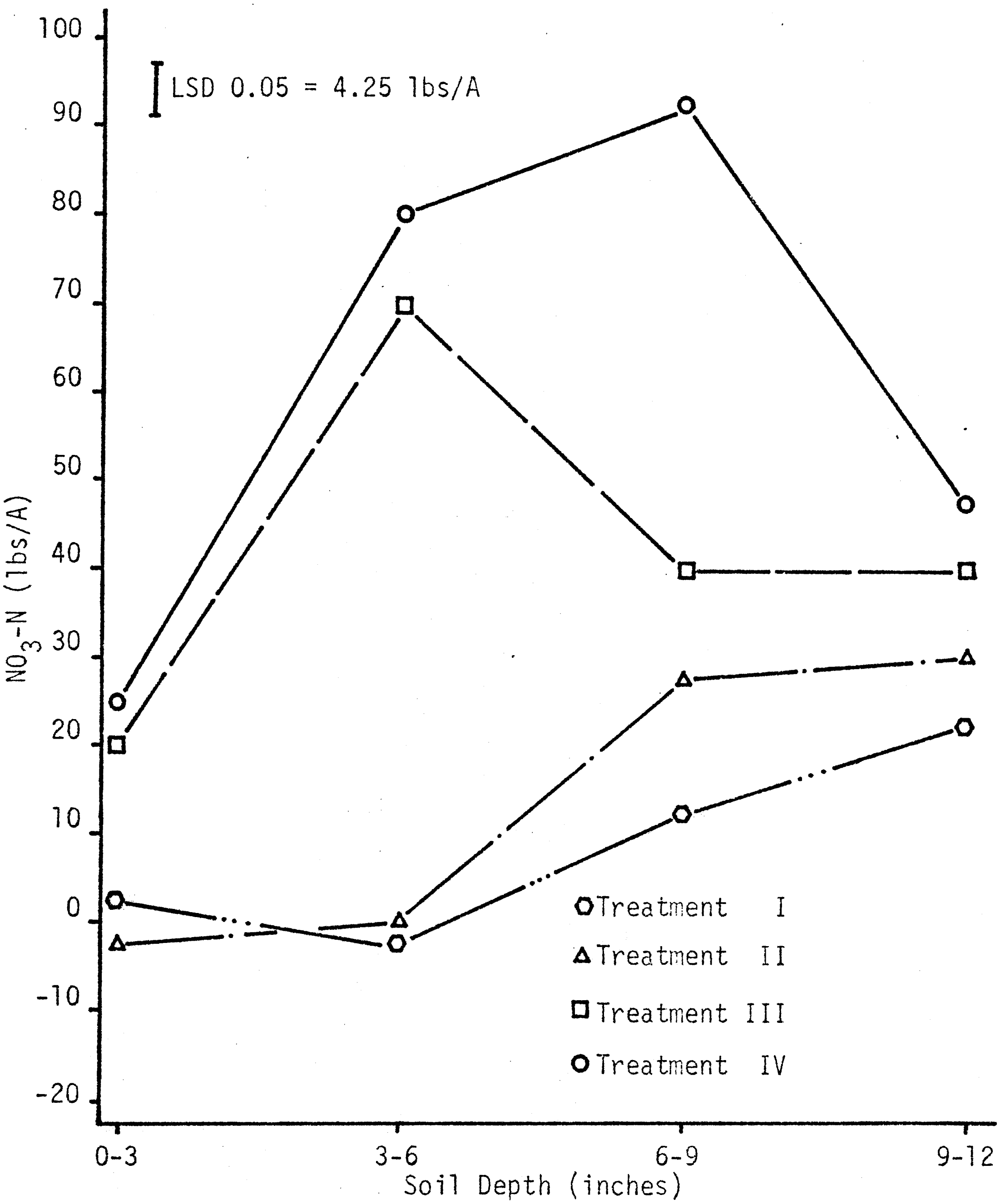

Figure 6. Difference Between the Final and Initial Analyses for NO_3-N in Carey Soil With Soil Depth

TABLE XI

DIFFERENCE BETWEEN THE FINAL AND INITIAL ANALYSES FOR Ca, Mg, K, NO_3-N, SOIL pH, AND ORGANIC MATTER IN SOIL

Soil Type	Trt	Depth (inches)	Available Ca (lb/A)*	Available Mg (lb/A)	Available K (lb/A)	NO_3-N (lb/A)	pH	Organic Matter (%)
Carey	I	0- 3	419.0**	-1391.5	-431.0	3.1	-0.05	-0.21
		3- 6	-187.0	-1893.5	-220.0	-2.5	-0.05	-0.50
		6- 9	-307.0	-1246.0	-90.5	11.7	-0.45	-0.33
		0-12	-82.5	-1210.0	-144.0	21.5	-0.50	-0.22
	II	0- 3	933.0	-1096.5	-311.0	-3.5	-0.10	-0.59
		3- 6	-760.0	-2168.5	-358.0	1.0	-0.10	-0.46
		6- 9	45.0	-1283.5	-0.5	27.5	-0.55	0.24
		9-12	-28.5	-1238.0	-176.5	30.1	-0.65	-0.41
	III	0- 3	365.0	-1896.0	-279.5	19.5	-0.25	-0.28
		3- 6	157.0	-1929.0	-241.0	70.1	-0.50	-0.28
		6- 9	464.5	-2151.0	-187.5	38.7	-1.00	0.38
		9-12	-14.5	-1174.0	-183.5	38.8	-0.55	-0.21
	IV	0- 3	777.0	-2057.0	-325.5	25.5	-0.05	0.09
		3- 6	646.5	-2001.5	-265.5	80.0	-0.25	0.20
		6- 9	-964.5	-2490.0	-124.0	92.0	-1.00	0.14
		9-12	514.5	-2777.0	-91.0	46.8	-0.65	0.07
Taloka	I	0- 3	110.0	-41.0	-11.0	0.0	0.35	0.60
		3- 6	59.5	-66.0	-13.0	1.2	0.20	-0.08
		6- 9	-405.0	-641.0	23.5	-1.0	-0.55	-0.24
		9-12	141.5	-855.0	30.5	1.5	-0.05	-0.09
	II	0- 3	195.0	-32.0	-29.0	0.5	-0.00	0.01
		3- 6	135.0	-39.0	-25.0	0.5	-0.10	0.03
		6- 9	149.0	-412.0	14.5	-1.0	-0.45	0.16
		9-12	71.5	-861.5	25.5	-1.0	-0.10	-0.32
	III	0- 3	882.5	-21.0	-46.5	2.2	0.45	-0.39
		3- 6	677.5	-32.0	-30.5	1.2	0.25	0.93
		6- 9	794.5	-848.5	53.0	0.7	-0.25	0.93
		9-12	259.0	-826.0	24.5	-1.0	-0.30	-0.20
	IV	0- 3	1783.0	0.5	-22.0	4.5	1.15	0.26
		3- 6	1801.5	13.0	-11.0	5.5	1.15	0.39
		6- 9	1274.0	-820.5	95.0	1.0	0.15	0.15
		9-12	709.5	-858.5	55.5	-1.0	-0.15	-0.23

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*Available Ca, Mg, K, and NO_3^--N given in lbs/afs equivalent (to convert to μg/g soil, divide by 2).

**Numbers are averages of two replicates.

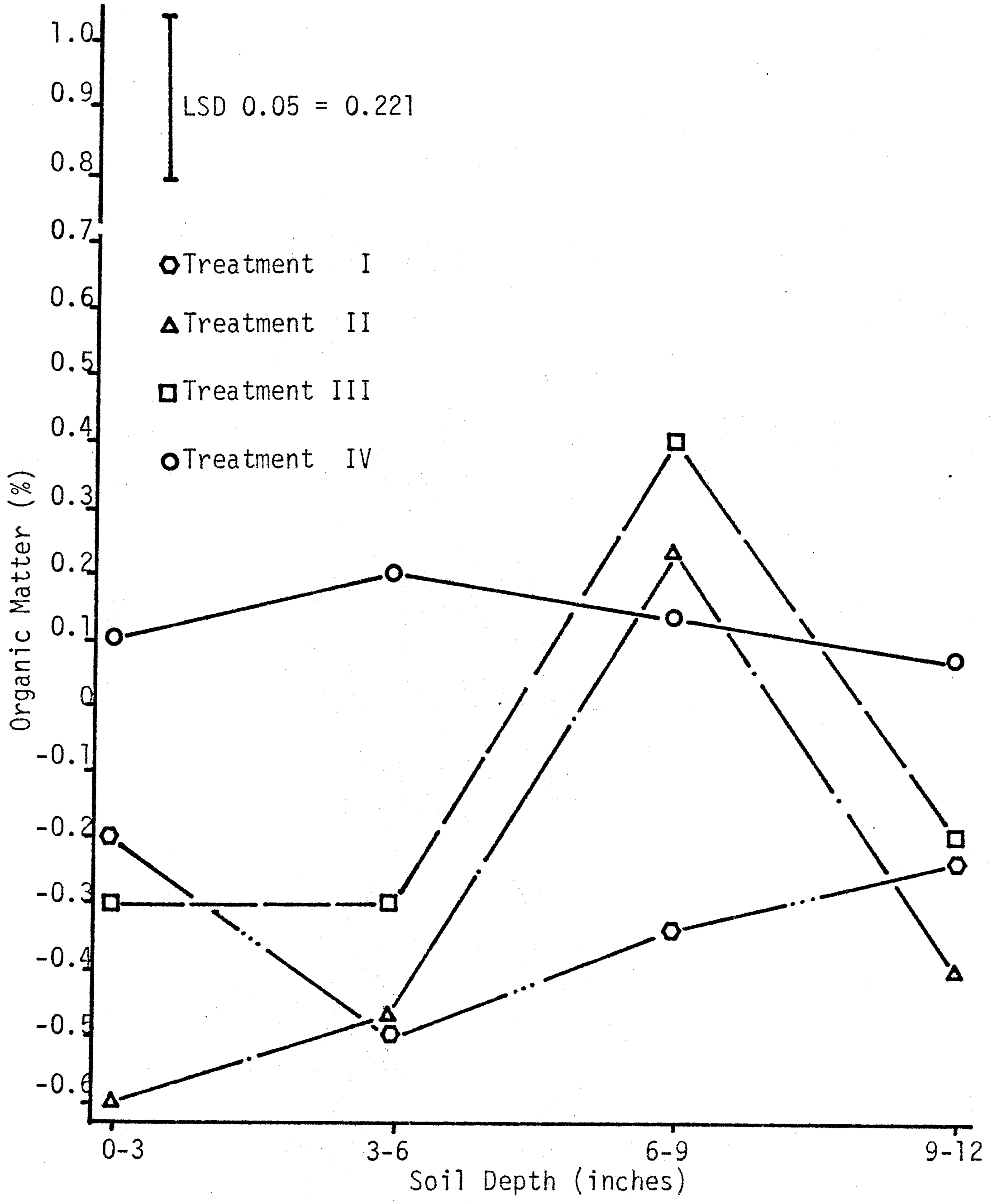

Figure 7. Difference Between the Final and Initial Analyses for Organic Matter in Carey Soil with Soil Depth

