

DETERMINATION OF PHOSPHATES IN SOILS IN NIHORT, IDI-ISHIN, JERICHO, IBADAN

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ABSTRACT

Increased knowledge of Phosphorus (P) fractions in soils is required to optimise its use in crop production and minimize the adverse environmental effects to croplands through fertilizer, a major source of P. This study sought to ascertain the long term effects of cultivation and associated fertilizer applications on the soil P fractions at different depths and to assess the risk of phosphorus leaching on the environment. Field studies were conducted and amounts of phosphorus fractions were determined for the topsoils (0-15cm) and subsoils (15-30cm) of six different agricultural plots in Nigerian Horticultural Research Institute (NIHORT), Idi-Ishin, Ibadan. The six plots had received different treatments; two of the plots have been cultivated and fertilized since inception of the institute in 1975; three of the plots have been cultivated but not fertilized while the last plot was used as the virgin analogue (neither fertilized nor cultivated). Fractions of P -Total Phosphates (TP), Inorganic Phosphates (IP) and Organic Phosphates (OP) were extracted from the soil samples using ignition/ sulphuric acid method. The extracts were determined using ascorbic acid colorimetric method (Bray's No 1) at a wavelength of 880nm. Results showed that TP in the soils varied from 86.6mgkg⁻¹ to 527.9mgkg⁻¹. IP varied from 78.0mgkg⁻¹ to 510.6mgkg⁻¹. OP had very low values between 6.5mgkg⁻¹ and 105.4mgkg⁻¹ when compared with the other fractions of P. The low values of OP may be reversed by management practices which allow a buildup of soil organic matter. The fractionations of IP and their extractants determined had the following results on the average: Saloid bound (NH₄Cl) 0.073 mgkg⁻¹, Al bound (NH₄F + NH₄OH) 0.035mgkg⁻¹, Fe bound (excess NaCl + NaOH) 0.032mgkg⁻¹, Ca bound (NaCl + H₂SO₄) 0.113mg/kg⁻¹, Reductant soluble bound (NaCl + KMnO₄.+ sodium Dithionite) 0.048mgkg. A recovery study was also carried out for the forms of phosphates and values >90% were obtained. Results obtained showed very high values of phosphates even in the virgin soils. This could be attributed to leaching from fertilized soils to unfertilized soils and could pose a major threat to the waterways.

Keywords: *Phosphates, soils, fertilizer, physic-chemical, NIHORT, Ibadan*

INTRODUCTION

Soil receives enormous quantities of fertilizers as an inevitable result of their application to crops. The importance of fertilizers in soil fertility and productivity has been established while its successful use in the increase of soil status and high yields cannot be overemphasized. These great benefits of fertilizers do not come without a cost. One such cost is environmental pollution.

Hera, (1996) observed that only a fraction of the fertilizer applied to the soil is taken up by the crop, the rest either remains in the soil or is lost through leaching, physical wash-off, fixation by the soil or release to the atmosphere through chemical and microbiological process. The degradation and eventual fate of these fertilizers on soil have been an environmental concern in recent years.

One major component of fertilizer and a limiting nutrient for plant growth, phosphorus (P), has been pinpointed as the major culprit in environmental problems. Akinrinde, (2006) stated that P is necessary for root development and cell division in plants and is not quantitatively used in large amounts as the other essential nutrient elements: nitrogen (N) and potassium (K). But the relative poor utilization of P by individual crops and fixation-immobilization phenomena in the soil are some of the factors which have prompted attention of scientist and farmers towards the most efficient management of fertilizer application.

When phosphorus is applied as fertilizer, it leaches from the soil through the different profiles into the water table and presents potential hazard to surface water quality. This is evident in the identification of agricultural non-point pollution sources including run-offs, as a major source of stream and lake contamination that prevents the attainment of water quality goals.

Cho, (2003) confirmed this by stating that the water quality of stream and lakes has not been improved significantly though the installation of water treatment equipment at point sources of pollution has been promoted.

This means that the effect of agricultural non-point sources such as; run-offs on the water environment has not been evaluated properly.

McDowel et al (2003) in his study of effect of stimulated cattle treading on soil infiltration rate and macro porosity and the consequent loss of soil and phosphorus via overland flow in New Zealand showed that treading caused an increase in the phosphorus fractions in the grassland soils while decrease in the amount of phosphorus concentration was observed in the cultivated soil. In this study, they also noted that mobile inorganic ions such as $\text{NH}_4^+\text{-N}$ and $\text{NO}_3\text{-N}$ are removed more quickly than immobile inorganic such as P.

Over application of fertilizers to soils and phosphorus run-off from farmlands subsequently increase phosphorus concentration in surface waters, and this leads to eutrophication- a major environmental problem (Penn et al., 2005; Saleque et al., 2004).

