

1 Title: Effect of Phosphorus Fertilizer and Poultry Manure on P Fractions in some Derived
2 Savanna Soils of South Western Nigeria - A greenhouse study

5 ABSTRACT

6 The availability of phosphorus (P) in derived savanna soils differs among soil types and the effect of
7 amelioration on the soil P are site specific. The study was conducted to determine the determine the
8 effect of P fertilization and poultry manure on the distribution of P in some derived savanna soils. The
9 greenhouse experiment was carried out in the greenhouse of the Institute of Agricultural Research and
10 Training (I.A.R & T), Ibadan. The treatments consisted of five rates of poultry manure (0, 5, 15 and 20 t
11 ha⁻¹) and five rates of phosphorus (0, 15, 30, 45 and 60 kg P ha⁻¹) applied as single superphosphate
12 (SSP) and this was replicated three times. The soil was cropped with maize and there were two cycles of
13 cropping. Organic P was the largest extractable P fraction while Al-P and Ca-P fractions were the least
14 extractable P fraction. The inorganic P fractions (Fe-P, Al-P, Ca-P, reductant soluble P and residual P) all
15 increased in the soil series. Although there were more of increases in the P fractions in the second
16 greenhouse studies, some treatments reduced the P fractions. Application of 30 kg P ha⁻¹ of SSP with
17 different rates of poultry manure was effective in increasing the total P and Fe-P fractions in Temidire
18 series while it was the combined application of 45 kg P ha⁻¹ of SSP with different rates of poultry manure
19 in Apomu series.

20 **Keywords:** *P fractions, poultry manure, soil series, SSP.*

21 1. INTRODUCTION

22 Soils of Nigeria like other parts of sub-Saharan Africa are poor compared to most other parts of the world.
23 Inherent poor fertility in these soils has been attributed to short supply of phosphorus. Low phosphorus in
24 some savanna soils have been reported by various authors (1, 2). Various factors could be responsible
25 for P availability to crop plants. These include the form of native soil P, type of P applied to the soil and
26 soil reaction. Phosphorus reaction in the soil makes phosphate, the form by which plants take up P to be
27 either in the solution pool, active pool or in the fixed pool. One unique characteristic of P is its low
28 availability due to slow diffusion and high fixation in soils. However, application of poultry litter to cropland
29 may increase metal mobility, because the soluble organic ligands in poultry litter can form water- soluble
30 complexes with metals (3). All of this means that P can be a major limiting factor for plant growth.
31 Applications of chemical P fertilizers and animal manure to agricultural land have improved soil P fertility
32 and crop production, but caused environmental damage in the past decades (4). Soil P exists in various
33 chemical forms including inorganic P (Pi) and organic P (Po). These P forms differ in their behavior and
34 fate in soils (5). Pi usually accounts for 35% to 70% of total P in soil (calculation from 6). Effect of the

application of chemical P fertilizers and animal manure on P fractions differs with soils and the fertilizer applied. Manure application for instance has resulted in a significant increase in all the fractions considered i.e Fe-P and Ca-P (7) while added fertilizer P has been observed to increase NaHCO₃-P, NaOH-P and the residual P fractions in a separate experiment (8). Different soils in the southwestern Nigeria has been studied as relating to the effect of fertilization on P fractions (9) but with no coverage of the study area used for this research work. In this study the effect of added P to poultry manure on P fractions in three low-P derived savanna soils was studied.

2. MATERIALS AND METHODS

2.1 Background Study

The soil samples were collected from two farmland located in the derived savanna zone of the southwestern part of Nigeria. The farms have been cropped with maize and cassava for four years without fertilizer application. The classification of the soils on the series level followed earlier classification (10).

Table 1: Source of the soils used

Location	State	Site Location	Vegetation	Soil Series	Soil (USDA) Class
Ogbomosho I	Oyo	Lat 8°17.66'N Long 4°10.86'E	Derived Savanna	Temidire	Ferrudulf
Ogbomosho III	Oyo	Lat 8°17.93'N Long 4°10.94'E	Derived Savanna	Apomu	Hapludalf

2.2 Soil chemical analysis

Total P was determined by wet digestion using perchloric acid and nitric acid while organic P was by ignition method. Phosphorus concentration in the digests was determined using the ascorbic acid method (11).

2.3 Characterization of the poultry manure used

Total analysis of the sample was done by weighing 0.5 g of poultry manure adding 10 ml of HNO₃ / HClO₄, (2 :1) and digesting at 150 °C. The temperature was increased at 1.5 hours to 230 °C and 2 ml of HCl /H₂O (1:1) was added. The digestion was now continued for another 30 minutes. (12)

2.4 Phosphorus fractionation study

Fractionation procedure (13) was used to quantify different forms of inorganic P in the studied soils. Fractionation was done on the soil before and after amendment for the greenhouse studies.

2.5 Greenhouse Studies

The experiment was carried out in the greenhouse of the Institute of agricultural Research and Training, Ibadan. Five kilogram of air dried, sieved soils from the 2 different locations were used for the experiment. The treatment in the greenhouse consisted of 5 rates of poultry manure (0, 5, 10, 15 and 20 t ha⁻¹) and 5 rates of phosphorus (0, 15, 30, 45 and 60 kg P ha⁻¹) as applied as single superphosphate (SSP). The treatments were arranged in the greenhouse as a 5 X 5 factorial experiment in a completely randomized design (CRD) with 3 replicates. Two weeks after application, three seeds (TZB-SR) were planted per pot and later thinned to two plants per pot. Soil samples were taken before and after harvest and analyzed for P forms. The experiment was then repeated for another 6 weeks.

