



Speciation and dynamics of phosphorus in some organically amended soils of southwestern Nigeria

A. O. Soremi, M. T. Adetunji, J. O. Azeez, C. O. Adejuyigbe & J. G. Bodunde

To cite this article: A. O. Soremi, M. T. Adetunji, J. O. Azeez, C. O. Adejuyigbe & J. G. Bodunde (2017) Speciation and dynamics of phosphorus in some organically amended soils of southwestern Nigeria, *Chemical Speciation & Bioavailability*, 29:1, 42-53, DOI: [10.1080/09542299.2017.1287549](https://doi.org/10.1080/09542299.2017.1287549)

To link to this article: <https://doi.org/10.1080/09542299.2017.1287549>



© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 02 Feb 2017.



Submit your article to this journal [↗](#)



Article views: 1087



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 4 View citing articles [↗](#)

Speciation and dynamics of phosphorus in some organically amended soils of southwestern Nigeria

A. O. Soremi^a, M. T. Adetunji^a, J. O. Azeez^a, C. O. Adejuyigbe^a and J. G. Bodunde^b

^aDepartment of Soil Science and Land Management, Federal University of Agriculture, Abeokuta, Nigeria; ^bDepartment of Horticulture, Federal University of Agriculture, Abeokuta, Nigeria

ABSTRACT

Availability of soil phosphorus (P) is a function of its dynamics and can be improved by using organic amendments. Experiments were carried out to determine the effect of poultry manure (PM) on soil P fractions and bioavailability to soybean (*Glycine max*). Soils from ten farmers' fields in Southwest Nigeria, were used for incubation and pot experiments. Treatments were five rates of PM (0, 2.5, 5.0, 7.5 and 10 t ha⁻¹). Triplicate units in incubation and pot experiments were arranged in Completely Randomised Design. Soybean was grown for three consecutive growth cycles of seven weeks each and soil samples were analysed for Saloid P, Al-P, Fe-P, Ca-P, occluded P, reductant soluble P, and residual P. Results indicated that Fe-P was the dominant active inorganic P in the soils while residual P was the dominant inactive inorganic-P in most of the soils. In the pot experiment, application of poultry manure significantly increased organic P in the soils in the first growth cycle, but decreased slightly in second growth cycle. Highest and lowest ($P \leq 0.05$) organic P values were observed in soil samples from Ayetoro and Odeda, respectively. In the pot experiment, application of PM reduced P fixation and occluded P fraction in the soils. There was general increase in available P in most of the soils considered despite increase or decrease in other forms of P. Poultry manure reduced the fixation of P and release of occluded phosphorus. Generally, Poultry manure significantly improved soil P fractions and plant P tissue concentrations.

ARTICLE HISTORY

Received 20 July 2016
Accepted 24 January 2017

KEYWORDS

Phosphorus speciation;
dynamics; bioavailability;
southwest Nigeria

1. Introduction

One of the problems of crop production in the tropics is that tropical soils have low fertility status [1]. The soils are highly weathered and leached, low in organic matter and available nutrients, thus leading to low productivity within few years of cultivation [2,3]. Applying inorganic fertilizer is one of the widely accepted ways of increasing soil nutrients both in the temperate and tropical zones of the world. However, long term studies have shown that there is a limit to which inorganic fertilizer can sustain the productivity of intensely cultivated soil. This is because of problem of decrease in yield with time, enhancement of soil acidity, leaching losses, and degradation of soil physical and organic matter status [4,5]. Thus, there is an increase in studies on organic wastes as alternative fertilizers.

Organic wastes provide a continuous decomposing substrate and consequent gradual input of soil organic matter, thereby increasing soil nutrients and improving the soil physical properties. Combination of both organic and inorganic fertilizers has been recommended for the soil in order to sustain crop production and soil fertility [6,7].

Phosphorus has been widely observed as one of the yield limiting nutrients of crops in Nigerian soils [8–13]. The limitation is due to the inability of cultivated crops to achieve their full yield potential without sufficient P in the soil. Unfortunately, P does not occur as abundantly in soils as N and K. The total concentration in surface soils varies between 0.02 and 0.10% [8]. Unfortunately, the quantity of total P in soils has little relationship to the availability of P to plants [13–15]. In all its forms, including organic forms, P is very stable or insoluble, and only a very small proportion exists in the soil solution at a time due to its interactions with many soil chemical constituents. Therefore understanding the relationships and interactions of the various forms of P in soils and the numerous factors that influence P availability is essential for efficient P management [14,16].

The total inorganic phosphorus is divided into active and inactive forms. The former consists of Fe-P, Al-P, and Ca-P and the latter consists of occluded P, reductant soluble P and residual P [17]. The active forms are the fractions most available to plants. Active fraction refer to the fraction of P that is labile; those that could be taken up by crops if the soil condition is changed and favourable

Table 1. Descriptions of sites of the soils used for the study.

Location	State	Longitude	Latitude	Soil Order
Abeokuta	Ogun	N 7° 14.30'	E 3° 26.21'	Alfisol
Odeda	Ogun	N 7° 14.17'	E 3° 31.79'	Alfisol
Ayetero	Ogun	N 7° 15.00'	E 3° 30.00'	Alfisol
Ibadan	Oyo	N 7° 30.17'	E 3° 54.50'	Alfisol
Ikenne	Ogun	N 6° 50.95'	E 3° 42.57'	Alfisol
Badagry	Lagos	N 6° 25.00'	E 2° 55.00'	Entisol
Okemesi	Ekiti	N 7° 49.00'	E 4° 55.00'	Alfisol
Omu Ijebu	Ogun	N 6° 47.00'	E 3° 52.00'	Alfisol
Imeko	Ogun	N 7° 13.76'	E 3° 25.20'	Ultisol
Igboora	Oyo	N 7° 26.00'	E 3° 17.00'	Alfisol

but the inactive forms are the recalcitrant form of P in the soil. The inactive fraction does not necessarily correlate with soil uptake.

The supply of phosphorus to plants in soil is particularly governed by the content of active inorganic P and organic fractions. In tropical soils, organic P fractions contribute substantially to available phosphorus reserves following mineralization [18]. Organic P originates from soil organic matter, crop residues and different manures following decomposition and mineralization by soil microorganisms. Total organic P decreases steadily in continuous cropping situation without P fertilization [19]. Phosphorus tends to increase with soil age, particularly the recalcitrant species of soil P. In acidic soils for example, continuous application of P leads to the accumulation of Fe and Al-P [17], though the duo may not be available for plant uptake temporarily depending on soil pH. The vast majority of soil organic P occurs in relatively stabilized forms and not rapidly mineralized.

Although total P may give a total reserve of the nutrients in the soil, it is a poor indicator of the availability level since most of the P may be fixed or unavailable to the plant. Phosphorus status in soil is therefore assessed more from the relative abundance of different forms. Equally important is how they change with time. Most studies in the past concentrated on effects of organic manures on yields and other observable plant growth parameters as they are influenced by soil available P fractions. There is still need to examine the contributions and effects of other P fractions to their available fractions and their effects on agronomic parameters. The objective of this study is to evaluate changes in soil inorganic and organic P species as a result of poultry manure application.

2. Materials and methods

The study involved laboratory, screen house pot and field experiments.

2.1. Laboratory experiments

The laboratory experiments consisted of soil physical and chemical analysis, phosphorus fractionation experiments and incubation experiment. Surface soil samples

(0–20 cm depth) were collected from ten different locations as indicated in Table 1. These included soil samples from Abeokuta, Odeda, Ayetero, Ibadan, Ikenne, Badagry, Okemesi, Omu Ijebu, Imeko and Igboora. Soil samples were air dried, and sieved using a 2 mm sieve. Each of these soils was used for laboratory physical and chemical analysis, incubation studies, and phosphorus fractionation.

2.2. Soil physical and chemical analysis

Particle size distribution was determined by the hydrometer method [20]. Soil pH was determined in 1:1 (soil-water ratio) using pH glass electrode attached to a pH meter [21]. Nitrogen was determined by Kjeldahl method [21]. Organic matter was determined by the chromic acid wet digestion method [22]. Exchangeable sodium, potassium, calcium and magnesium in the soils were extracted with neutral ammonium acetate (1M NH₄OAc). Extracted K and Na were determined by flame photometry while Ca and Mg were determined by atomic absorption spectrophotometry [23]. Available phosphorus was determined by Bray 1 extraction method and analysed colorimetrically by molybdenum blue procedure [24]. Titrable acidity was extracted with KCl solution and determined by titration with 0.1N sodium hydroxide solution [25]. Effective cation exchange capacity was determined by summation of exchangeable cations and exchangeable acidity.