This environmental problem has led to the need for;

- i. Identification of threshold levels for soil phosphorus above which the potential enrichment of phosphorus in run-offs exceeds agronomic benefits.
- ii. Strategies to balance input and output of phosphorus.
- iii. Criteria to target primary sources of phosphorus for cost effective remedies.

The overall objective of the study is to have a greater understanding of the dynamics of phosphorus in the soil. Specifically, the accumulation of P in fertilized soil of a farmland, and the impact on their soil nutrients are focused.

Its environmental impact on site that has received long time application of fertilizers in comparison with a site that has been cultivated but not fertilized and a virgin site, that has neither been fertilized nor cultivated.

METHODOLOGY

Description of Sampling Sites

All the soil samples used in this study were collected from National Horticulture Research Institute (NIHORT). The study area is located within longitudes 3⁰50' and 3⁰52' E and latitudes 7⁰23' and 7⁰25'N. It is situated on 350 hectares of land in rainforest zone at Jericho Reservation Area, Idi-Ishin, Ibadan. NIHORT is located in the rainforest zone of Nigeria and has a tropical, humid climate. It has been an experimental centre for over three decades, known for growing fruits and vegetables in very large quantities for commercial and research purposes.

Sampling

A total of twelve soil samples were collected from six different locations in NIHORT and coded as follows: Citrus Fertilized Topsoil (CFT), Citrus Fertilized Subsoil (CFS), Citrus Unfertilized Topsoil (CUT), Citrus Unfertilized Subsoil (CUS), Fadama Unfertilized Topsoil (FUT), Fadama Unfertilized Subsoil (FUS), Fadama Fertilized Topsoil (FFT), Fadama Unfertilized Topsoil (FUT), Fadama Fertilized Subsoil (FFS), Pineapple Plot Topsoil (PPT), Pineapple Plot Subsoil (PPS), Fallow Topsoil (FT), Fallow Subsoil (FS).

Each of the site location was divided into three strata. From each stratum, samples were collected using clean soil auger at depth of 0-15cm for the top soils and 15-30cm for the subsoils.

Physico-chemical analysis of soil samples

One gram of each pre-weighed soil sample was dissolved in 20 ml of the prepared acid mixture. To increase the solubility, the sample solution was heated on hot plate until the volume was reduced to 3ml. Then, the solution was cooled and filtered into 25 ml volumetric flask using Whatman 42 filter paper. The filtrate was diluted up to the mark of distilled water. Parameters determined include: Particle size, pH organic matter, cation exchange capacity and Free iron (Fe₂O₃), and phosphate.

Determination of Phosphates

Fractions of Total phosphorus, Inorganic Phosphorus and Organic Phosphorus were extracted from the soil samples using ignition/sulphuric acid method. The extracts were determined using ascorbic acid calorimeter method (Bray's No. 1) at a wavelength of 880nm.

RESULTS AND DISCUSSION

The total, inorganic and organic phosphate levels in samples are shown in tables 1 to 3 respectively, while the result of physicochemical parameter of the soil is shown in table 4. Fractionation of soil inorganic phosphate is shown in table 5. Result of recovery study of inorganic and inorganic phosphate is shown in tables 6 and 7.

Table 1. Total Phosphate levels in samples

Sample	Absorbance	PO ₄ P(mg/kg ⁻¹)
CUS	0.257	185.6
CUT	0.120	86.6
CFS	0.611	441.2
CFT	0.587	423.9
FS	0.334	241.2
FT	0.643	464.4
FUS	0.636	459.3
FUT	0.649	468.7
FFS	0.587	423.9
FFT	0.731	527.9
PPS	0.161	116.2
PPT	0.264	170.6

Data in Table 1 shows that the soils investigated contain a significant amount of phosphorus irrespective of the crops grown and the fertilization period of the soil. From the table, the highest Total Phosphate (TP) value of 527.9mgkg⁻¹ was found in FFT, while the lowest value of 86.6mgkg⁻¹ was observed in CUT. The high value in FFT could be attributed to the use of inorganic fertilizers on the soil, in addition to alluvial deposits along the banks of River Ona which runs through the institute. High TP in FFT may have been as a result of high soil moisture since the soil is usually under high water table. The lowest value found in CUT, was expected because the soil has never received fertilizers but has been under cultivated for more than three decades.

All Fadama soils (FUS, FUT, FFS, and FFT) have very high TP values ranging from 423.9mgkg⁻¹ to 527.9mgkg⁻¹. This could be attributed to the various crops- maize, garlic, onions, pumpkin leaves grown on these soils. Data compiled by Withers and Bailey (2003), indicates that a significant proportion of maize on fields receive slurry in excess of that recommended under codes of good agricultural practice thus an increase in soil P status.