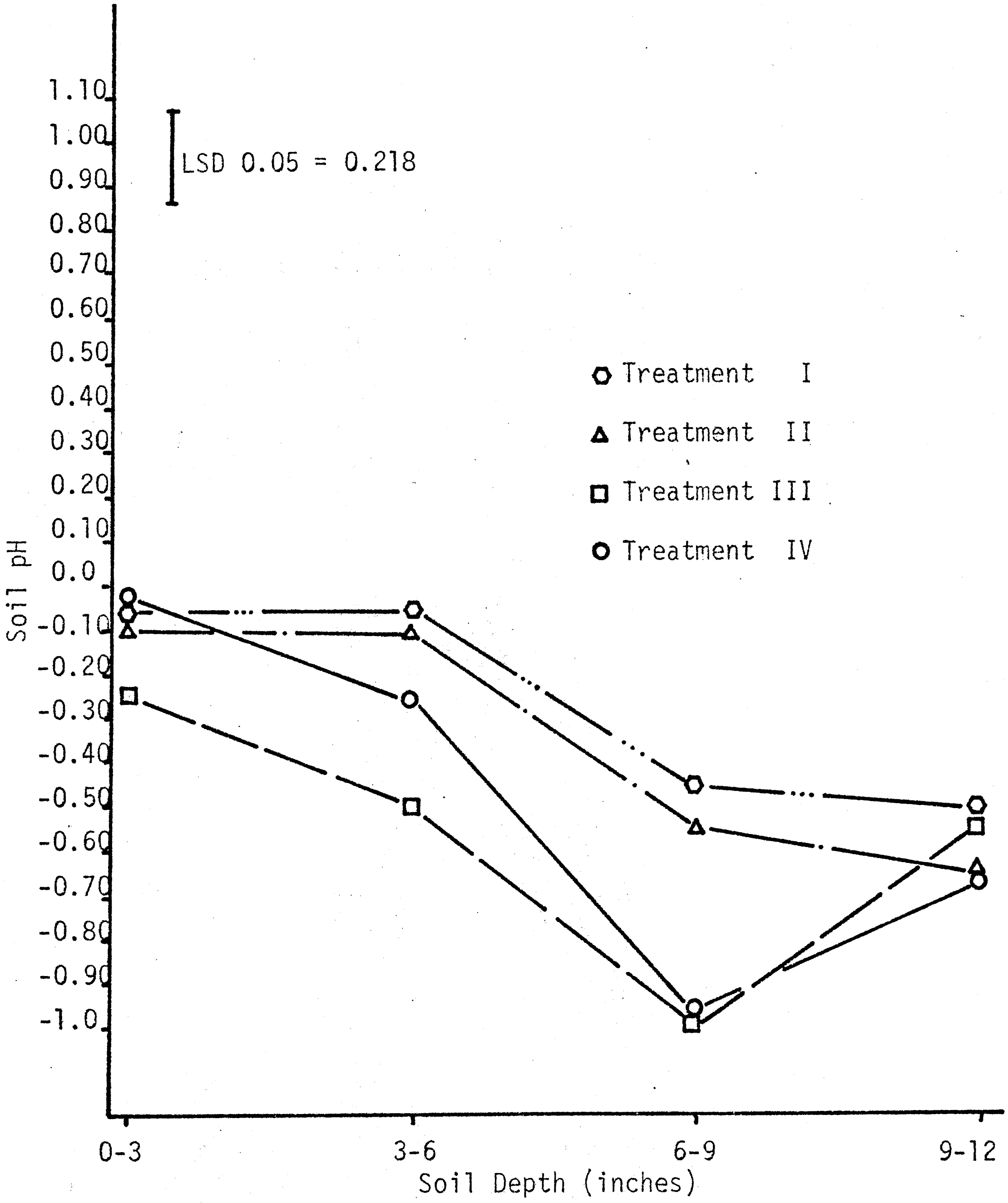

Figure 8. Difference Between Final and Initial Analyses for Soil pH in Carey Soil With Soil Depth

addition of Ca, Mg, and K in the OW must be considered also.

Larry and Morris (1972) pointed out that the application of sludge reduces soil pH with the implication of nitrification and oxidation of sulfides. Table XI presents information on available Ca, Mg, and K.

Taloka Soil

Examination of Table X and Figures 9, 10, 11, and 12 shows the same basic results for movement of total, inorganic, organic, and available P for the Taloka soil as noted for the Carey soil, though differing in detail. Some of this difference is interpreted to be due to the inability to keep the Taloka soil as well aerated as the Carey soil. A reduction in water permeability is evident after the third leaching. Evidence of poor aeration is implicated in Figure 13 and Table XI showing that either very little nitrification occurred or denitrification removed the NO_3^--N, or some combination of both. Increase in soil pH of Taloka is noted in Figure 14 and Table XI. Retention of added basic cations (see Table XI), denitrification, and retenion of NH_4^+-N are reported to increase soil pH with poor aeration (Pearsall, 1950; Bell, 1969, and Beek, 1977).

Figure 15 and Table XI depict changes in OM as a function of treatment and soil depth. The peak for treatment III seems to be in error. Note that Figure 15 shows a net loss of OM at the 9-12" (12.5-15 cm) depth for all treatments.

Leachate Studies

The statistical analysis of the data from leachate collection and analysis is shown in Table XII. The accumulative total, inorganic,

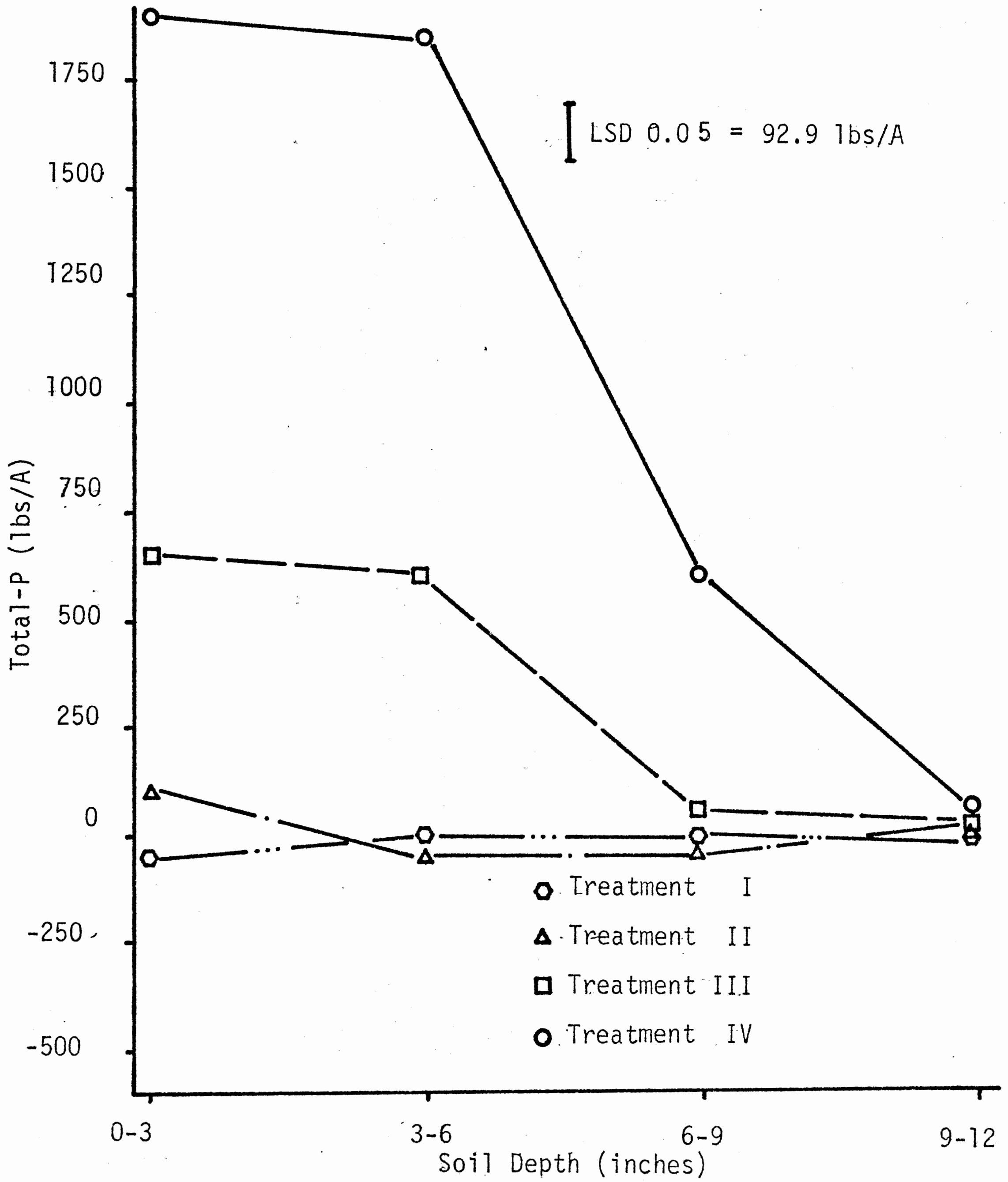

Figure 9. Difference Between the Final and Initial Analyses for Total P in Taloka Soil With Soil Depth