2.3. Phosphorus fractionation study

Phosphorus fractionation procedure was according to procedures of Chang and Jackson [17], however, the methods of Peterson and Corey [26] were used to determine different forms of inorganic P (Saloid P, Al-P, Fe-P, Ca-P, occluded P, reductant soluble P, and residual P) in the soils. This involved sequential extraction of 1.0 g soil with 50 ml of 1 M NH₄Cl, 0.5 M NH₄F, 0.1 M NaOH, and 0.25 M H₂SO₄. The extraction is a sequential procedure, where 50 ml of the solutions were added to the same soil (1g) in succession. The soil solution mixtures were shaken for 16 hours at 20°C. At each time, the solutions are then filtered and the filtrate analysed for their P content. The different fractions of P were determined in all the samples taken from soils before and after organic amendment for incubation in the laboratory and pot experiments. Organic P was determined by ignition method [22,27]. Total P was determined as the summation of all inorganic P fractions (Saloid P, Al-P, Fe-P, Ca-P, occluded P, reductant soluble P, and residual P) and organic P. Saloid means loosely-bound P, occluded P means P occluded in Fe/Al oxides, reductant soluble means P extracted by citrate-dithionite-bicarbonate while residual P means P from the soil residue remaining after the last acid extraction which was digested

Table 2. Some initial physico-chemical properties of the soils used in this study.

Soil	Sand	Silt	Clay	Textural	pH	Organic C	Available P	N	Ca	Mg	K	Na	E A	ECEC
Location	g kg ⁻¹			Class	H ₂ O	g kg ⁻¹	mg kg ⁻¹	g kg ⁻¹	cmol kg ⁻¹					
Abeokuta	772.0	88.0	140.0	LS	6.3	29.0	12.7	1.7	1.88	1.25	0.34	0.29	0.10	3.86
Odeda	912.0	28.0	60.0	S	6.1	24.0	9.8	1.6	0.80	1.21	0.17	0.13	0.11	2.42
Ayetoro	872.0	48.0	80.0	S	6.2	40.8	27.0	3.3	3.25	1.32	0.43	0.30	0.10	5.40
Ibadan	852.0	68.0	80.0	LS	6.3	8.8	17.5	1.0	1.13	1.19	0.28	0.17	0.09	2.86
Ikenne	772.0	88.0	14.00	LS	6.2	26.4	10.6	2.3	1.25	1.20	0.28	0.16	0.10	2.99
Badagry	912.0	28.0	60.0	S	4.8	33.6	39.2	2.0	0.40	1.10	0.13	0.14	0.81	2.58
Okemesi	872.0	118.0	80.0	S	6.3	21.6	11.0	1.5	1.23	1.22	0.27	0.24	0.10	3.06
Omu Ijebu	820.0	72.0	108.0	LS	5.8	21.5	16.1	1.1	1.68	1.20	0.14	0.10	0.30	3.12
Imeko	762.0	60.0	178.0	SL	6.1	28.0	15.4	2.1	1.90	1.26	0.40	0.15	0.20	3.91
Igboora	880.0	52.0	68.0	LS	6.2	21.0	13.3	1.6	1.60	1.10	0.23	0.11	0.14	3.18
Mean	842.6	65.0	86.8		6.0	25.5	17.2	1.8	1.51	1.21	0.27	0.18	0.21	3.34
SD	57.6	28.2	45.7		0.5	8.5	9.2	0.7	0.77	0.07	0.10	0.07	0.22	0.87

Note: LS – Loamy sand; S – Sand; SL – Sandy loam; SD – Standard deviation; EA – Exchangeable acidity; ECEC – Effective Cation Exchange Capacity.

Table 3. Some chemical properties of the poultry manure used.

Parameter	Value (g kg ⁻¹)
Nitrogen	23.6
Phosphorus	14.9
Potassium	14.2
Calcium	4.3
Magnesium	1.8
Iron	7.0
Sulphur	5.7
Organic carbon	128.4
C:N	5.44

with H₂SO₄/H₂O₂ at 360 °C. Available phosphorus was determined by Bray 1 extraction method and all the P fractions were analysed colorimetrically by molybdenum blue procedure [24].

2.4. Pot experiments

The pot experiments were carried out at research farm of Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. Soil samples from five locations out of the ten locations used for the incubation experiment were used for the experiment. These included soil samples taken from experimental farms in Abeokuta, Odeda, Ayetoro, Ibadan and Ikenne. Five kilogrammes of soil samples already air-dried and sieved through 2 mm sieve was weighed into each pot. Each pot was taken as an experimental unit. The treatments consisted of five rates of organic manure (poultry manure) at 0, 2.5, 5, 7.5 and 10 t ha⁻¹ in three replicates and 100 kg ha⁻¹ of NPK 20:10:10 fertilizer as basal application for all treatments. The experimental design was completely randomised block design. The poultry manure was incorporated into the soil two weeks before sowing of soya bean seeds. The variety of soya beans used was TGX 1448-2E. Three seeds per pot were sown, but were thinned to 2 seedlings after 2 weeks of germination. The soya bean plants were grown for 3 growth cycles at 7 weeks per growth cycle. Plant height and dry matter yield were determined in each growth cycle (Agronomic data not reported). Plant samples were taken and analysed at the end of each growth cycle to determine the plant P concentrations. Plant shoots were oven dried at 65 °C for 48 hours

to constant weight and dry matter yield was determined. Plant samples were ground with electric grinder with stainless steel grinding chamber. Total P in the plant samples were determined as follows: the plant samples were ashed in a muffle furnace at a temperature of 450 °C. The nutrients in the ash were extracted by washing with 0.1 N HCl. Phosphorus was determined colorimetrically by the vanadomolybdate method by measuring the absorbance of the sample colours with a spectrophotometer at a wavelength of 880 nm.

2.5. Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) using GENSTAT software. Means were separated by Duncan Multiple Range Test at 5%.

3. Result and discussion

3.1. Some initial physico-chemical properties of soils and the manure used for experimentation

The initial physico-chemical properties of soils used before application of manure treatment in the experiments are shown in Table 2. Five of the soils were loamy sand, four soils were sandy and one was sandy loam. The values of pH ranged from 4.8 to 6.3. Organic carbon ranged from 8.8 to 40.8 g kg⁻¹. Available P was highest in Badagry soil (39.2 mg kg⁻¹) and least in Odeda soil (9.80 mg kg⁻¹). Generally, the cations order of abundance was: Ca > Mg > K > Na, except in Odeda where it was in order of Mg > Ca > K > Na and Badagry where it was in order of Mg > Ca > Na > K. The values of ECEC ranged from 2.42 cmol kg⁻¹ (in Odeda soil sample) to 5.40 cmol kg⁻¹ (in Ayetoro soil sample). Generally, the soils were moderately acid, high in organic matter and moderately high in total nitrogen. The texture of the soil (sand content) could indicate that soil nutrients could be leached and the subsequent low soil fertility. The available P in the soils were very low while the exchangeable cations were also very low. The low P implies that the soils response to P application is feasible. However, P have been reported low for southwestern Nigerian soils [8–13]. Generally, the

Table 4. Initial phosphorus fractions of the soils used in the study.

Location	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
Abeokuta	24.22	19.22	63.82	26.44	94.44	70.74	121.33	115.32	535.53	12.70
Odeda	30.58	16.21	17.83	3.61	92.86	126.36	110.12	82.71	480.28	9.85
Ayetoro	34.07	9.51	12.91	9.68	60.78	64.54	70.67	123.63	385.79	26.99
Ibadan	25.68	21.33	69.10	52.88	106.16	57.36	50.38	110.92	493.81	17.45
Ikenne	35.10	11.42	14.52	10.34	56.43	41.96	92.08	112.65	374.50	10.60
Badagry	27.91	13.67	16.59	1.54	85.73	22.45	66.29	90.32	324.50	12.15
Okemesi	20.32	6.17	20.57	9.68	21.66	48.06	33.42	120.41	280.29	11.02
Omu Ijebu	20.53	12.55	47.32	14.18	30.16	45.86	108.08	125.68	404.36	16.06
Imeko	25.86	10.53	35.90	14.30	80.51	25.77	95.49	98.64	387.00	15.43
Igboora	17.38	5.97	27.18	8.24	12.20	32.60	128.99	101.53	334.09	13.25
Mean	26.17	12.66	32.57	15.09	64.09	53.57	87.69	108.18	400.02	14.55
SD	5.89	5.11	20.81	14.91	32.28	30.06	31.48	14.44	80.99	5.02

Note: SD-Standard deviation.

Table 5. Effects of organic manure application on phosphorus fractions and Bray 1 P of soils of Abeokuta and Odeda at 6 WAI.

Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
<i>Abeokuta</i>										
0	22.54 a	18.26 a	33.19 a	23.45 a	127.86 a	67.92 a	79.72 b	131.49 a	504.43 a	22.36 c
2.5	12.29 b	6.58 b	13.83 b	2.36 c	120.60 a	33.20 b	93.28 ab	148.96 a	431.10 b	22.20 c
5	18.37 ab	1.58 d	13.66 b	2.12 c	123.83 a	20.25 c	108.40 a	168.38 a	456.59 ab	26.35 b
7.5	22.99 a	4.22 c	16.14 b	14.30 b	128.91 a	36.00 b	114.15 a	160.62 a	497.33 a	30.72 a
10	24.73 a	2.53 cd	16.38 b	14.71 b	71.88 b	12.95 c	93.28 ab	170.54 a	407.00 b	33.83 a
<i>Odeda</i>										
0	7.52 d	10.24 a	15.39 ab	9.36 a	78.43 a	50.26 b	80.25 b	92.46 b	343.91 ab	14.88 c
2.5	13.02 c	5.05 b	11.44 b	9.56 a	29.46 b	30.95 c	62.88 c	136.94 a	299.30 b	19.99 bc
5	14.90 bc	6.03 b	16.94 a	9.04 a	12.64 c	72.00 a	63.25 c	147.90 a	342.70 ab	26.73 b
7.5	18.80 ab	5.05 b	15.25 ab	8.48 a	10.50 c	54.10 b	107.02 a	160.07 a	379.27 a	36.62 a
10	22.42 a	6.41 b	12.49 ab	8.90 a	6.33 c	56.80 ab	94.48 ab	164.42 a	372.25 a	39.40 a

Note: Means in a column followed by the same letters are not significantly different at 5% probability level.

soil values for fertility indicators is low [8–13]. In Table 3, it was shown that the poultry manure used for the trial was relatively higher in N, while the P and K content were similar. The cations were moderate while the CN ration is favourable for microbial mineralization of the manure nutrients.

3.2. Initial phosphorus fractions of soils used

The initial phosphorus fractions of the ten soil samples collected from different locations are shown in Table 4. The results indicated that the initial phosphorus fractions of the soil is dominated (about 25%) by the organic pool. This is followed by residual P and least in Al-P. The organic P pool has however, been reported to replenish other P pools in the soil upon depletion [18]. The available P is only about 3.5% of the total soil P, indicating that large pool of P in the soil is not captured by the popular P availability index (Bray -1 P). As reported earlier, the quantity of total P in soils has little relationship to the availability of P to plants [13–15], this is clearly evident in the relative proportions of the soil P species. Generally in the soils the P forms are in the order: Organic P > residual-P > occluded-P > reductant-P > Fe-P > saloid-P > Ca-P > Al-P. The trend observed is similar to that observed by [8,19]. The data also indicated that Alfisol had higher soil total P than Entisol and Ultisol.

3.3. Phosphorus fractions and available P in incubation study

Results obtained from Abeokuta soil incubation experiment are shown in Table 5. Phosphorus fractions were in this order of abundance: organic P > occluded P > residual P > reductant soluble P > saloid P > Fe-P > Ca-P > Al-P. Manure application had significant effects on all the phosphorus fractions except organic P. The highest organic P was obtained in treatment of 10 t ha⁻¹ with value of 170.54 mg kg⁻¹. However, total P at treatment rate of 0 t ha⁻¹ had the highest value. Highest Fe-P value of 33.19 mg kg⁻¹ was obtained at 0 t ha⁻¹ and lowest value of 13.83 mg kg⁻¹ was obtained at 2.5 t ha⁻¹. This showed that Fe-P was significant reduced by the manure treatment. Highest value of Al-P was obtained at 0 t ha⁻¹. This indicated reduction with treatment application. This shows that the application of manure in the soil reduced the amount of Al-P. This pool of P have been known to be readily unavailable for plant uptake [8]. Occluded P had highest reduction at 10 t ha⁻¹ with a value of 71.88 mg kg⁻¹ compared to control experiment with value of 127.86 mg kg⁻¹. Treatment had significant effect on Bray 1 P. It was highest at 10 t ha⁻¹ with value of 33.83 mg kg⁻¹. This showed 51.3% increase over control experiment with value of 22.36 mg kg⁻¹. Reductant soluble P decreased as treatment rate increased till 7.5 t ha⁻¹ while at 10 t ha⁻¹ it decreased again. Treatment did not

Table 6. Effects of organic manure application on phosphorus fractions and Bray 1 P of soils of Ayetoro and Ibadan at 6 WAI.

Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
<i>Ayetoro</i>										
0	28.67 ab	10.42 ab	28.44 c	14.40 b	73.58 bc	91.20 b	80.12 a	162.43 b	488.07 b	30.10 d
2.5	31.10 a	11.99 a	48.40 b	27.63 a	79.82 bc	42.85 d	63.74 c	206.86 ab	512.39 b	35.64 c
5	20.68 b	10.42 ab	92.26 a	17.17 b	54.65 c	91.15 b	69.57 bc	229.02 a	584.92 a	42.06 b
7.5	20.83 b	10.42 ab	35.88 c	27.10 a	86.10 ab	66.95 c	78.85 ab	236.90 a	563.03 ab	39.02 b
10	28.06 ab	6.94 b	34.60 c	12.39 b	115.51 a	125.45 a	83.19 a	224.34 a	630.48 a	51.34 a
<i>Ibadan</i>										
0	21.98 bc	18.21 a	72.96 a	4.25 a	29.41 c	57.20 a	80.12 a	110.87 b	395.50 b	33.92 a
2.5	17.07 c	11.05 bc	58.45 b	3.88 a	44.11 bc	15.67 b	67.06 b	142.45 ab	359.74 b	41.27 a
5	26.32 bc	5.37 cd	36.42 c	2.42 a	50.41 b	32.05 ab	52.11 c	170.97 ab	376.07 b	42.65 a
7.5	41.65 a	4.74 d	37.50 c	4.42 a	44.11 bc	18.55 b	46.59 c	176.58 a	374.14 b	40.07 a
10	34.13 ab	14.84 a	40.03 c	3.72 ab	92.41 a	48.40 a	71.20 ab	181.82 a	486.55 a	42.40 a

Note: Means in a column followed by the same letters are not significantly different at 5% probability level.

Table 7. Effects of organic manure application on phosphorus fractions and Bray 1 P of soils of Ikenne and Badagry at 6 WAI.

Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
<i>Ikenne</i>										
0	25.74 a	9.15 ab	11.43 c	3.28 b	45.70 a	38.54 b	48.51 bc	126.96 a	309.31 bc	19.66 c
2.5	29.79 a	10.73 a	4.34 c	3.60 b	33.62 bc	28.51 c	42.61 c	153.76 a	306.60 c	31.42 b
5	35.58 a	11.69 a	23.40 b	7.42 a	35.70 b	16.90 d	58.53 a	182.82 a	372.04 ab	44.14 a
7.5	36.16 a	11.36 a	47.33 a	6.36 a	12.62 d	43.30 b	54.56 ab	184.82 a	396.51 a	39.65 ab
10	31.60 a	5.43 b	25.62 b	8.92 a	26.81 c	56.25 a	56.67 ab	190.50 a	401.80 a	37.99 ab
<i>Badagry</i>										
0	7.47 b	10.14 a	32.80 ab	10.60 b	90.23 b	23.90 a	64.19 a	100.72 a	340.00 ab	43.77 a
2.5	9.97 b	4.33 b	42.88 a	35.63 a	129.84 a	17.45 b	56.49 ab	101.51 a	398.10 a	45.63 a
5	19.10 a	2.27 c	15.28 c	6.99 b	108.16 ab	19.15 ab	59.43 ab	112.97 a	343.44 ab	46.89 a
7.5	19.45 a	3.37 bc	20.80 bc	13.66 b	93.31 b	6.20 c	64.77 a	115.70 a	337.05 ab	46.18 a
10	19.82 a	4.19 bc	14.86 c	6.46 b	87.84 b	16.20 b	51.15 b	121.38 a	321.90 b	42.31 a

Note: Means in a column followed by the same letters are not significantly different at 5% probability level according to LSD.

Table 8. Effects of organic manure application on phosphorus fractions and Bray 1 P of soils of Okemesi and Omu Ijebu at 6 WAI.

Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
<i>Okemesi</i>										
0	13.79 b	5.26 a	17.44 c	1.91 d	18.34 a	30.77 b	29.50 b	110.15 b	227.16 b	21.82 c
2.5	15.94 b	4.32 a	18.28 c	2.65 d	16.71 a	5.65 c	40.78 b	112.26 b	216.59 b	34.04 b
5	67.94 a	4.86 a	42.88 a	11.44 a	24.11 a	37.15 b	39.92 b	129.64 ab	357.94 a	36.87 b
7.5	25.85 b	3.97 a	12.34 d	4.98 c	22.00 a	86.65 a	35.19 b	150.95 a	341.93 a	37.53 b
10	19.10 b	5.11 a	30.36 b	7.94 b	23.81 a	25.90 b	79.51 a	142.73 ab	334.46 a	47.92 a
<i>Omu-Ijebu</i>										
0	23.84 a	6.78 a	38.06 a	16.31 a	34.21 b	32.65 a	97.11 a	175.02 a	423.98 ab	18.95 a
2.5	21.85 a	7.41 a	29.5 b	17.36 a	46.41 a	90.55 b	83.70 ab	183.94 a	480.72 a	20.45 a
5	11.20 b	9.78 a	12.78 c	4.22 b	46.9 a	47.25 b	47.60 d	202.27 a	382.00 b	20.12 a
7.5	10.05 b	8.59 a	9.76 c	5.82 b	44.32 a	42.20 b	61.15 cd	201.32 a	383.21 b	20.41 a
10	9.34 b	9.38 a	12.08 c	13.24 a	51.12 a	34.52 b	71.35 bc	205.85 a	406.88 ab	22.20 a

Note: Means in a column followed by the same letters are not significantly different at 5% probability level according to LSD.