All top soils (0-15cm), except the citrus group (CUS, CUT, CFS, CFT), had a higher phosphate value than its corresponding subsoil (15-30cm). For instance, PPT had a TP value of

170.6mgkg⁻¹ while PPS had its value as 116.2mgkg⁻¹. The decreases in TP values from top to subsoils indicate movement of phosphates through the soil profile. If the movement of P through the soil profile is allowed to continue, there is a possibility of P being exported to the waterways adjacent to the site of application and hence it may contribute to enhanced eutrophication of the waterways. The exception of the citrus group from a higher topsoil TP value than its corresponding subsoil could be as a result of so many factors, one of which is the method of application of the fertilizer. This comes into play since a given fertilizer placement method does not function the same way on different soils, in different years, crops and locations (McConnell et al., 1986).

Fallow topsoil (FT) had a TP value of 464.4mgkg⁻¹ almost twice the value of its subsoil (FS) 241.2mgkg⁻¹. This indicates movement of P from fertilized soils into the unfertilized and uncultivated soils with higher accumulation in the topsoil. There is considerable evidence worldwide that the net concentration of soluble P in runoff rises with accumulation of P in soils (McDowell et al., 2003).

Table 2. Total Phosphate levels in samples

Sample	Absorbance	PO ₄ P(mg/kg ⁻¹)
CUS	0.168	117.7
CUT	0.108	78.0
CFS	0.596	430.4
CFT	0.537	387.8
FS	0.237	171.1
FT	0.525	379.1
FUS	0.490	353.8
FUT	0.640	462.2
FFS	0.575	415.2
FFT	0.707	510.6
PPS	0.137	98.9
PPT	0.185	133.6

Table 2 shows the Inorganic Phosphate (IP) values for all the soils investigated. CUT also had the lowest value of 78.0mgkg⁻¹ while FFT had the highest value of 510.6mgkg⁻¹ as in the total phosphates. Generally, the IP values are higher than the Organic Phosphates (OP) values in table 3. This could be due to the fact that the sample locations are not close to residential areas or market places where there is the likelihood of direct dumping of waste products containing high levels of OP.

However, the high IP values indicate frequent use of inorganic fertilizers and other agricultural chemicals. OP can be increased by implementation of cultivation practices which increase soil organic matter and as a result OP (Sharpley and Smith, 1985). Vanoverstraeten and Hanotiaux (1996) stated that a higher soil OP value is more environmentally friendly than soil IP.

Table 3. Organic Phosphate levels in samples

Sample	PO₄.P(mg/kg⁻¹)
CUS	67.9
CUT	8.6
CFS	10.8
CFT	36.1
FS	70.0
FT	85.2
FUS	105.4
FUT	6.5
FES	8.6
FFT	17.3
PPS	17.3
PPT	37.0

Table 4. Result of physicochemical parameters of soil samples

Sample	pH	OC (g/kg)	Ca (cmol/kg)	Mg(cmol/kg)	K(cmol/kg)	Na	Al	Acidity (cmol/kg)	ECEC(cmol/kg)	Fe (mg/kg)	Clay%	Silt%	Sand%
FT	6.3	20.73	10.83	6.75	1.44	0.97	0.00	0.35	20.16	1,275.63	9.4	21.4	69.2
FS	5.9	14.04	9.70	5.38	1.28	0.74		0.55	19.65	1,086.16	3.4	25.4	71.2
CFT	6.2	18.36	12.19	6.93	1.59	1.06		0.30	22.07	1,393.52	5.4	9.4	85.2
CUT	5.9	8.46	10.01	6.11	1.53	0.81		0.25	18.71	1,510.09	9.4	5.4	85.2
CUS	5.7	13.86	9.14	5.92	1.62	1.00		0.25	17.92	1,459.29	7.4	7.4	85.2
CFS	6.2	29.34	12.76	7.12	1.65	1.01		0.20	22.74	1,265.37	9.4	7.4	83.2
FFT	5.8	30.06	10.68	6.55	1.61	0.89		0.25	19.94	1,368.04	13.4	25.4	61.2
FUT	5.2	31.14	9.82	6.01	1.53	0.82		0.30	18.48	1,318.61	3.4	25.4	71.2
FUS	5.6	16.90	8.30	5.56	1.42	0.72		0.20	16.20	1,138.47	11.4	21.4	67.2
FFS	5.9	14.40	10.81	6.08	1.56	0.97		0.15	19.57	1,301,20	17.4	23.4	69.2
PPT	5.6	12.42	8.73	5.47	1.36	0.78		0.15	16.49	1,650.03	9.4	5.4	65.2
PPS	5.3	6.30	10.60	6.44	1.53	0.87		0.30	19.74	1,577.64	7.4	3.4	89.2