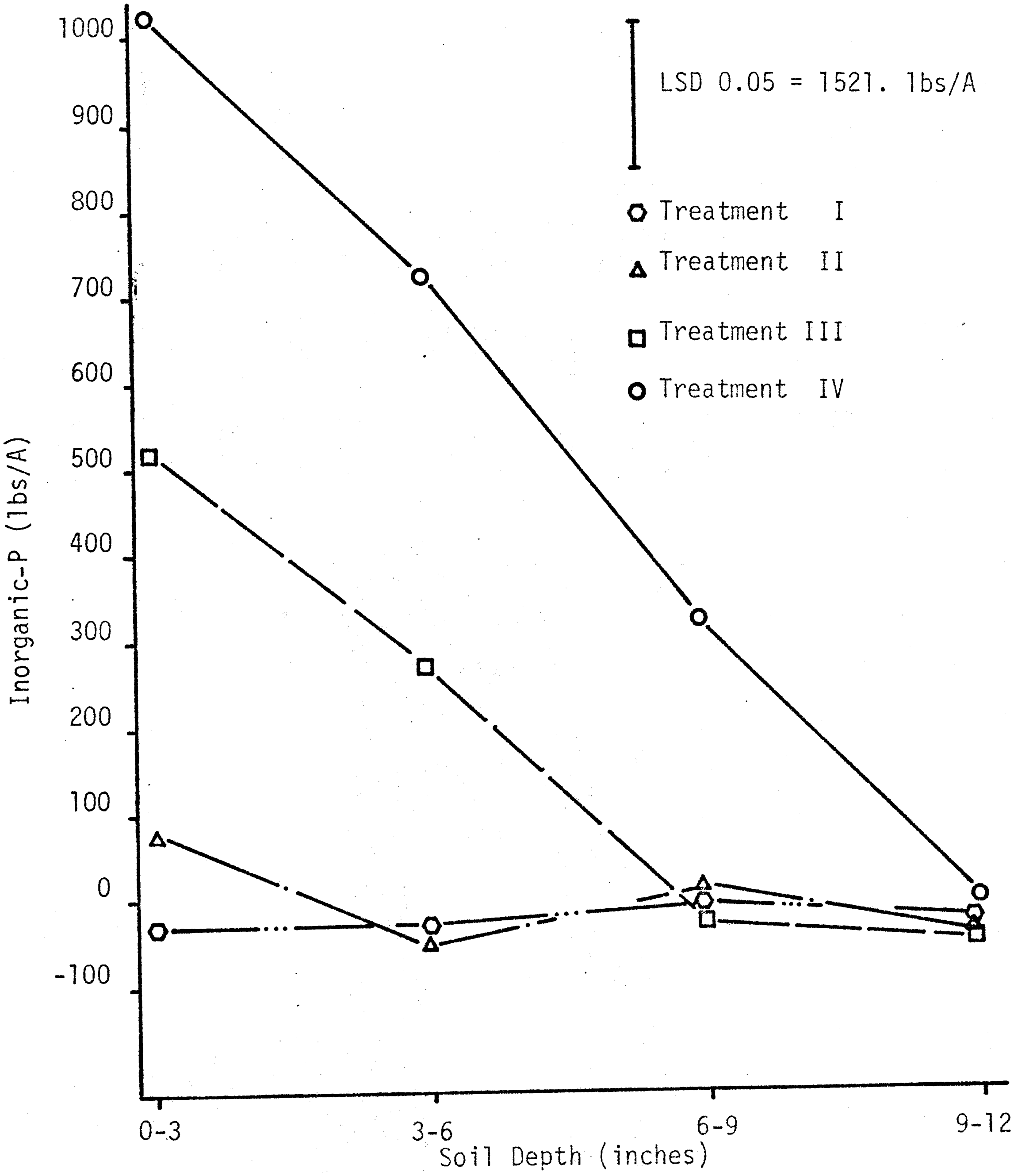

Figure 10. Difference Between the Final and Initial Analyses for Inorganic P in Taloka Soil With Soil Depth

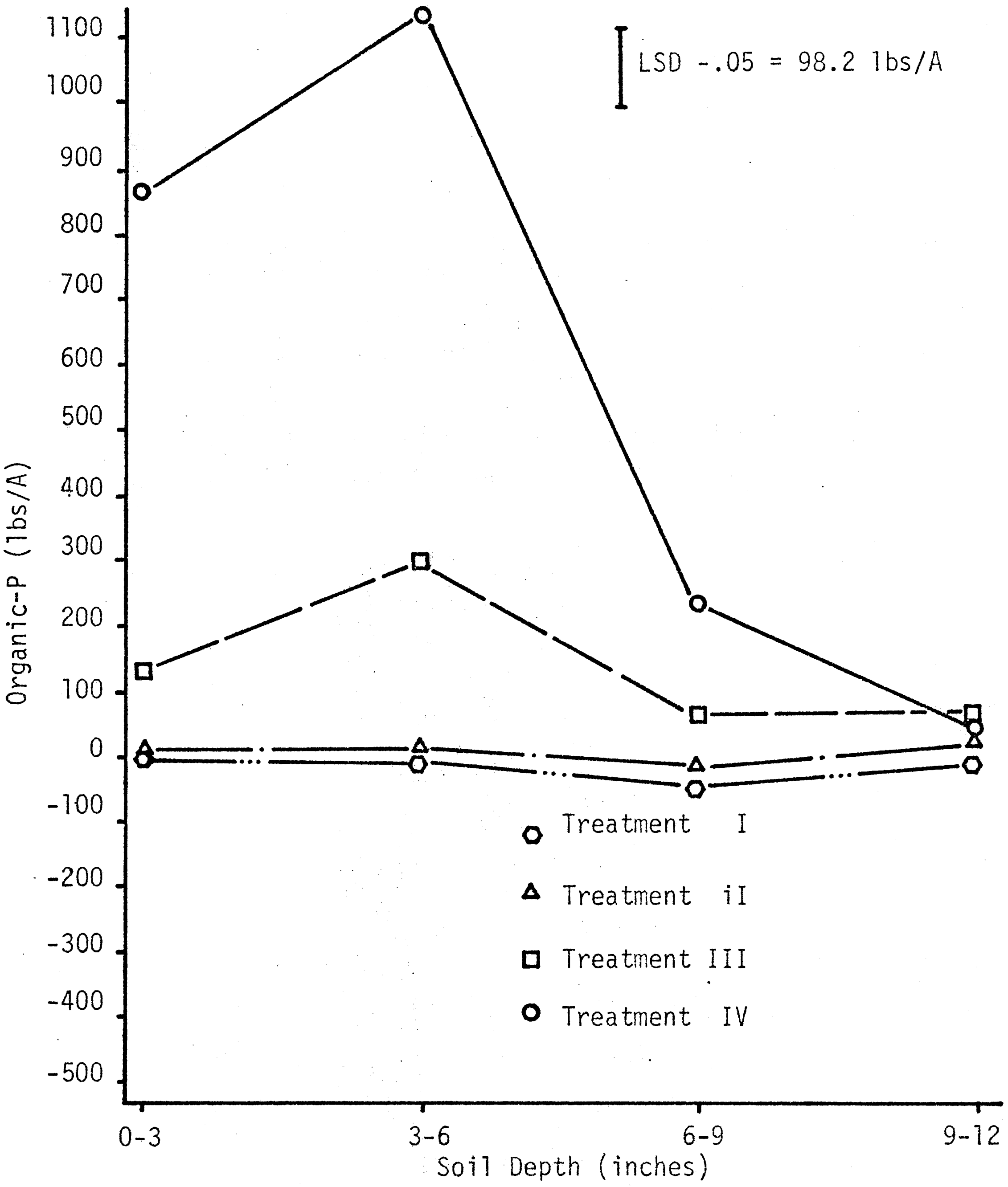

Figure 11. Difference Between the Final and Initial Analyses for Organic P in Taloka Soil with Soil Depth

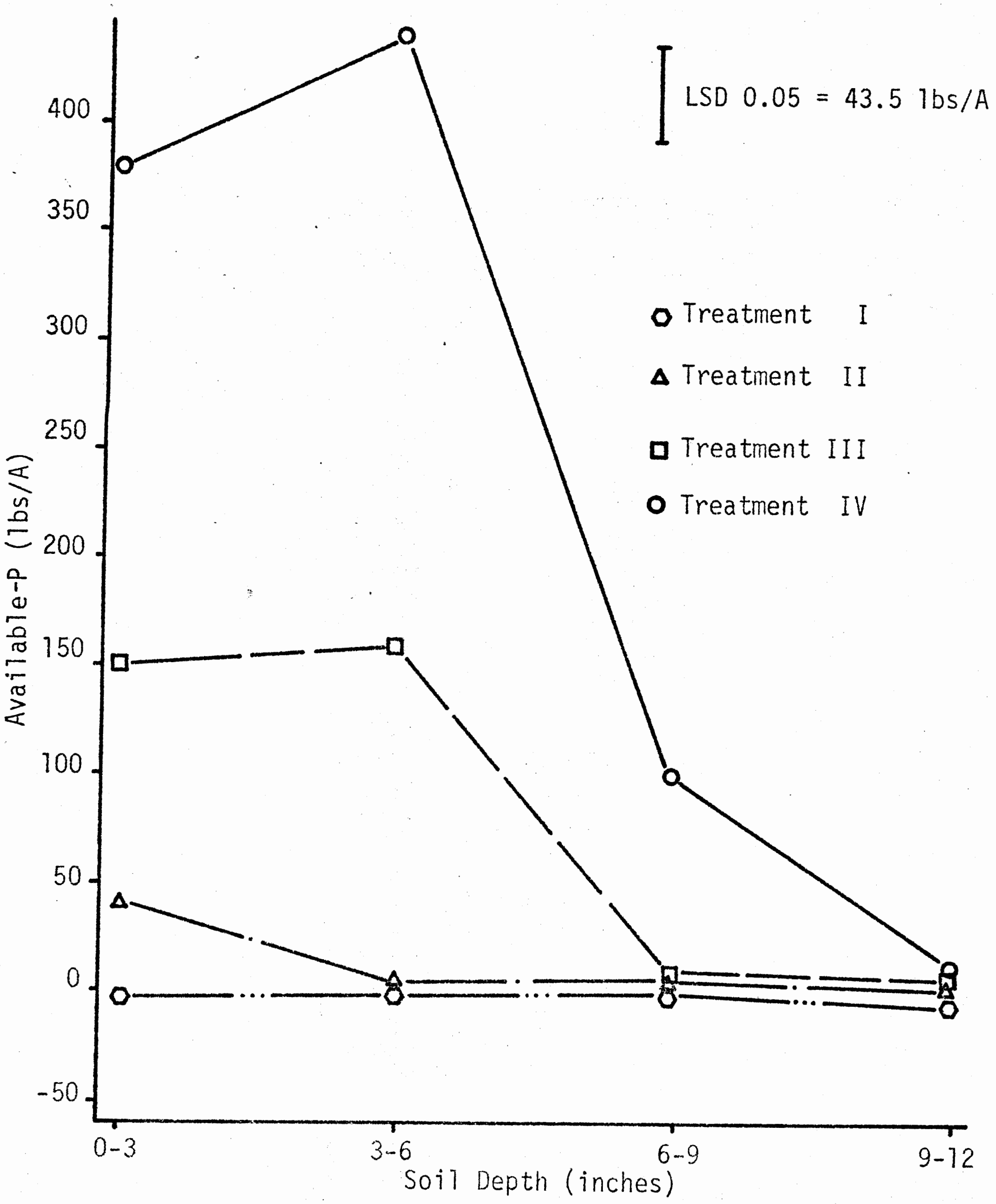

Figure 12. Difference Between the Final and Initial Analyses for Available P in Taloka Soil With Soil Depth