Table 9. Effects of organic manure application on phosphorus fractions and Bray 1 P of soils of Imeko and Igboora at 6 WAI.

Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									
	Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	Bray 1 P
<i>Imeko</i>										
0	19.19 b	4.60 a	13.16 b	9.74 a	48.26 bc	10.88 ab	64.43 b	108.91 a	279.17 abc	28.76 c
2.5	14.79 b	1.84 b	19.74 a	5.76 b	24.63 d	6.20 b	64.92 b	111.58 a	249.46 c	31.96 c
5	20.25 b	2.32 b	10.40 b	4.78 bc	75.62 a	7.75 b	82.37 a	110.77 a	314.26 ab	58.43 a
7.5	52.14 a	3.09 ab	12.70 b	4.20 c	34.61 cd	8.45 b	36.63 c	124.72 a	276.54 bc	48.58 b
10	54.00 a	4.18 a	11.76 b	5.62 b	51.82 b	19.25 a	45.78 c	127.84 a	320.25 a	53.55 ab
<i>Igboora</i>										
0	29.16 b	3.17 b	9.56 a	3.78 b	51.21 a	39.25 a	58.83 b	110.59 a	305.55 a	18.67 c
2.5	50.41 a	3.28 b	12.50 a	4.35 b	19.50 b	28.55 b	72.49 a	130.82 a	321.90 a	35.06 b
5	34.47 b	2.98 c	11.72 a	6.74 a	21.20 b	13.55 c	73.78 a	139.36 a	303.80 a	41.49 ab
7.5	31.89 b	4.34 ab	9.82 a	6.09 a	17.11 b	11.25 c	71.22 a	122.83 a	274.55 a	47.96 a
10	36.48 ab	5.76 a	8.92 a	4.14 b	19.52 b	29.80 b	69.22 a	134.75 a	308.59 a	46.45 a

Note: Means in a column followed by the same letters are not significantly different at 5% probability level according to LSD.

have significant effect on organic manure despite relative increase with the rate of treatment. Inorganic P is 66.03% of the total P and organic P was 33.97% of total P.

The results of phosphorus fractionation in Odeda soil sample is also shown in Table 5. Phosphorus fractions differed in the order of abundance: organic P > residual P > reductant soluble P > occluded P > saloid P > Fe-P > Ca-P > Al-P. All the fractions showed significant response to treatment application except Ca-P. Total P with value of 379.27 mg kg⁻¹ was the highest and the lowest value of 299.30 mg kg⁻¹ obtained at 10 and 2.5 t ha⁻¹ of poultry manure respectively. Occluded P decreased with the increase in the rate of treatment. At treatment rate of 10 t ha⁻¹ it reached 91.9% decrease compared with the control experiment. Residual P was highest with value of 107.02 mg kg⁻¹ at 7.5 t ha⁻¹ and lowest at 2.5 t ha⁻¹ with value of 62.88 mg kg⁻¹. Organic P increased relatively as the rate of treatment application increased. This confirms the known assertions that organic materials are the principal source of soil organic P [19]. Inorganic P and organic P were 58.68% and 41.32% of total P, respectively. Bray 1 P increased from 14.88 mg kg⁻¹ in control experiment to 39.40 mg kg⁻¹ obtained at 10 t ha⁻¹. The reduction in some of the P fractions (e.g. Al-P) due to the addition of manure could be the results of the organic compound from the manure blocking/preventing the fractional sites onto which the P is fixed to the metallic components. This might also mean more P being available in the solution pool or the available P. Other studies have also reported that the addition of manure increases the availability of P and prevents the fixation of P by soil components [8,22,28,29].

Results of Ayetoro soil incubation experiment are shown in Table 6. All the phosphorus fractions responded significantly with treatment application. Total P was highest at 10 t ha⁻¹ and lowest at 0 t ha⁻¹ with values of 630.48 mg kg⁻¹ and 488.07 mg kg⁻¹ respectively. Phosphorus fractions were in this order of abundance: organic P > residual P > reductant soluble P > occluded P > Fe-P > saloid P > Ca-P > Al-P. The highest value for Fe-P was 92.26 mg kg⁻¹ obtained at 5 t ha⁻¹ and lowest was 28.44 mg kg⁻¹ obtained at control experiment. Available P responded significantly with the treatment application, reaching the highest value of 51.34 mg kg⁻¹ at 10 t ha⁻¹. This is 70.6% increase over the control experiment. Inorganic P and organic P were 61.91 and 38.09% of total P, respectively. It thus implied that P is made more available by the addition of manure. The chemistry of this action is stated above and supported by the report of [8,22,28,29].

For soil sample from Ibadan, all the phosphorus fractions also responded significantly with the treatment application except for Ca-P. Phosphorus fractions followed this order of abundance: organic P > residual P > occluded P > Fe-P > reductant soluble P > saloid P > Al-P > Ca-P. The highest value of total P was 486.55

mg kg⁻¹ obtained at 10 t ha⁻¹, while lowest value of 359.74 mg kg⁻¹ was obtained at 2.5 t ha⁻¹. Organic P increased as the rate of treatment increased reaching the highest value at 10 t ha⁻¹. The lowest value of residual P was at 7.5 t ha⁻¹, while highest value was at 0 t ha⁻¹. There were general decreases in active fractions (Fe-P, Al-P and Ca-P) following the application of the manure treatment. Organic P is 39.3% of the total P. Inorganic fractions constituted 60.7% of the total P. There was no significant increase in available P in the different rates of treatment.

The P fractionation results after incubation of Ikenne soil sample are shown in Table 7. Phosphorus fractions followed this order of abundance: organic P > residual P > reductant soluble P > saloid P > occluded P > Fe-P > Al-P > Ca-P. All the fractions responded significantly with the treatment except for organic P and saloid P. Organic P constituted 46.94% of total P while inorganic fractions constituted 53.06% of total P. Organic P increased with increasing rate of treatment reaching 190.50 mg kg⁻¹ at 10 t ha⁻¹. There was relative increase in total P and highest value of 401.80 mg kg⁻¹ was obtained at 10 t ha⁻¹. Occluded P decreased with increasing rate of treatment and reached the lowest value of 12.62 mg kg⁻¹ at 7.5 t ha⁻¹. Fe-P had the highest value of 47.33 mg kg⁻¹ at 7.5 t ha⁻¹. Highest value of available P (44.14 mg kg⁻¹) was obtained at 5.0 t ha⁻¹ afterward it decreased to 37.99 mg kg⁻¹ at 10 t ha⁻¹. Results of Badagry soil incubation experiment also shown in the table also revealed that P fractions followed this order of abundance: organic P > occluded P > residual P > Fe-P > reductant soluble P > saloid P > Ca-P > Al-P. Organic P constituted 31.5% of total P while inorganic P constituted 67.9%. The lowest value of total P was 321.90 mg kg⁻¹ obtained at 10 t ha⁻¹ of treatment application and highest was obtained at 5 t ha⁻¹. All the fractions responded significantly with the manure treatment except for organic P and Bray 1 P. Occluded P was lowest at 87.84 mg kg⁻¹ at 10 t ha⁻¹. It reached highest value of 108.16 mg kg⁻¹ at 5.0 t ha⁻¹. There were general decreases in active fractions (Fe-P, Al-P and Ca-P). Fe-P obtained 54.6% decrease from the control experiment. Bray 1 P did not show any significant increase due to treatment application.

The results of P fractionation of Okemesi soil sample are shown in Table 8. Phosphorus fractions followed this order of abundance: organic P > residual P > reductant soluble P > saloid P > Fe-P > occluded P > Ca-P > Al-P. Organic P and inorganic fractions were 43.7 and 56.3% of total P respectively. Fe-P gave the highest value of the inorganic active fractions at 5.0 t ha⁻¹. The fractions showed significant responses to treatment except for Al-P and occluded P. The highest values of total P (357.94 mg kg⁻¹), Al-P (5.26 mg kg⁻¹), Ca-P (11.44 mg kg⁻¹) were obtained at 5.0, 0, 5.0 t ha⁻¹ respectively. Bray 1 P increased with increasing rate of treatment with 47.92 mg kg⁻¹ as the highest value at 10 t ha⁻¹. This is 93.9%

increase over the control experiment. The results of P fractionation in Omu-ljebu soil sample showed that organic P and inorganic fractions were 43.7 and 56.3% of total P, respectively. Phosphorus fractions followed this order of abundance: organic P > residual P > occluded P > reductant soluble P > Fe-P > saloid P > Ca-P > Al-P. The fractions showed significant responses to treatment except Al-P and organic P. The occluded P and organic-P had their highest rate at 10 t ha⁻¹. The highest and lowest values of residual P were 83.70 mg kg⁻¹ and 47.60 mg kg⁻¹ obtained at 10 and 5.0 t ha⁻¹ respectively. Fe-P decreased with the rate of treatment reaching the lowest value (9.76 mg kg⁻¹) at 7.5 t ha⁻¹. Ca-P reached the lowest value (5.82 mg kg⁻¹) at 5.0 t ha⁻¹. Bray 1 P did not show significant different with treatment application but the highest value was obtained at 10 t ha⁻¹ and lowest at 0 t ha⁻¹.