OC = Organic Carbon, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, Al = Aluminium,

Table 5. Fractionation of soil inorganic phosphates

Samples	Saloid bound	Al bound	Fe bound	Ca bound	Reductant soluble
CFT	0.267	0.061	0.055	0.232	0.054
CFS	0.294	0.061	0.102	0.217	0.058
FUT	0.008	0.046	0.064	0.134	0.043
FUS	0.020	0.009	0.001	0.146	0.041
CUT	0.060	0.060	0.064	0.057	0.037
CUS	0.010	0.010	0.005	0.006	0.048
FFT	0.029	0.010	0.011	0.143	0.052
FFS	0.011	0.022	0.011	0.166	0.067
FS	0.105	0.026	0.021	0.170	0.057
FT	0.020	0.023	0.010	0.043	0.049
PPT	0.007	0.063	0.033	0.002	0.031
PPS	0.039	0.011	0.011	0.039	0.067

Result of physico-chemical parameters of soil samples used in the PO₄-P experiment are listed in Table 4. The soils used had a range of pH from 5.2 to 6.3 with average of 5.8. FUT had the lowest pH while FT had the highest pH. The pH values were relatively uniform. This is important since pH can have a strong effect on the charge properties of soils as well as the solubility of Al and Fe, which can influence P behaviour (Penn et al., 2005). The variation in clay content among soils indicates that FS and FUT possessed the lowest clay content, FFT had the highest while FT, CUT, CFS, PPT had intermediate clay content. One exception of this was FFS, which had a much higher percentage of clay (17.4%) than the other soils. This may be due to the fact that this soil was collected from a region of high water table and a steep slope and much of the topsoil may have been eroded leaving the subsoil exposed.

The results obtained for the Fe oxides properties of the soil samples were very high, between 1,086.16mgkg⁻¹ and 1,650.03mgkg⁻¹ inclusive. Penn et al. (2005) suggests several possibilities for these extremes:

- Some co-correlation could exist between Fe and other minerals which accounts for their varying values.
- The high surface area of certain minerals like Fe oxides could play a major role in the high Fe oxide values.

The acidity of these soils ranged from 0.15cmolkg⁻¹ to 0.50cmolkg⁻¹ with an average of 0.27cmolkg⁻¹. FT and FS showed an increase in acidity with soil depth having 0.35cmolkg⁻¹ and 0.55cmolkg⁻¹ respectively. With the exception of CUT and CUS that had the same acidity level (0.25cmolkg⁻¹), the other soil samples decreased with soil depth when compared with their corresponding analogue. For instance, CFT had an acidity of 0.30cmolkg⁻¹ while CFS had an

acidity of 0.20 cmolkg^{-1} . FFT had 0.25 cmolkg^{-1} while FFS had 0.15 cmolkg^{-1} . The decrease in acidity with soil depth indicates that this property of soil did not move deeper into the soil profile. This reduction in acidity observed in the lower soils is good especially considering its environmental implications.

Table 6. Result of recovery study of inorganic phosphate

Samples	Initial Concentration	Spiked Concentration	Final Concentration	%Recovery
FFT	510.6	200	708.33	98.87
			695.50	92.45
			686.20	87.80
			702.00	95.20
			700.00	94.70
CUT	78.0	100	173.33	95.33
			171.17	93.17
			171.17	93.17
			170.44	92.44
			167.56	89.56

Average % Recovery of FFT = 93.8%

Average % Recovery of CUT = 92.7%

Table 7. Result of recovery study of total phosphate

Samples	Initial Concentration	Spiked Concentration	Final Concentration	%Recovery
FFT	529.9	200	718.75	
			718.78	
			711.81	
			725.70	
			725.20	
CUT			179.83	93.23
			184.88	98.29
			178.38	91.79
			182.72	96.12
			178.38	91.79

Average % Recovery of FFT = 96.1%

Average % Recovery of CUT = 94.2%

CONCLUSION

It can be deduced from the study that the examined soils are polluted anthropogenically. This is so because there is a significant amount of phosphates on all soils, even those that have neither been cultivated nor fertilized. P distribution in soil profiles should be monitored often in order to assess the risk of P leaching. The use of inorganic fertilizers and other management practices which introduce phosphates should be reduced.

The concept of maintenance fertilization can also be imbibed. This concept refers to P fertilizer applications to compensate for crop removal of P from soils considered sufficiently high in P to the extent that the soils do not require a P fertility build -up.

Finally, further research into the status of the soils should be carried out. This would contribute to further identification of the measurable fraction of soil P in relation to P dynamics in the soil and with the soil type.

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