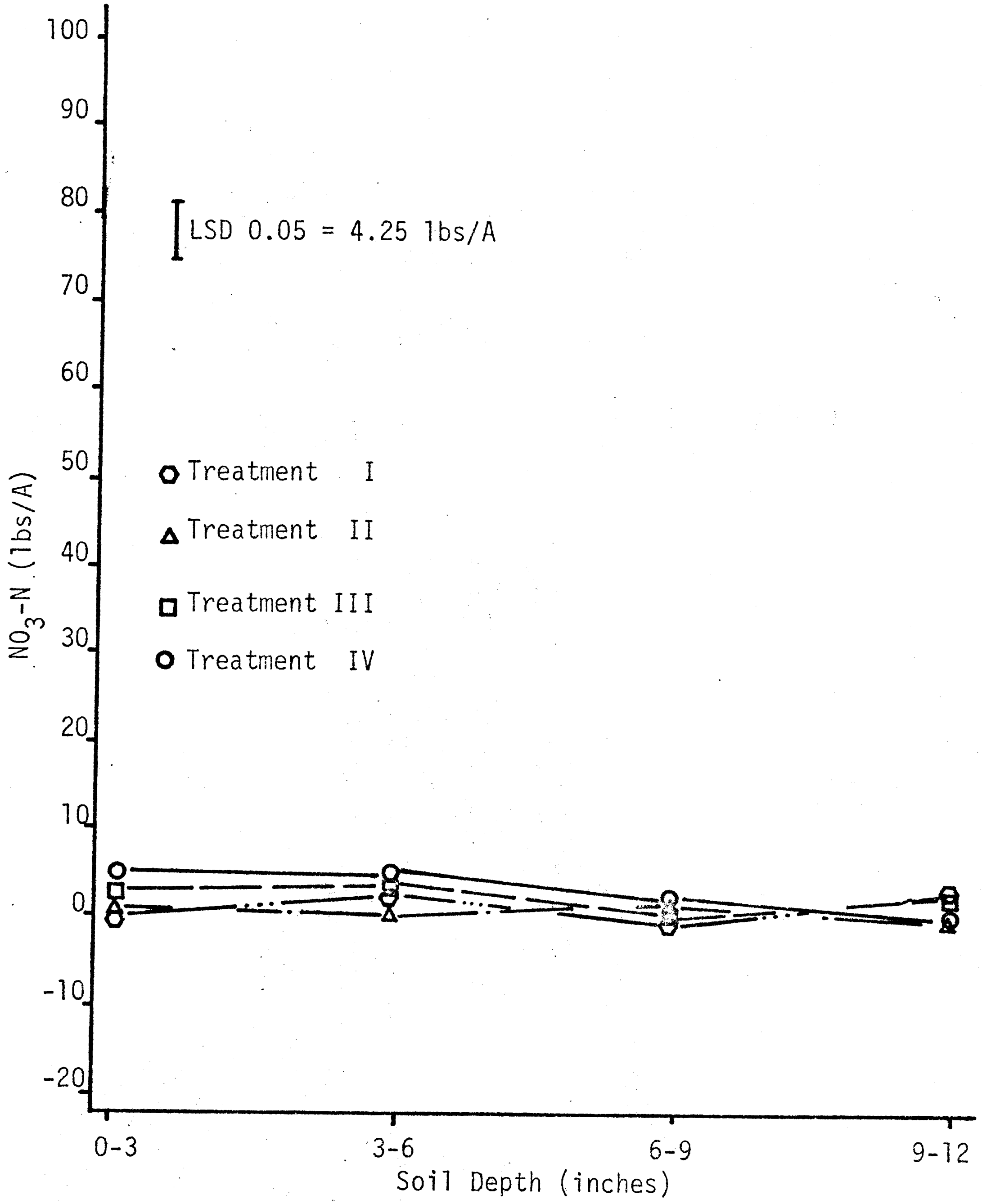

Figure 13. Difference Between the Final and Initial Analyses for NO_3-N in Taloka Soil With Soil Depth

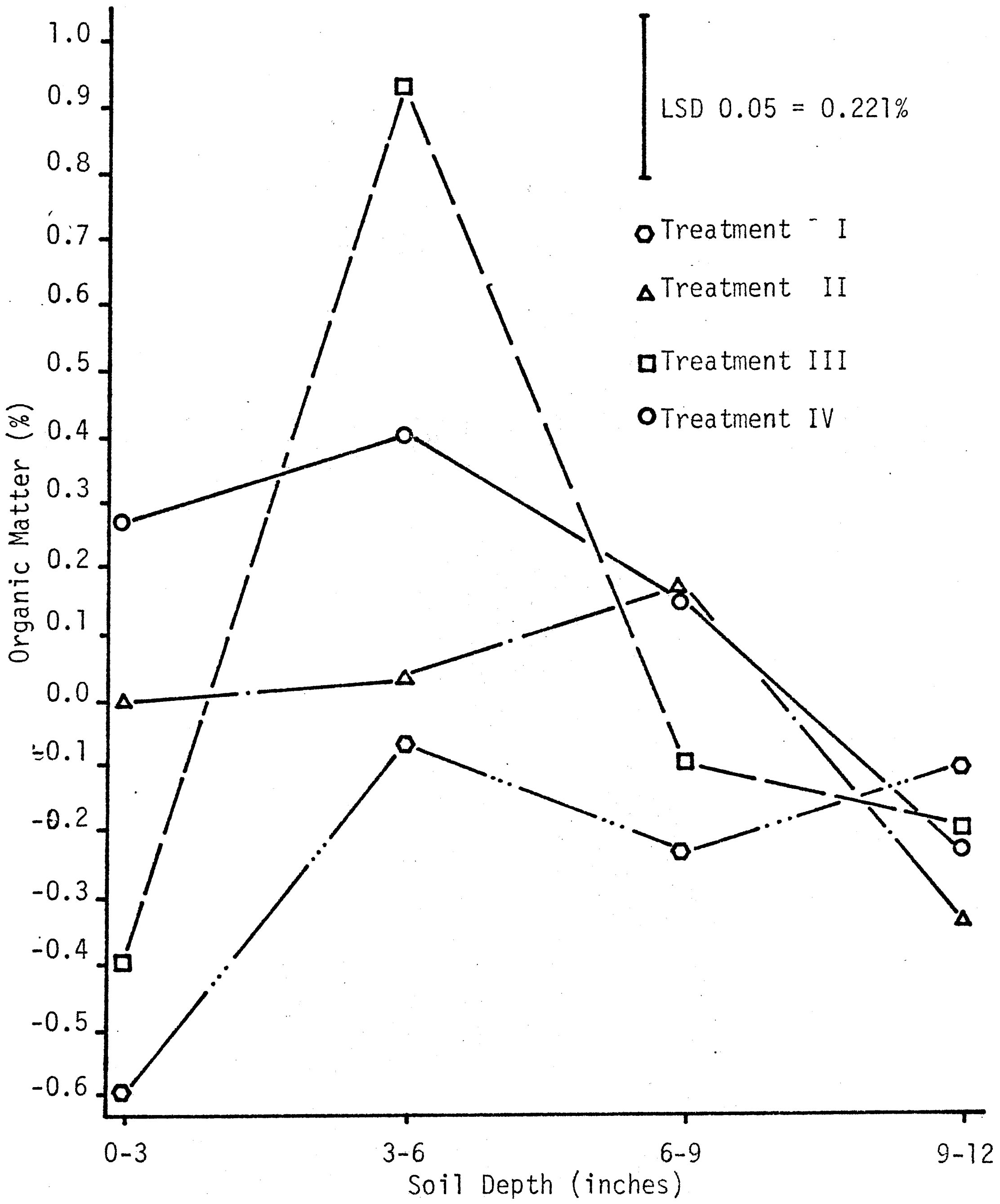

Figure 14. Difference Between the Final and Initial Analyses for Organic Matter in Taloka Soil With Soil Depth

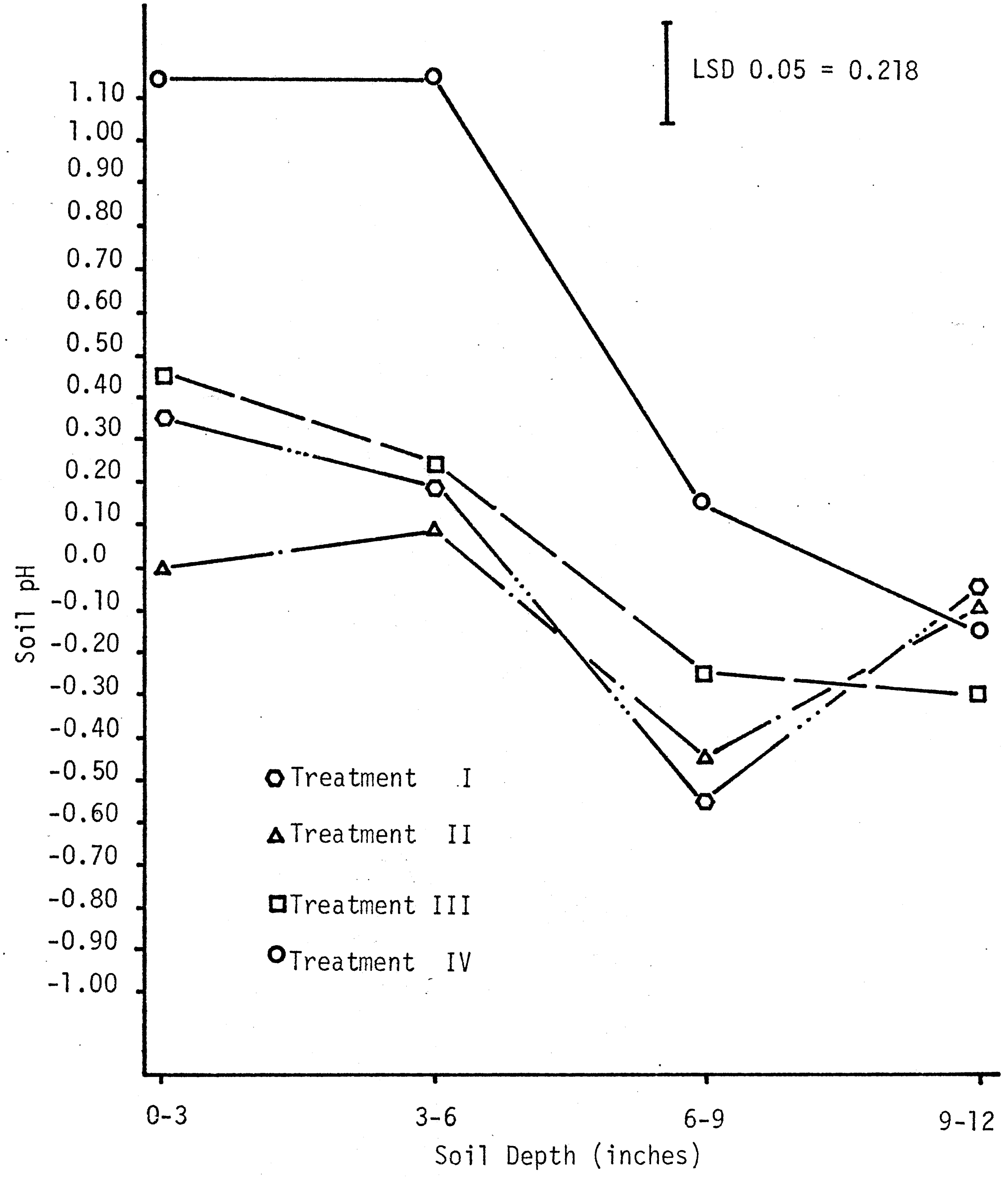

Figure 15. Difference Between the Final and Initial Analyses for Soil pH in Taloka Soil With Soil Depth

TABLE XII

SUMMARY OF THE ANALYSIS OF VARIANCE FOR ACCUMULATIVE LEACHATE ANALYSES IN CAREY AND TALOKA SOILS

Variable	ST		Trt		ST x Trt		T		ST x T		Trt x T		ST x T x Trt		E.M.S.	dF
	F	OSL*	F	OSL	F	OSL	F	OSL	F	OSL	F	OSL	F	OSL		
Total P	49.96	0.0001	12.55	0.0001	3.05	0.035	142.95	0.0001	12.44	0.0001	7.12	0.0001	5.19	0.0001	935.7	56
Inorganic P	16.42	0.0002	10.42	0.0001	6.05	0.0013	74.56	0.0001	17.20	0.0001	4.65	0.0001	3.81	0.0001	555.4	56
Organic P	16.42	0.0002	2.11	0.107	4.12	0.010	32.78	0.0001	3.47	0.0038	5.47	0.0001	4.14	0.0001	903.4	56
Organic Matter	8.16	0.006	1.84	0.14	15.31	0.0001	108.4	0.0001	55.4	0.0001	11.08	0.0001	4.36	0.0001	83.6	56

ST = soil type
Trt = treatment
T = time
E.M.S.= error mean square
dF = degree of freedom

*OSL = observed statistical level

organic P, and organic matter were shown to be highly significant for all cases except organic P vs. treatment (OSL = 0.107), organic matter vs. treatment (OSL = 0.140), and total P vs. the interaction of soil type X treatment (OSL = 0.035).