Results of incubation study in Imeko soil sample are shown in Table 9. Phosphorus fractions followed this order of abundance: organic P > residual P > occluded P > Fe-P > reductant soluble P > saloid P > Ca-P > Al-P. The fractions showed significant responses to the treatment except organic P. The inorganic fractions are 59.5% of total P and 40.5% of total P. The total P, organic P, reductant soluble P and saloid P had highest values of 320.25, 127.84, 19.25, 54.00 mg kg⁻¹ at treatment rate of 10 t ha⁻¹ respectively. The lowest value of residual P was obtained at 7.5 t ha⁻¹ with a value of 36.63 mg kg⁻¹. Bray 1 P had the lowest (28.76 mg kg⁻¹) and highest values (53.55 mg kg⁻¹) at 0 and 5.0 t ha⁻¹ respectively. Results of P fractionation in Igboora soil sample indicated that inorganic fractions are 57.85% of total P and 42.15% of total P. Phosphorus fractions followed this order of abundance: organic P > residual P > saloid P > occluded P > reductant soluble P > Fe-P > Ca-P > Al-P. The fractions showed significant responses to the treatment except Fe-P, organic P and total P. Treated soils showed significant reduction in occluded P compared with control experiment. The values of Al-P ranged from 2.98 to 5.76 mg kg⁻¹. Ca-P ranged from 3.78 to 6.74 mg kg⁻¹. Reductant soluble P had the lowest value of 11.25 mg kg⁻¹ at 7.5 t ha⁻¹, and highest value of 51.21 mg kg⁻¹ at 0 t ha⁻¹. Bray 1 P showed significant increase in treated soils compared to the control experiment.

Increase in organic P fraction of the soils is attributed to organic manure application. Out of the three active inorganic P fractions (Al-P, Fe-P and Ca-P), Fe-P was observed to be the highest in all the incubated soils. This supported the observation earlier made by [8,30–33] that most Nigerian soils are dominated by Fe-P fraction. Phosphorus released as a result of mineralization of organic manure and inorganic fertilizers can be converted to Fe-P and Ca-P in many soils [31].

In the incubated soils, significant decrease in Fe-P observed at some rates of poultry manure application in most soils, while there was significant increase in some other soils which showed that different soils could react

differently to organic amendment. Brady [34] stated that the availability of inorganic phosphorus is largely determined by (a) soil pH, (b) soluble iron, aluminum and manganese; (c) presence of iron, aluminium and manganese containing minerals; (d) available calcium and calcium minerals; (e) amount and decomposition of organic matter; and (f) activities of microorganisms. Moreover, organic anions mobilize inorganic P through complexing metal cations (Fe, Al, Ca, and Mg) that bind phosphate and displace phosphate from the soil matrix by ligand exchange [35,36]. Similarly, Akintokun et al. [37] stated that changes in the values of the P fractions in soils are significantly affected by soil type, P source and rate of application of amendment. Significant decrease in occluded P in Ayetoro could be attributed to organic compounds and enzymes contained in organic manure which broke down occluded P and release the P held up [28,38]. This is similar to the increase in the available P in incubated soils could be attributed to mineralisation of organic P in the organic matter. This is similar to result obtained by [29]. This higher amount of P could also have been due to the release of P initially fixed or in occlusion. In most of the soils, available P increased with increase in rate of manure application. This could partly be due to the released P from the manure or the action of microbes and enzymes from the manure on some other pools of P that hitherto not made available for extraction [28,38]. The relative increase in available P in the soils is more probable due to the reduction in some of the other competing P fractions. The addition of manure could promote organic compound from the manure blocking/preventing the fractional sites onto which the P is fixed to the metallic components. This will result into more P being available in the solution pool or the available P [8,22,28,29].

3.4. Effects of organic manure application on phosphorus fractions and available P in pot experiments

The effects of organic manure application on P fractions and available P in pot experiments in Abeokuta soil sample are shown in Table 10. In the first growth cycle, all the P fractions showed significant responses to manure treatment application except Fe-P, Ca-P and organic P. Highest values of total P, reductant soluble P, and residual P were obtained at treatment rate of 10 t ha⁻¹. The values of P obtained in incubation study for the second and third growth cycle were generally lower than those in the first growth cycle of the pot experiment. In the second growth cycle, values of saloid P, Al-P, occluded P, reductant soluble P and residual P were lower than those obtained in the first growth cycle. The values Fe-P increased in second and third experiments in the treated soils. The values of Ca-P increased in second and third experiments in the treated soils. The values of Occluded P decreased in the

Table 10. Effects of organic manure application on phosphorus fractions and Bray 1 P in pot experiments using Abeokuta soil sample.

Cycle	Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									Bray 1 P
		Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reduct-ant P	Residual P	Organic P	Total P	
First	0	10.70 d	6.90 a	8.44 a	7.08 a	12.42 d	11.80 b	184.63 bc	126.09 a	368.10 c	14.87 b
	2.5	12.58 cd	5.68 ab	9.62 a	5.98 a	22.76 bc	15.55 b	283.49 a	143.27 a	498.93 b	19.28 ab
	5.0	19.24 ab	3.79 bc	9.95 a	6.14 a	24.80 b	11.70 b	249.18 ab	155.78 a	480.58 b	21.73 a
	7.5	18.37 bc	3.16 c	10.41 a	6.42 a	16.53 cd	14.80 b	147.23 c	148.62 a	365.54 c	23.27 a
	10.0	25.17 a	4.74 abc	10.08 a	5.74 a	59.82 a	30.90 a	308.22 a	167.12 a	611.79 a	23.31 a
Second	0	8.42 a	5.62 a	10.04 c	6.42 b	3.12 c	2.48 b	92.86 bc	110.78 b	239.74 c	20.44 b
	2.5	4.60 b	0.38 c	23.53 b	10.65 a	1.20 e	3.66 b	84.06 cd	152.55 a	280.63 b	50.71 a
	5.0	3.45 b	2.85 b	20.82 b	11.12 a	5.20 b	5.24 a	79.02 d	142.21 a	269.91 bc	55.32 a
	7.5	8.77 a	3.10 b	38.84 a	12.67 a	6.90 a	6.30 a	94.27 b	132.37 ab	303.22 ab	54.46 a
	10.0	9.50 a	0.52 c	23.81 b	14.49 a	2.18 d	3.24 b	104.45 a	155.97 a	314.16 a	58.12 a
Third	0	6.50 b	0.21 b	14.49 d	5.00 c	1.09 bc	0.52 c	82.46 b	102.56 c	212.83 d	25.56 b
	2.5	2.90 d	0.41 b	45.47 ab	9.52 bc	0.73 c	0.84 b	93.65 ab	158.09 a	311.61 a	53.82 a
	5.0	4.30 cd	0.36 b	29.09 c	14.75 b	2.30 a	0.53 c	86.34 ab	128.44 b	266.11 c	60.76 a
	7.5	5.70 bc	1.28 a	54.18 a	13.73 b	0.18 d	0.31 c	97.56 a	112.31 bc	285.25 bc	63.83 a
	10.0	10.70 a	0.63 b	41.79 b	22.50 a	1.27 b	4.08 a	91.06 ab	132.14 b	304.17 ab	58.13 a

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

Table 11. Effects of organic manure application on phosphorus fractions and Bray 1 P in pot experiments using Odeda soil sample.

Cycle	Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									Bray 1 P
		Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reduct-ant P	Residual P	Organic P	Total P	
First	0	19.96 c	3.79 b	16.14 bc	2.96 b	6.30 b	75.95 ab	82.56 a	107.81 b	315.52 a	12.55 d
	2.5	18.51 c	6.31 b	15.70 bc	9.43 a	16.36 a	56.25 c	69.13 ab	130.65 ab	322.34 a	19.90 c
	5.0	22.99 bc	5.05 b	23.78 ab	4.55 b	6.30 b	83.82 a	73.19 ab	142.34 ab	362.10 a	26.80 b
	7.5	28.35 ab	6.63 b	9.74 c	8.40 a	4.25 b	64.70 bc	79.62 a	145.69 a	347.38 a	31.59 b
	10.0	30.22 a	12.31 a	28.16 a	7.64 a	16.84 a	10.50 d	43.11 b	150.21 a	298.64 a	42.12 a
Second	0	1.90 d	2.56 a	14.66 c	3.24 c	2.24 b	1.20 b	89.34 ab	112.22 c	227.36 c	25.28 b
	2.5	2.20 d	0.73 cd	18.06 bc	9.34 b	9.52 a	1.99 ab	72.07 b	138.35 b	245.28 b	54.13 a
	5.0	6.24 c	0.45 d	28.72 a	12.88 b	3.33 b	2.23 a	81.15 ab	149.48 a	284.48 a	57.97 a
	7.5	9.86 b	1.62 b	20.23 b	10.52 b	2.48 b	1.98 ab	95.92 a	156.33 a	298.94 a	56.82 a
	10.0	16.40 a	1.29 bc	26.42 a	23.10 a	4.36 b	2.51 a	69.84 b	159.45 a	303.37 a	59.17 a
Third	0	3.60 cd	0.84 c	26.15 b	4.76 d	0.46 c	0.94 a	70.86 c	92.6 c	200.21 d	23.16 b
	2.5	1.90 d	0.96 c	33.50 b	8.59 c	1.09 b	2.12 c	83.52 b	122.78 bc	254.46 c	48.73 a
	5.0	4.40 c	1.46 b	36.23 b	17.37 b	0.36 c	3.24 b	92.06 ab	156.03 a	311.15 b	61.15 a
	7.5	8.80 b	2.01 a	29.44 b	12.14 c	1.09 b	2.42 c	101.44 a	150.75 ab	308.09 b	54.94 a
	10.0	15.00 a	0.86 c	58.17 a	39.83 a	3.27 c	3.97 a	86.92 b	167.04 a	375.06 a	64.14 a

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

Table 12. Effects of organic manure application on phosphorus fractions and Bray 1 P in pot experiments using Ayetoro soil sample.

Cycle	Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									Bray 1 P
		Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reduct-ant P	Residual P	Organic P	Total P	
First	0	29.94 b	5.68 b	18.68 b	6.56 b	68.22 a	40.05 c	76.44 b	153.87 a	399.44 b	19.07 a
	2.5	33.12 ab	5.05 b	27.10 a	15.08 a	90.33 a	32.46 c	108.03 a	180.52 a	491.69 a	20.36 a
	5.0	32.40 ab	8.84 a	13.38 c	13.24 a	75.69 a	103.50 a	39.95 d	208.21 a	495.21 a	19.28 a
	7.5	35.00 ab	7.89 a	17.26 bc	7.86 b	21.12 a	73.15 b	70.45 bc	210.06 a	442.79 ab	19.74 a
	10.0	37.31 a	4.74 b	19.69 b	17.62 a	27.30 b	71.85 b	48.29 cd	230.45 a	457.10 ab	26.18 a
Second	0	8.56 b	1.24 a	35.43 a	32.24 a	4.66 b	5.56 a	89.34 ab	142.88 c	319.91 cd	28.53 c
	2.5	6.30 b	1.36 a	26.08 b	37.35 a	5.81 ab	6.89 a	72.07 bc	155.74 c	311.60 d	38.26 bc
	5.0	13.23 a	1.98 a	22.98 b	20.21 bc	7.69 a	3.58 b	81.15 abc	188.90 b	339.72 c	32.07 bc
	7.5	11.54 a	2.02 a	37.04 a	24.45 b	8.22 a	5.88 a	95.92 a	212.83 ab	397.90 a	46.85 ab
	10.0	12.70 a	1.14 a	36.23 a	14.94 c	6.18 ab	6.06 a	69.84 c	221.05 a	368.14 b	55.26 a
Third	0	5.40 a	0.70 c	49.77 c	13.16 c	4.72 b	4.81 c	70.86 b	122.65 d	272.07 c	35.81 b
	2.5	6.40 a	3.95 a	26.08 d	13.17 c	9.63 a	8.99 a	83.52 ab	150.14 c	301.88 c	35.04 b
	5.0	8.10 a	2.19 b	77.70 a	23.33 b	4.36 b	4.00 c	92.06 a	174.31 bc	386.05 ab	37.71 b
	7.5	7.40 a	1.77 b	63.95 b	41.74 a	3.27 b	4.29 c	100.68 a	195.54 ab	418.64 a	44.35 ab
	10.0	5.70 a	0.55 c	50.72 c	12.89 c	7.81 a	6.17 b	86.92 ab	204.82 a	375.58 b	63.01 a

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

second and third experiments. Bray 1 P increased in the second and third experiments. At the end of third growth cycle, P fractions followed this order of abundance: organic P > residual P > Fe-P > Ca-P > saloid P > occluded P > reductant soluble P > Al-P.

The P fractions and available P in pot experiments using Odeda soil sample are shown in Table 11. At the end of third growth cycle, P fractions followed this order of abundance: organic P > residual P > Fe-P > Ca-P > saloid P > reductant soluble P > occluded P > Al P. All the P

Table 13. Effects of organic manure application on phosphorus fractions and Bray 1 P in pot experiments using Ibadan soil sample.

Cycle	Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									Bray 1 P
		Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	
First	0	26.90 a	9.21 bc	25.78 a	3.40 b	42.12 a	66.40 a	60.69 a	114.80 a	349.30 a	34.36 b
	2.5	28.70 a	4.30 c	30.49 a	3.06 b	10.54 c	23.65 b	59.12 b	167.91 a	307.77 a	38.02 b
	5.0	31.10 a	4.42 c	23.40 a	8.50 a	12.65 c	28.70 b	65.67 a	155.87 a	330.31 a	36.65 b
	7.5	35.72 a	16.73 a	29.04 a	8.38 a	31.50 ab	21.42 bc	39.82 b	170.43 a	353.04 a	42.17 ab
	10.0	39.71 a	12.94 ab	28.91 a	11.40 a	18.95 bc	12.80 c	46.09 b	183.38 a	353.28 a	48.03 a
Second	0	4.28 b	1.20 a	25.24 a	8.24 c	8.29 a	2.40 b	91.31 b	116.34 c	257.30 c	45.07 c
	2.5	4.80 b	0.92 a	27.41 a	32.68 a	5.24 b	1.15 b	88.24 bc	175.77 ab	336.21 b	86.39 a
	5.0	20.04 a	0.60 b	15.55 b	8.21 c	3.50 bc	3.25 b	112.19 a	160.74 b	324.08 b	72.32 b
	7.5	22.74 a	0.56 b	17.98 b	9.24 c	2.20 cd	2.60 b	82.90 bc	182.39 ab	320.61 b	76.61 ab
	10.0	25.70 a	0.11 c	25.73 a	16.23 b	1.45 d	7.53 a	76.28 c	194.43 a	347.46 a	89.42 a
Third	0	5.30 c	0.81 ab	32.32 a	16.62 b	5.33 a	4.61 bc	97.73 abc	104.46 d	267.18 c	50.24 d
	2.5	6.20 c	0.41 cd	36.44 a	27.03 a	4.89 a	5.92 b	101.84 a	142.29 bc	325.02 ab	63.59 c
	5.0	13.70 b	0.33 d	20.46 b	21.38 ab	3.94 a	3.88 bc	100.98 ab	139.33 c	304.00 bc	82.10 ab
	7.5	17.40 ab	0.72 bc	11.34 c	19.04 b	5.08 a	2.76 c	81.57 c	178.52 a	316.43 b	85.05 a
	10.0	20.10 a	1.11 a	24.36 b	15.66 a	5.21 a	9.09 a	83.45 bc	171.54 ab	330.52 a	75.26 b

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

Table 14. Effects of organic manure application on phosphorus fractions and Bray 1 P in pot experiments using Ikenne soil sample.

Cycle	Manure rate (t ha ⁻¹)	Phosphorus fractions (mg kg ⁻¹)									Bray 1 P
		Saloid P	Al-P	Fe-P	Ca-P	Occluded P	Reductant P	Residual P	Organic P	Total P	
First	0	14.22 c	7.52 a	9.52 a	7.00 a	34.82 b	8.45 a	46.54 c	139.67 a	267.74 b	13.42 b
	2.5	14.36 c	5.43 a	13.45 a	4.04 b	39.17 ab	8.10 a	71.36 a	173.25 a	329.16 ab	20.36 b
	5.0	31.40 b	8.73 a	11.46 a	7.64 a	42.20 ab	5.65 a	44.97 c	150.52 a	302.57 ab	36.65 a
	7.5	25.82 b	7.79 a	12.49 a	3.38 b	40.21 ab	6.15 a	49.78 bc	166.65 a	312.27 ab	42.55 a
	10.0	40.93 a	8.29 a	14.93 a	4.06 b	59.61 a	4.56 a	60.49 ab	176.08 a	368.95 a	39.68 a
Second	0	12.23 b	1.10 b	8.78 c	5.24 b	5.54 a	5.43 a	62.04 c	102.54 d	202.90 c	30.82 c
	2.5	11.70 b	0.58 c	8.61 c	4.88 b	3.69 ab	4.68 ab	82.62 ab	132.43 b	249.19 b	65.23 b
	5.0	14.30 b	0.78 bc	12.21 bc	10.66 a	4.03 ab	3.35 ab	65.65 c	155.98 a	266.96 ab	73.08 ab
	7.5	17.45 ab	1.50 a	19.32 a	15.48 a	3.32 ab	3.41 ab	98.25 a	118.72 c	277.45 a	82.23 a
	10.0	24.60 a	0.67 c	15.54 ab	13.57 a	1.82 b	2.72 b	73.36 bc	123.16 c	255.44 ab	85.63 a
Third	0	7.00 bc	0.30 b	9.40 c	1.96 d	2.63 a	0.53 c	71.38 b	89.65 a	182.85 c	24.75 b
	2.5	24.60 a	2.06 a	12.81 c	2.05 d	0.55 b	1.33 b	95.23 a	110.23 a	248.86 b	58.20 a
	5.0	10.10 bc	2.34 a	19.22 b	24.93 b	0.18 b	3.21 a	99.24 a	120.06 a	279.28 a	56.42 a
	7.5	4.70 c	1.70 a	25.62 a	15.13 c	0.20 b	2.96 a	67.43 b	110.96 a	228.70 b	58.43 a
	10.0	12.30 b	0.11 b	27.72 a	32.22 a	2.18 a	3.04 a	59.82 b	115.65 a	253.04 b	51.64 a