Analytical data for leachate collections and accumulative totals of total, inorganic, and organic P and organic matter are given in Tables XIII and XIV for the Carey soil, with graphical representations from the accumulative collections given in Figures 16, 17, 18, and 19. The high OW treatment resulted in the highest P mobility though the greatest amount of inorganic P was collected for treatment II (OSP only). Organic matter loss was greatest from the control, an unexpected result. No inorganic P was collected after the 57-day reaction period, but some organic P was collected on continuation of the experiment. The treatment sequence producing the highest OM in leachate was I, II, III, and IV. The amount of organic P collected, on the other hand, was in reverse order, but total P collected showed a treatment sequence of IV, II, I, and III.

Data from Taloka leachate collection are presented in Tables XV and XVI, with graphical representations given in Figures 20 through 23 for accumulations of total P, inorganic P, organic P, and organic matter. Note that the inorganic P level plateaued at the fifth collection, as with the Carey soil. The sequence of amounts of OM collected is treatments IV, III, II, I, and with organic P treatment sequence of III, I, II, and IV. With the addition of inorganic P, treatment IV produced the greatest amount of leachate P, total. The differences in sequences are a likely result of changes in microbial activity due to aeration and to soil P retention capacity.

TABLE XIII

LEACHATE ANALYSES FOR TOTAL, INORGANIC, AND ORGANIC P, AND ORGANIC MATTER IN CAREY SOIL

Trt.	Leaching Number	Total P (μg)	Inorganic P (μg)	Organic P (μg)	Organic Matter (mg)
I	1	259.5*	234.6	24.8	22.8
	2	67.3	7.0	60.3	21.8
	3	206.5	25.3	181.1	44.0
	4	131.0	21.4	109.6	53.1
	5	94.2	61.3	32.9	24.5
	6	60.4	0.0	60.4	65.1
	7	22.2	0.0	22.2	64.8
	8	27.2	0.0	27.2	45.7
II	1	324.0	274.5	49.5	50.4
	2	57.8	6.2	51.6	25.0
	3	144.1	23.5	120.6	34.4
	4	243.7	128.9	114.8	49.7
	5	60.4	28.8	31.5	24.7
	6	114.4	0.0	114.4	56.4
	7	60.4	0.0	60.4	40.5
	8	45.0	0.0	45.0	43.7
III	1	335.4	90.9	244.4	45.3
	2	43.7	13.5	30.1	18.1
	3	74.7	14.1	60.6	34.9
	4	126.8	62.7	64.1	52.9
	5	68.1	46.6	21.4	11.7
	6	48.7	0.0	48.7	37.7
	7	71.7	0.0	71.7	35.9
	8	57.0	0.0	57.0	58.0
IV	1	574.7	248.4	326.3	79.3
	2	76.3	23.8	52.4	12.1
	3	222.0	80.6	141.3	12.6
	4	91.0	23.6	67.4	18.0
	5	88.0	37.7	50.2	6.3
	6	51.0	0.0	51.0	23.2
	7	92.6	0.0	92.6	18.2
	8	67.0	0.0	67.0	24.4

*Numbers are averages of two replicates.

TABLE XIV

LEACHATE ACCUMULATIVE ANALYSES FOR TOTAL, INORGANIC, AND ORGANIC P, AND ORGANIC MATTER IN CAREY SOIL

Trt.	Leaching Number	Total P (μg)	Inorganic P (μg)	Organic P (μg)	Organic Matter (mg)
I	1	259.5*	234.6	24.8	22.8
	2	326.9	241.7	85.1	44.7
	3	533.4	267.0	266.3	88.7
	4	664.5	288.5	375.9	141.8
	5	758.8	349.8	408.9	166.3
	6	819.2	349.8	469.4	231.4
	7	841.4	349.8	491.6	296.3
	8	868.6	349.8	518.8	342.0
II	1	324.0	274.5	49.5	50.4
	2	381.9	280.7	101.1	75.4
	3	526.1	304.3	221.8	109.9
	4	769.9	433.2	336.7	159.6
	5	830.3	462.0	368.2	184.3
	6	944.7	462.0	482.7	240.8
	7	1005.2	462.0	543.1	281.4
	8	1050.2	462.0	588.2	325.1
III	1	335.4	90.9	244.4	45.3
	2	379.1	104.5	274.6	63.5
	3	453.8	118.6	335.2	98.5
	4	580.7	181.4	399.3	151.4
	5	648.9	228.0	420.8	163.1
	6	697.7	228.0	469.6	200.8
	7	769.4	228.0	541.3	236.8
	8	826.5	228.0	598.4	294.8
IV	1	574.1	248.4	326.3	79.3
	2	651.0	272.2	378.8	91.5
	3	873.1	352.9	520.2	104.1
	4	964.1	376.5	587.6	122.2
	5	1052.2	414.3	637.9	128.5
	6	1103.2	414.3	688.9	151.7
	7	1195.8	414.3	781.5	170.0
	8	1262.8	414.3	848.5	194.5

*Accumulative amounts determined by using averages of two replicates.

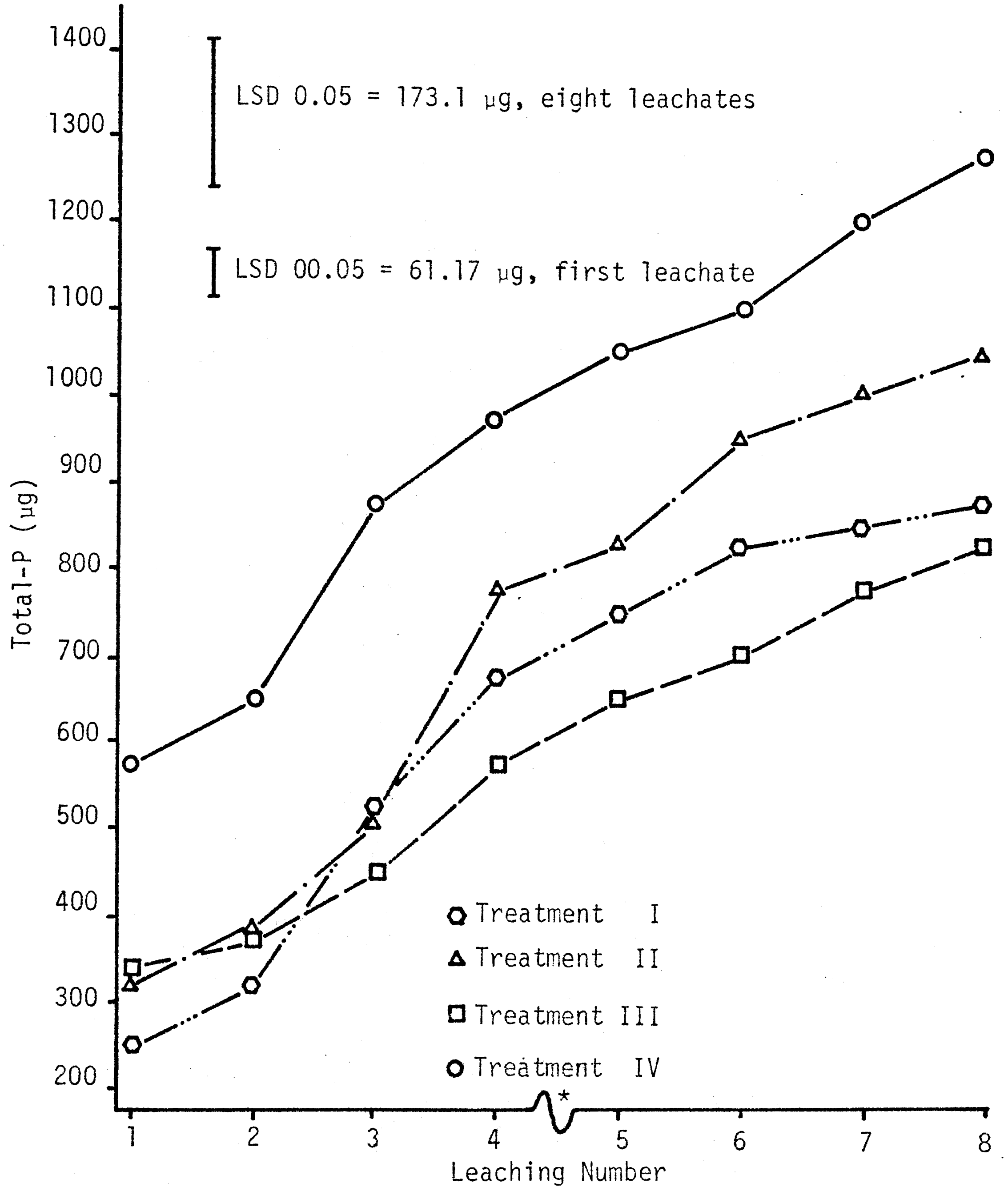

Figure 16. Accumulation of Total P From Sequential Leachings of Soil Columns of Carey Soil