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

fractions in the three growth cycles showed significant responses to manure treatment application except total P in the first growth cycle. Occluded P reached the highest value of 16.84 mg kg⁻¹ at 10 t ha⁻¹ in the first growth cycle and afterward it declined in the second and third growth cycle. Control experiments for occluded P soil were significantly different from the treated soils. Total P showed increases from first to third growth cycles. Highest values of available P were obtained at 10 t ha⁻¹ in all the three growth cycles. Organic P was 41.12, 52.14 and 47.57% of total P in the first, second and third growth cycle. Reductant soluble P showed a remarkable decline in the second and third growth cycle. The values of Al-P declined in the second and third growth cycle and control experiment was significantly different from treated soils. Highest values of saloid P were obtained in the first growth cycle afterward they declined in the second and third growth cycle.

Phosphorus fractions and available P in pot experiment using Ayetoro soil sample are shown in Table 12. P fractions followed this order of abundance: organic P > residual P > Fe-P > Ca-P > saloid P > occluded

P > reductant soluble P. Fe-P significantly increased with the highest value of 77.70 mg kg⁻¹ observed at 5 t ha⁻¹ of the third growth cycle. Similarly, values of occluded P reduced in second and third growth cycle with least value of 3.27 mg kg⁻¹ obtained at 7.5 t ha⁻¹ (84.52% reduction). Total P responded significantly to the manure treatment application, but there were increases in some rates it recorded decreases in other rates. However, the highest total P was observed at 7.5 t ha⁻¹ in the third experiment. Bray 1 P increased significantly across the treatments when compared to the control in the second and third experiments. 10 t ha⁻¹ of organic manure gave the highest value of 63.01 mg kg⁻¹ of Bray 1 P. Residual P had the highest values in the third growth cycle and the least value in the first growth cycle. Application of 10 t ha⁻¹ of poultry manure in the first growth cycle significantly increased saloid P compared to other treatment rates and decreased in the subsequent growth cycles.

Phosphorus fractions and Bray 1 P in pot experiments in Ibadan soil sample are shown in Table 13. P fractions followed this order of abundance: organic P > residual P > Fe-P > Ca-P > saloid P > reductant soluble

P > occluded P. Values of total P in the third growth cycle were slightly lower than those in first and second growth cycle. The application of poultry manure did not have significant effect on total P in the first growth cycle but it did in subsequent growth cycles. Occluded P in the control was significantly higher than in treated soils of first and second growth cycle but treatment was insignificant in third growth cycle. Fe-P responded significantly to manure treatment application in second and third growth cycle only and highest value of 36.44 mg kg⁻¹ was obtained at treatment rate of 2.5 t ha⁻¹ of the third growth cycle. Application of 10 t ha⁻¹ of poultry manure significantly increased organic P compared to other treatment rates in second growth cycle with highest value (194.43 mg kg⁻¹) at 10 t ha⁻¹. No significant effect was observed in first growth cycle. Bray 1 P was significantly different in all the three growth cycles. Its values in treated soils were higher than in control. Highest value of Bray 1 P (89.42 mg kg⁻¹) in second growth cycle was 98.40% higher than the control.

Phosphorus fractions and available P in Ikenne soil sample are indicated in Table 14. Results of third growth cycle showed that phosphorus fractions followed this order of abundance: organic P > residual P > Fe-P > Ca-P > saloid P > reductant soluble > Al-P > occluded P. All the fractions responded significantly to the manure treatment application in the third growth cycle. Application of 10 t ha⁻¹ of poultry manure significantly increased total P and resulted in highest value of 368.95 mg kg⁻¹ in the first growth cycle. However, it declined in second and third growth cycle. Similarly, trend was obtained for organic P where its highest and lowest values were 176.08 and 89.65 mg kg⁻¹ in first and third growth cycle respectively. Fe-P in third growth cycle is the highest when compared to first and second growth cycle, ranging values which ranged from 9.52 to 14.9 mg kg⁻¹. Occluded P increased over the control in the first growth cycle but drastically decreased in the two subsequent growth cycles. The values of Ca-P increased in most treated soils of second and third growth cycle and highest value (32.22 mg kg⁻¹) obtained at 10 t ha⁻¹. Lower values were obtained in the first growth cycle. Saloid P was highest in the first growth cycle but declined in the second and third growth cycle. Bray 1 P increased significantly across the treatments when compared to the control. Highest value of 85.63 mg kg⁻¹ was obtained at 10 t ha⁻¹ in the second growth cycle; third growth cycle produced lower values which were significantly different. The observed trend showed that plant uptake reduced the soil P fractions, however, the relative reduction in the P amount differed among the pools. The five soils used for pot experiments did not totally follow the same pattern in their responses to application of organic manure when phosphorus fractionation was done. These variations could be attributed to difference in soil pH, soluble iron, aluminum and manganese, presence of iron, aluminum and

manganese containing minerals, available calcium and calcium minerals, amount and decomposition of organic matter and activities of microorganisms [34]. In the pot experiments, increase in Fe-P observed in second and third growth cycle compared to the first growth cycle with few exceptions, especially in the control experiments and some rates in Odeda, Ibadan and Ikenne soils could be attributed to build up of Fe-P due to the release of P during the mineralisation of organic P in the soil. All of these inorganic P released could not have been fixed since there was increase in available P in all these soils. Ca-P followed a pattern similar to Fe-P. Similar increase in Ca-P in most pots in second and third growth cycle could be attributed to build up of Ca-P due to fixation of released inorganic P from mineralization of organic P by Ca compounds. Organic P was relatively stable in most of the treated soils, although there were slight decreases in most of the soils after the first growth cycle. Refs. [39,40] observed that soil organic P mainly exists in stabilized forms as inositol phosphates and phosphonates, and active forms as orthophosphate diesters, labile orthophosphate monoesters, and organic polyphosphates. Decreases of organic P recorded in pots could be attributed to the conversion of organic P to inorganic P. This was evident as values of available P and organic P were higher in the treated soils than the control. The trend observed in the data from Tables 10–14, shows that P abundance in the various soil fractions could be temporal. Cropping drastically reduced the amount of P in the soil fractions. However, the proportion of P reduction among the soil P fractions differ, even with manure application. The reduction in soil without manure application is however, higher, showing that manure application is a credible way of reducing the effect of crop removal of soil P from the soil P fractions.

3.5. Tissue concentration of Phosphorus in soya bean leaves in the pot experiments

Table 15 shows concentration of phosphorus in soya bean leaves. The results showed that manure application had significant effects on tissue concentrations in the five soils used. In most of the soils highest tissue concentrations were observed at high rates of manure application. Increases in dry matter yields (data not shown) and concentrations of P in the plant tissue could be associated with more essential nutrients available for the crop following decomposition and mineralisation of organic manure applied to the soils. The relative increase in available P is due to the addition of manure, this addition could create a shield or manure blockage and thus preventing the fractional sites onto which the P is fixed to the metallic components from fixing soil P. This will result into more P being available in the solution pool or the available P pool [8,22,28,29] and the subsequent uptake by the soybean plant.

Table 15. The tissue concentrations of Phosphorus in soya bean leaves in the three cycles of pot experiments.

Cycle	Manure rate (t ha ⁻¹)	% P				
		Abeokuta	Odeda	Ayetoro	Ibadan	Ikenne
First	0	0.12 ab	0.07 cd	0.06 d	0.06 b	0.06 b
	2.5	0.10 b	0.03 d	0.11 cd	0.10 ab	0.06 b
	5.0	0.12 ab	0.10 bc	0.19 bc	0.07 ab	0.09 a
	7.5	0.18 a	0.14 b	0.27 a	0.11 a	0.10 a
	10.0	0.16 ab	0.37 a	0.23 ab	0.09 ab	0.07 b
Second	0	0.09 d	0.05 c	0.07 d	0.09 a	0.07 d
	2.5	0.08 d	0.11 bc	0.16 c	0.08 b	0.10 cd
	5.0	0.18 c	0.08 c	0.30 b	0.07 b	0.12 bc
	7.5	0.31 a	0.19 b	0.41 a	0.12 ab	0.16 a
	10.0	0.25 b	0.46 a	0.38 a	0.15 a	0.14 ab
Third	0	0.14 c	0.03 c	0.11 d	0.05 d	0.05 d
	2.5	0.17 bc	0.12 b	0.14 d	0.19 bc	0.12 c
	5.0	0.27 b	0.13 b	0.26 c	0.16 c	0.13 c
	7.5	0.24 bc	0.16 b	0.36 b	0.24 b	0.23 b
	10.0	0.39 a	0.23 a	0.45 a	0.34 a	0.36 a

Note: Means in a column followed by the same letters within cycle are not significantly different at 5% probability level.