*See Table VI for delay and sequence

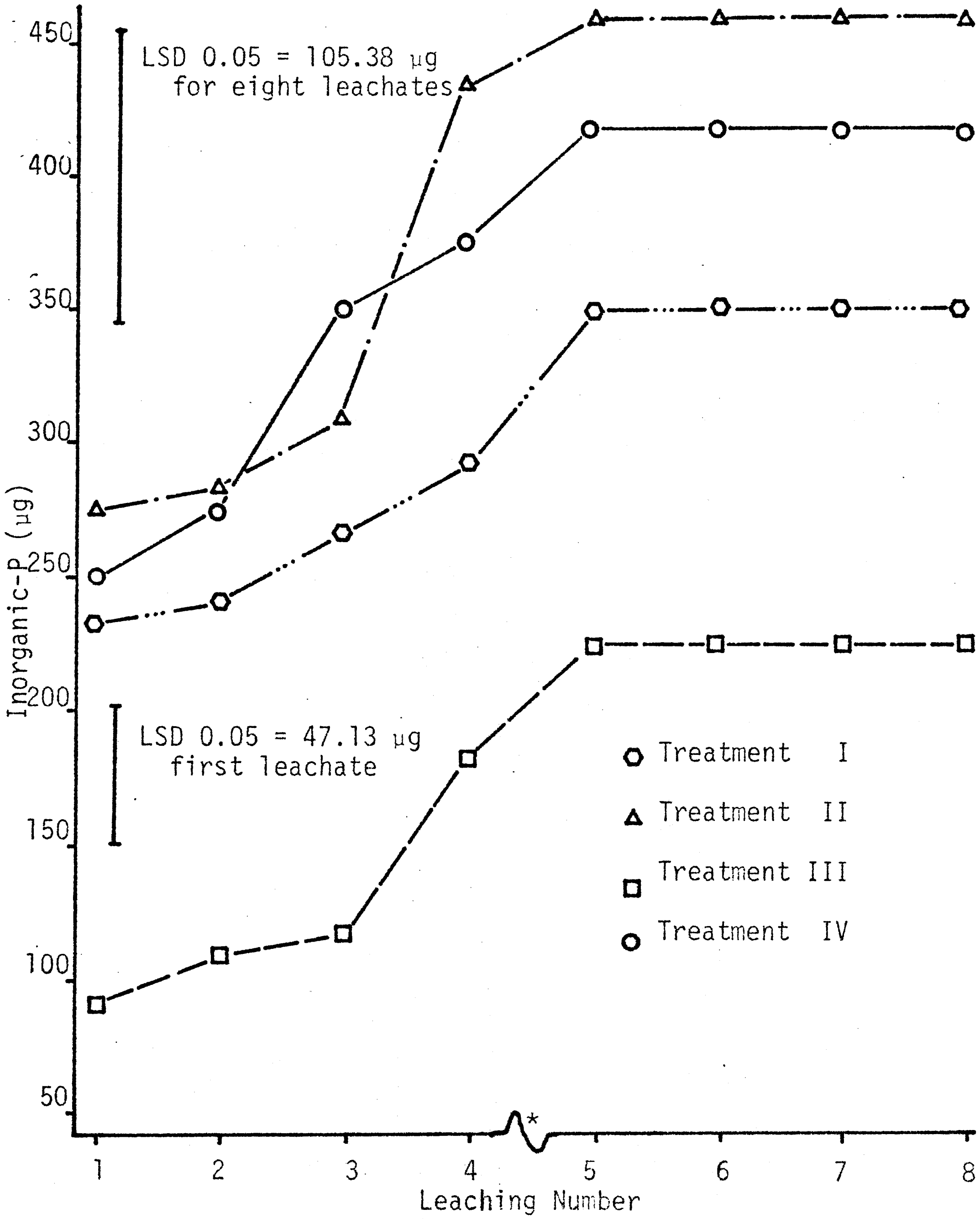

Figure 17. Accumulation of Inorganic P From Seouential Leachings of Soil Columns of Carey Soil

*See Table VI for delay and sequence

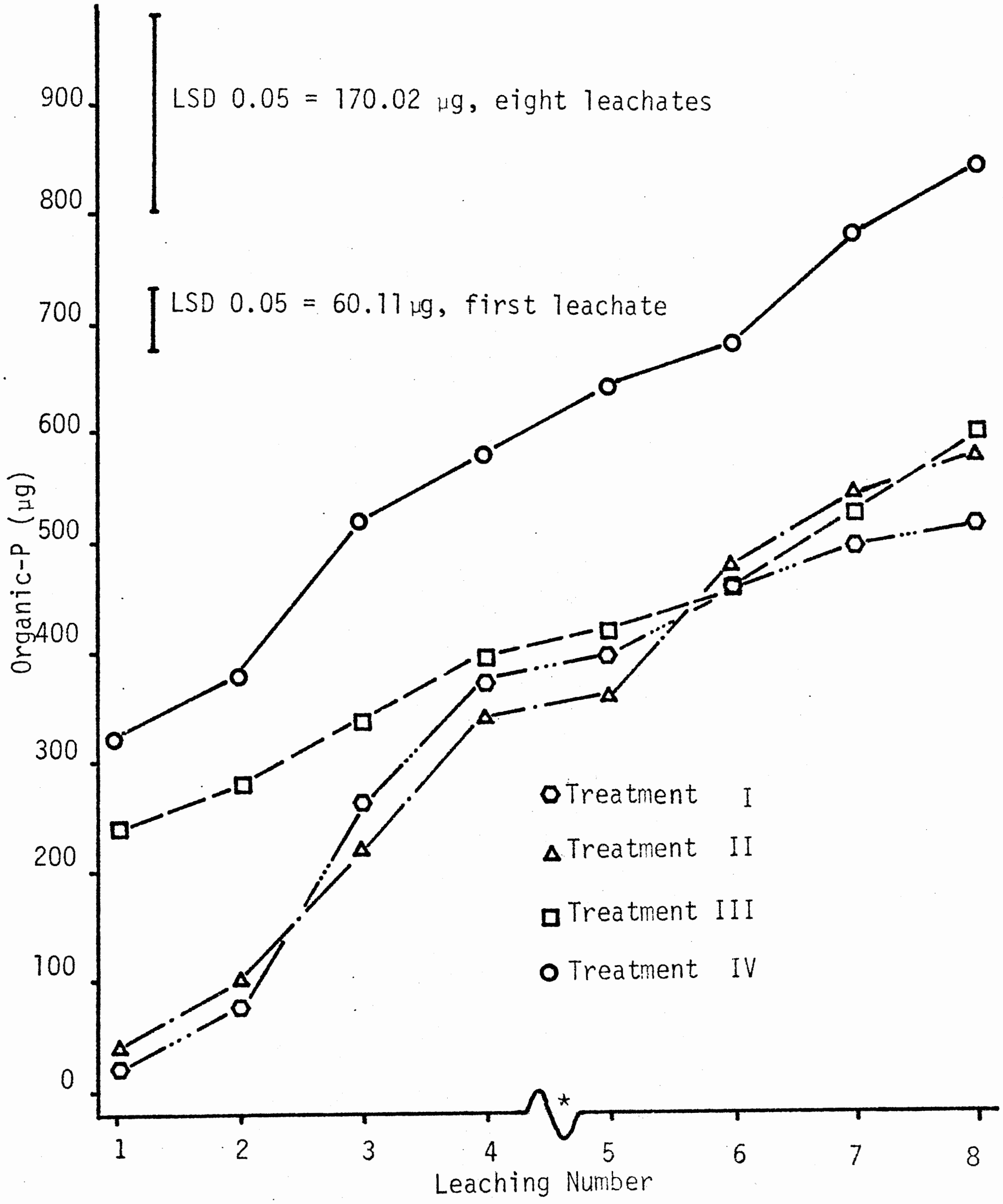

Figure 18. Accumulation of Organic P From Sequential Leachings of Soil Columns of Carey Soil

*See Table VI for delay and sequence

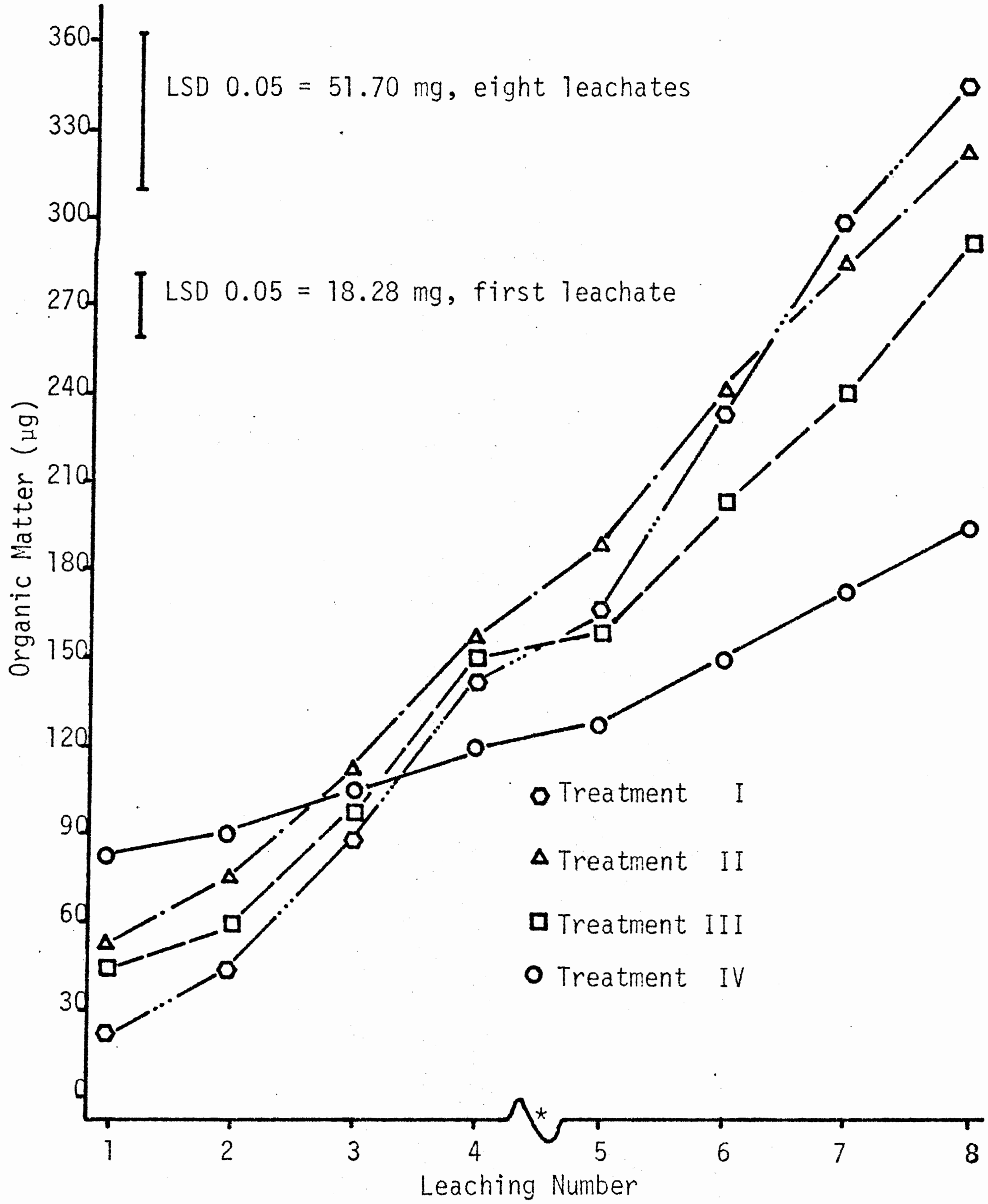

Figure 19. Accumulation of Organic Matter From Sequential Leachings of Soil Columns of Carey Soil