Time was needed for these processes of mineralisation to take place. That is why third growth cycle had highest dry matter yields. Soybean plant was also able to extract more P in the third growth cycle, the results in Table 14 also confirms that the low soil P fraction is the result of the higher dry matter accumulation and nutrient mining by the plants at the third growth cycle. This also showed that manure application has residual effect on soil nutrients.

4. Conclusion

The results indicated above shows that Fe-P was the dominant active inorganic P in the soils considered. However, residual P was the dominant inactive inorganic P in most of the soils considered. There was significant decrease in total P, occluded P and reductant soluble P in the soils. There was general increase in available P in most of the soils considered despite increase or decrease in other P forms. Poultry manure contributed to the reduction in fixation of phosphorus and release of occluded phosphorus. Poultry manure significantly improved soil nutrient status as shown in increases in plant P tissue concentrations.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Agbede TM. Tillage and fertilizer effects on some soil properties, leaf nutrient concentrations, growth and sweet potato yield on an Alfisol in southwestern Nigeria. *Soil Tillage Res.* 2010;110:25–32.

[2] Agboola AA, Omuetti JA. Soil fertility problem and its management in tropical Africa. In: Paper presented at the International Institute of Tropical Agriculture (IITA). Ibadan: Nigeria; 1982; p. 25.

[3] Zingore SP, Mafongoya P, Nyamugafata P, et al. Nitrogen mineralization and maize yields following applications of tree pruning to a sandy soil in Zimbabwe. *Agrofor Syst.* 2003;57:199–211.

[4] Obi ME, Ebo PO. The effects of organic and inorganic amendments on soil physical properties and maize production in a severely degraded sandy soil in southern Nigeria. *Biores Tech.* 1995;51:117–123.

[5] Ojeniyi SO. Effect of goat manure on soil nutrient and okra yield in a rainforest area of Nigeria. *Appl Trop Agric.* 2000;5:20–23.

[6] Agboola AA, Tijani-Eniola H, Eneji AE, et al. Changes required in the traditional slash and burn agriculture to make it sustainable. *Sols Africans.* 1995;28:209–218.

[7] Mbagwu JSC, Lal R, Scott TW. Effects of artificial desurfacing on Alfisols and Ultisols in southern Nigeria: II. Changes in soil physical properties. *Soil Sci Soc Am J.* 1984;48:834–838.

[8] Adetunji MT. Evaluation of P supplying capacities of South Western Nigeria soils. *J Indian Soc Soil Sci.* 1994a;42:208–213.

[9] Jubrin JM, Chude VO, Horst WJ, et al. The response of ten leguminous cover crops and maize to native and applied phosphate. *Proceeding of 26th Annual Conference of Soil Science Society Nigeria, Ibadan, Oyo State; 2000 Oct 30–Nov 3; 2000; p. 294–300.*

[10] Akinrinde OO. Strategies for improving crop's use – efficiencies of fertilizer nutrients in sustainable agricultural systems. *Pakistan J Nut.* 2006;5:185–193.

[11] Olaniyi JO. Growth and seed yield response of egusi melon to nitrogen and phosphorus fertilizers application. *American-Eurasian J Sust Agric.* 2008;2:255–260.

[12] Uzoho BU, Oti NN. Phosphorus adsorption characteristics of selected south eastern Nigerian soils. *J Agric Food, Environ Ext.* 2005;4:50–55.

[13] Ayeni LS. Integrated plant nutrition management: A panacea for sustainable crop production in Nigeria. *Int J Soil Sci.* 2011;6:19–24.

[14] Tisdale SL, Nelson WL, Beaton JO, et al. Soil and fertilizer phosphorus. In: Tisdale SL, Nelson WL, Beaton JD, and Havlin JL, editors. *Soil fertility and fertilizers.* New York, NY: Macmillan Publishing Company; 1993; p. 176–229.

[15] Uddin M, Kashem A, Osman KT. Effect of organic and inorganic amendments on the phytoavailability of phosphorus to corn (*Zea mays*). *Open J Soil Sci.* 2012;02:50–54.

[16] Holford ICR. Soil phosphorus: its measurement, uptake by plants. *Aust J Soil Res.* 1997;35:227–240.

[17] Chang SC, Jackson ML. Fractionation of soil phosphorus. *Soil Sci.* 1957;84:133–144.

[18] Sare CG, Udo EJ. Phosphorus status of some soils from People's Republic of Benin. *J Agric Sci Assoc.* 1988;31:11–23.

[19] Adetunji MT. Phosphorus requirement of a maize-cowpea sequential cropping on a paleudult. *Fert Res.* 1994b;39:161–166.

[20] Bouyoucos GH. A calibration of the hydrometer method for testing mechanical analysis of the soils. *Agron J.* 1962;43:434–438.

[21] IITA. International Institute of tropical agriculture Nigeria. Selected methods for soil and plant analysis, Revised Edition, Manual Series. 1979;1:69–70.

[22] Walker TW, Adams AFR. Studies on soil organic matter, 1. Influence of phosphorus content of parent materials on accumulation of carbon, nitrogen, sulfur and organic phosphorus in grassland soils. *Soil Sci.* 1958;85:307–318.

- [23] Page AL, Miller RH, Keeney DR. Methods of soil analysis Part 2 – chemical and microbiological properties. Madison: American Society of Agronomy; 1982. p. 1159.
- [24] Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.* 1945;59:39–46.
- [25] McLean EO. Aluminum. In: Black CA, editor. Methods of soil analysis: Part 2. Chemical methods. Madison, WI: American Society of Agronomy. 1965;978–998.
- [26] Peterson GW, Corey RB. A modified Chang and Jackson procedure for routine fractionation of inorganic soil phosphorus. *Soil Sci Soc Am Proc.* 1966;30:563–565.
- [27] Legg JO, Black CA. Determination of organic phosphorus in soils. 2. Ignition method. *Soil Sci Soc Am Proc.* 1955;19:139–143.
- [28] Ojo AO, Adetunji MT, Okeleye KA, et al. Soil fertility, phosphorus fractions, and maize yield as affected by poultry manure and single superphosphate. *Int Scholarly Res Notices.* 2015; 2015. Article ID 616213.8p. doi: <http://dx.doi.org/10.1155/2015/616213>.
- [29] Ojo AO, Adetunji MT, Okeleye KA, et al. Changes in Phosphorus fractions in manure and phosphorus fertilizer amended soil of Southwestern Nigeria. *Inter J Plant Soil Sci.* 2014;3:71–84.
- [30] Adepetu JA, Corey RB. Organic phosphorus as a predictor of plant available phosphorus in Southern Nigeria. *Soil Sci.* 1975;122:159–164.
- [31] Udo EJ, Uzu FO. Characteristics of phosphorus adsorption of some Nigeria soils. *Proc Soil Sci Soc Am.* 1972;36:879–883.
- [32] Enwezor WO. Soil testing for phosphorus in some Nigerian soils. 3 forms of phosphorus in soils of south western Nigeria and their relationship to plant available phosphorus. *Soil Sci.* 1977;124:27–33.
- [33] Attoe EE, Amalu UC. Evaluation of phosphorus status of some soils under estate rubber (*Hevea brasiliensis* Muel. Argo.) Trees in southern Cross River State. *Global. J Agric Sci.* 2005;4:55–61.
- [34] Brady NC. Phosphorus and potassium. The nature and properties of soils. 10th ed. New York, NY: Macmillan Publishing Company; 1990; p. 351–380.
- [35] Raghohama KG, Karthikeyan AS. Phosphate acquisition. *Plant Soil.* 2005;274:37–49.
- [36] Balemi T, Negisho K. Management of soil phosphorus and plant adaptation mechanisms to phosphorus stress for sustainable crop production: a review. *J Soil Sci Plant Nutr.* 2012;12:547–562.
- [37] Akintokun OO, Adetunji MT, Akintokun PO. Phosphorus availability to soya bean from an indigenous phosphate rock sample from southwest Nigeria. *Nutr Cycl Agroecos.* 2003;65:35–41.
- [38] Iyamuremye F, Dick RP, Baham J. Organic amendments and phosphorus dynamics: I. Phosphorus chemistry and sorption. *Soil Sci.* 1996;161:426–435.
- [39] Turner BL, Paphazy MJ, Haygarth PM, et al. Inositol phosphates in the environment. *Philos Trans R Soc Lond B Biol Sci.* 2002;357:449–469.
- [40] Condron LM, Turner BL, Cade-Menun BJ. Chemistry and dynamics of soil organic phosphorus. In: Sims JT, Sharpley AN, editors. Phosphorus: agriculture and the environment. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; 2005. p. 87–121.