*See Table VI for delay and sequence

TABLE XV

LEACHATE ANALYSES FOR TOTAL, INORGANIC, AND ORGANIC P, AND ORGANIC MATTER IN TALOKA SOIL

Trt.	Leaching Number	Total P (μg)	Inorganic P (μg)	Organic P (μg)	Organic Matter (mg)
I	1	187.5*	74.4	113.1	100.7
	2	67.0	20.1	46.9	44.2
	3	55.2	30.0	25.2	26.5
	4	226.5	84.3	142.2	21.5
	5	38.8	9.5	29.2	22.6
	6	20.3	0.0	20.3	23.7
	7	38.3	0.0	38.3	38.2
	8	54.5	0.0	54.5	35.7
II	1	217.1	48.3	168.8	124.3
	2	28.2	8.9	19.2	5.4
	3	89.5	32.9	56.6	9.0
	4	40.1	12.8	27.2	22.0
	5	30.1	9.8	20.3	11.7
	6	55.0	0.0	55.0	24.8
	7	32.0	0.0	32.0	63.1
	8	72.5	0.0	72.5	26.9
III	1	203.3	10.7	192.6	126.7
	2	18.2	3.8	14.4	5.5
	3	36.9	6.5	30.3	25.2
	4	235.8	94.0	142.1	3.6
	5	15.9	10.5	5.3	22.2
	6	38.0	0.0	38.0	46.9
	7	29.6	0.0	29.6	42.2
	8	67.2	0.0	67.2	54.8
IV	1	339.3	192.8	146.5	189.1
	2	48.3	36.7	11.6	28.3
	3	130.6	51.6	78.9	9.3
	4	240.7	162.9	77.7	65.1
	5	22.4	18.8	3.1	7.4
	6	43.1	0.0	43.1	7.9
	7	21.5	0.0	21.5	44.4
	8	40.5	0.0	40.5	23.9

*Numbers are averages of two replicates.

TABLE XVI

LEACHATE ACCUMULATIVE ANALYSES FOR TOTAL, INORGANIC, AND ORGANIC P, AND ORGANIC MATTER IN TALOKA SOIL

Trt.	Leaching Number	Total P (μg)	Inorganic P (μg)	Organic P (μg)	Organic Matter (mg)
I	1	187.5*	74.4	113.1	100.7
	2	254.6	94.5	160.0	145.0
	3	309.9	124.5	185.3	171.5
	4	536.4	208.8	327.6	193.0
	5	575.3	218.4	356.8	215.7
	6	595.6	218.4	377.2	239.4
	7	633.9	218.4	415.5	277.6
	8	688.4	218.4	470.0	313.3
II	1	217.1	48.3	168.8	124.3
	2	245.3	57.2	188.0	129.7
	3	334.9	90.2	244.7	138.8
	4	375.0	103.0	271.9	160.8
	5	405.2	112.9	292.2	172.6
	6	460.2	112.9	347.3	197.4
	7	492.2	112.9	379.3	260.6
	8	564.7	112.9	451.8	287.6
III	1	203.3	10.7	192.6	126.7
	2	221.6	14.6	207.0	132.3
	3	258.5	21.1	237.3	157.5
	4	494.4	115.2	379.5	161.1
	5	510.3	125.7	384.9	183.4
	6	548.3	125.7	422.9	230.4
	7	578.0	125.7	452.5	272.6
	8	645.2	125.7	519.8	327.5
IV	1	339.3	192.8	146.5	189.1
	2	387.7	229.5	158.2	217.5
	3	518.3	281.2	237.1	226.9
	4	759.1	444.1	314.9	292.0
	5	781.5	462.9	318.0	299.5
	6	824.5	462.9	361.2	307.4
	7	846.2	462.9	382.7	351.9
	8	886.7	462.9	423.3	375.8

*Accumulative amounts determined by using averages of two replicates.

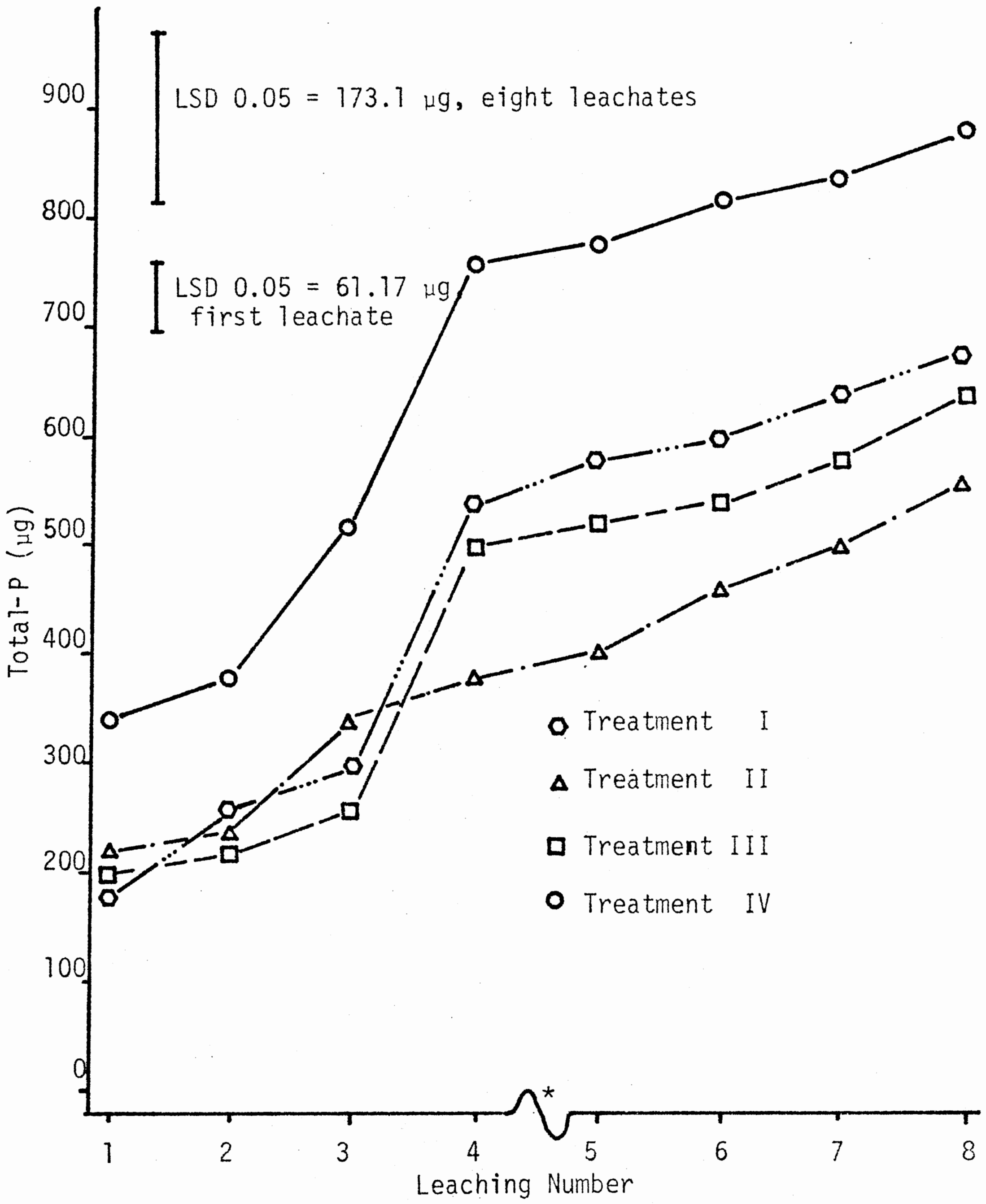

Figure 20. Accumulation of Total-P From Sequential Leachings of Soil Columns of Talóka Soil

*See Table VI for delay and sequence

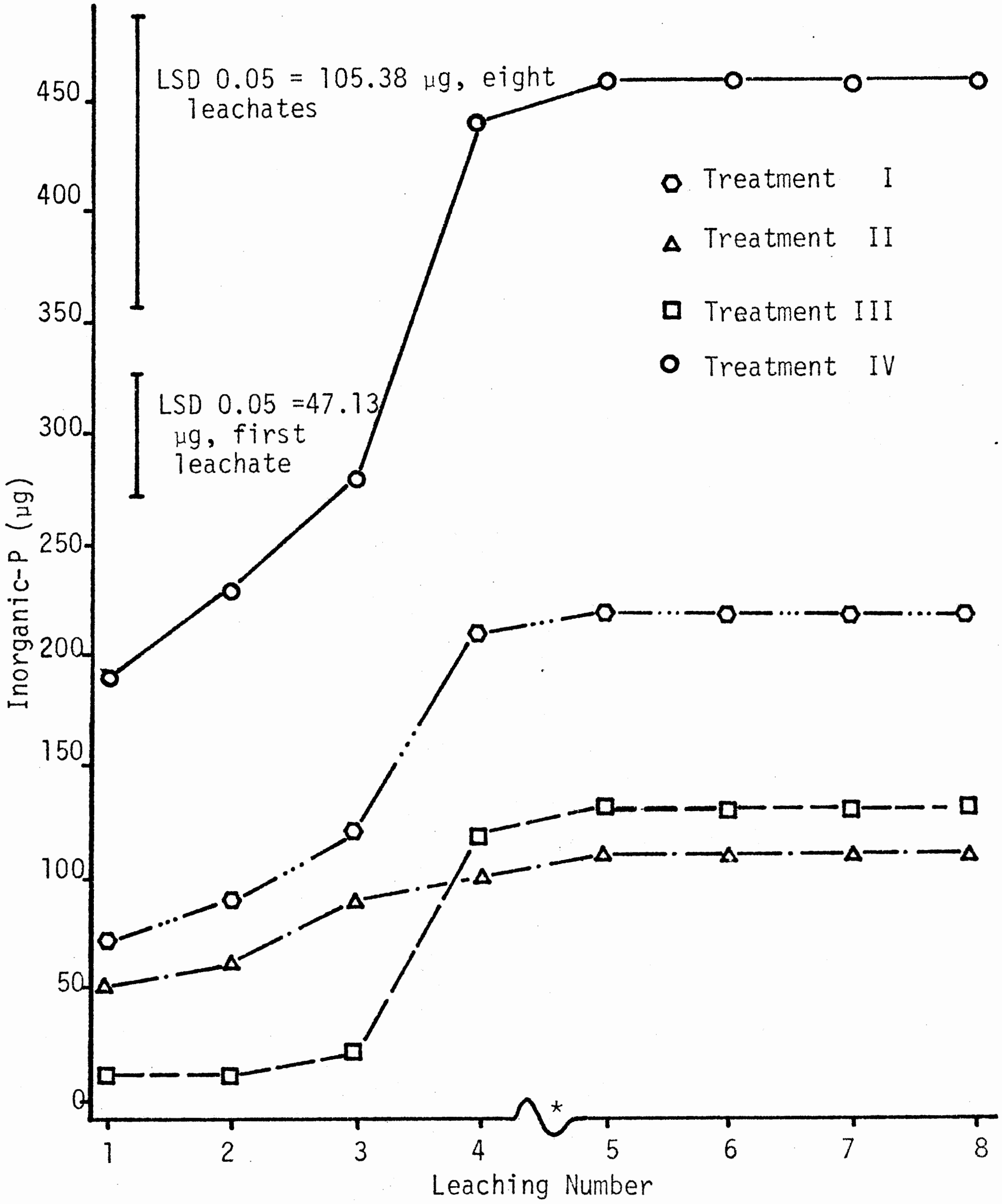

Figure 21. Accumulation of Inorganic-P From Sequential Leachings of Soil Columns of Taloka Soil

*See Table VI for delay and sequence

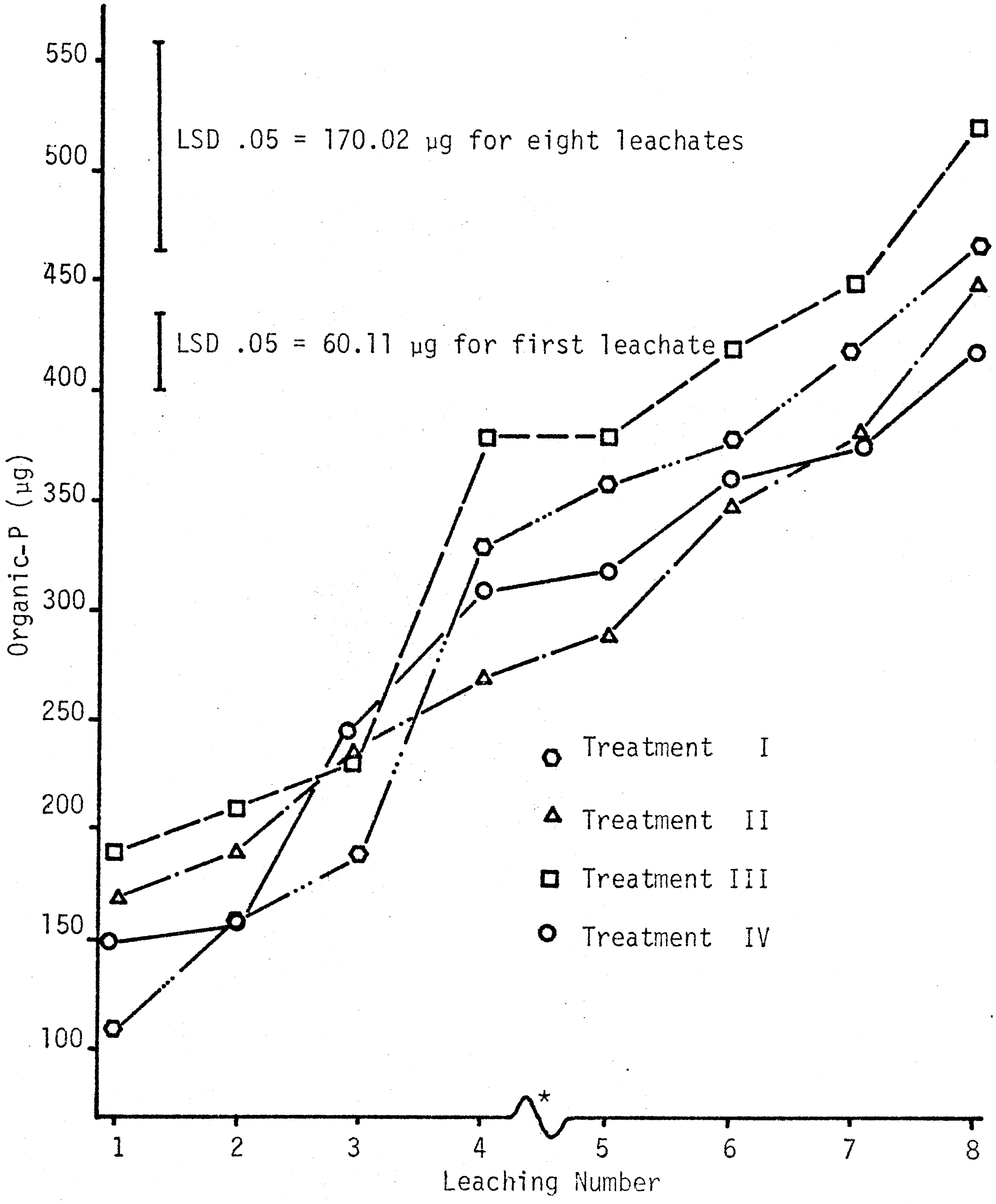

Figure 22. Accumulation of Organic-P From Sequential Leachings of Soil Columns of Taloka Soil

*See Table VI for delay and sequence

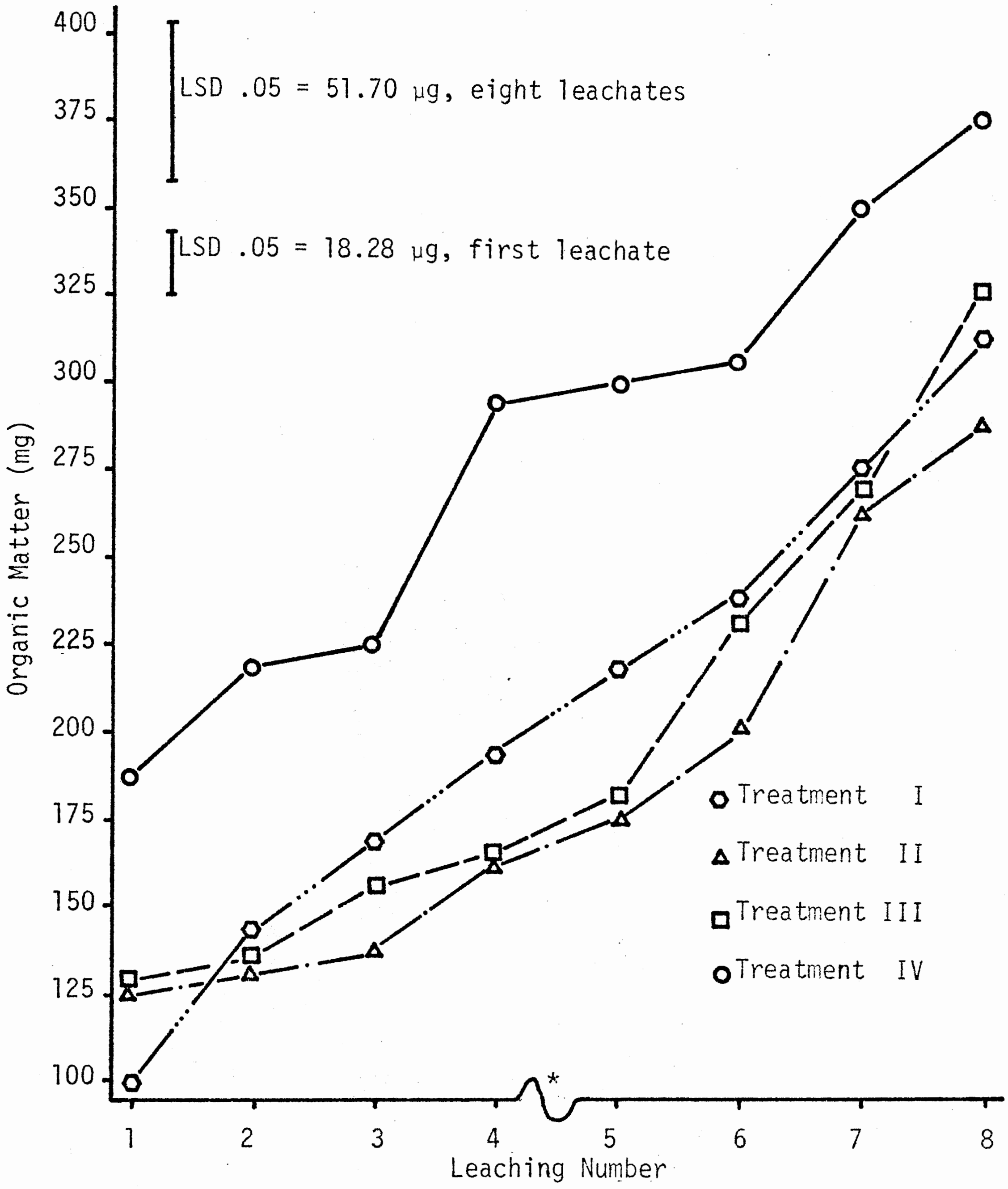

Figure 23. Accumulation of Organic Matter From Sequential Leachings of Soil Columns of Taloka Soil

*See Table VI for delay and sequence

Two factors stand out in leachate collection: 1) P was mobilized by the highest OW treatment, and 2) oxidative decomposition of the applied OW leadsto a greater mobility of P than was shown for the soil where poorer aeration was predominate. Without doubt, clay type and clay content and soil pH are also involved (see analysis of variance, Table XII), but this experiment was not designed such that close evaluation of these factors could be obtained.

CHAPTER V

CONCLUSIONS

The conclusions from the experimental work reported in this thesis can be summarized as follows:

1. Generally organic and inorganic P mobility can be demonstrated by this leaching and analytical technique for normal soils without added P fertilization and without added organic wastes.

2. Total P mobility in soils will be increased with high organic waste loading rates (60 T/A); however, an organic loading of 20 T/A did not increase P mobility over no organic waste treatments.

3. Condition of aeration of the treated soils affects P mobility. Poor aeration caused by low water permeability led to less inorganic P movement but maintained relatively high organic P movement rates.

4. The Taloka soil pH was increased by organic waste treatment and poor aeration. Reduction of oxidation, nitrification, and increased denitrification appear as contributing factors. Accumulation of basic cations contained in the waste materials will also have an influence. Accumulation of NH_4-N has been reported to increase soil pH under flooded conditions also, but was not measured in this experiment.

5. NO_3^--N, Ca^{++}, Mg^{++}, and K^+ removal from soils is increased by better soil aeration. Better aeration increased organic decomposition and nitrification compared to poorer soil aeration and, hence, will provide the above ions in greater amounts from the organic waste decomposed

and they will be subjected to the leaching processes.

6. Detectible movement of organic matter in the soil profile and shown in the collected leachates was less for the Carey soil (well aerated) than for the Taloka soil (poorly aerated). This is interpreted to be a direct result of faster and more complete oxidative processes in the Carey soil, reducing organic moieties that are leachable. While on the other hand, partial anaerobic decomposition processes seemed to produce organic moieties that were somewhat leachable.

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