2.6 Statistical analysis

The data collected were subjected to analysis of variance using the statistical analysis system (SAS) – general Linear Model (14). Means were separated by Duncan Multiple Range Test.

3. Results and Discussion

3.1 Initial phosphorus fractions of the two soils

The total P content of the soils was in the order Temidire series > Apomu series. In Temidire series, Al-P had the highest contribution to total P content of the soil, followed by organic P while Ca-P was the least (Table 2). A similar result was obtained in a study on the characterization of phosphorus status in soils of the Guinea Savanna zone of Nigeria (15) where the initial total P in another two derived Savanna soils have been reported to vary. The various P fractions extracted i.e. both the organic and inorganic P fractions were in low amounts in Apomu series. The difference in the two soils could be due to the different parent materials.

88 Table 2: Initial phosphorus fractions of the different soils

	Total P	Organic P	Al-P	Ca-P	Fe-P	Occluded P	Reductant Soluble P	Residual P
	mg P kg ⁻¹							
Temidire Series	273.08	52.09	68.39	22.10	38.96	27.83	30.32	33.39
Apomu Series	207.51	44.52	44.52	27.90	7.79	44.52	25.70	12.56

89

90 3.2 Characterization of the organic manure used

91 The percentage of N.P.K in the poultry manure was 5.82:5.54:0.94 (Table 3). Invariably some
 92 mineralization process has taken place which is evident in the N and P values. The value of organic C
 93 (13.38%) was also a confirmation of carbon release from the cured poultry manure used. Although the C:
 94 N ratio was low, the residual effect of the poultry manure applied was still evident in the second
 95 greenhouse studies carried out. However, some micronutrients were present in the poultry manure.

96 Table 3: Characterization of the poultry manure used

Nitrogen (N) (%)	5.82
Phosphorus (P) (%)	5.54
Potassium (K) (%)	0.94
Na (%)	1.30
SO ₄ -S (%)	0.14
Organic C (%)	13.38
C/N	2.30
Calcium (%)	8.04
Magnesium (%)	0.61
Iron (mg kg ⁻¹)	1555
Copper (mg kg ⁻¹)	33.30
Zinc (mg kg ⁻¹)	100.30
Manganese (mg kg ⁻¹)	180.00

97

3.3. Effect of the combined application of poultry manure and SSP on the various P fractions in Temidire Series during the first greenhouse studies

The sole and combined application of the two treatments had a significant effect on the total P as well as the organic and inorganic P extracted (Table 4). After crop removal in the first greenhouse studies, the combined application of 20 t ha⁻¹ of poultry manure and 30 kg P ha⁻¹ of SSP had the highest total P. Poultry litter application to soils have been observed to significantly increase total P (16). In this soil type, the order of the P fractions was organic P > Fe-P > occluded P > reductant soluble P > residual P > Al-P ≈ Ca-P. As observed for total P, the combined application of the two treatments i.e. the combined application of 10 t ha⁻¹ of poultry manure and 30 kg P ha⁻¹ of SSP gave the largest organic P fraction. In some studies, soil organic P has been observed to be mainly derived from manures, plant material and the products of the decomposition (17, 18). Fe-P which has been considered as the sink of this soil was higher when poultry manure was applied alone than when SSP was solely applied. This was observed with the sole application of 15 t ha⁻¹ of poultry manure which was not too different from when 10 t ha⁻¹ of poultry manure was applied. Application of 15 t ha⁻¹ of poultry manure and 30 kg P ha⁻¹ of SSP however gave the highest amount of Fe-P. Phosphorus occlusion was significantly reduced when poultry manure was applied solely especially with the sole application of 15 t ha⁻¹ which was not too different from when 20 t ha⁻¹ of poultry manure was applied. Fe-P was significantly increased with the sole application of poultry manure as compared to the sole application of SSP. The highest extractable Fe-P fraction resulted from the combined application of 15 t ha⁻¹ of poultry manure and 30 kg P ha⁻¹ of SSP. There were reductions in Al-P, Ca-P, reductant soluble P and residual P fractions as compared to the initial P fraction.

Table 4 : Effects of treatments on phosphorus fractions in the first greenhouse studies using soil samples from Ogbomosho I(Temidire Series)

Treatments		Phosphorus Fractions (mg kg ⁻¹)							
PM	P rates	Total P	Organic P	Al-P	Ca-P	Fe-P	Occluded P	Reduc	Residual
t ha ⁻¹	Kg P ha ⁻¹						P	Soluble P	P
0	0	262.42	53.12	56.98	24.15	35.76	30.33	28.96	23.12
	15	360.14	131.88	4.95	5.86	115.44	73.42	4.47	24.12
	30	385.29	85.29	4.27	4.85	150.79	31.92	23.51	6.20
	45	406.46	177.48	6.60	4.89	143.11	47.56	2.45	24.37
	60	465.83	184.38	5.97	4.70	122.89	86.74	42.05	19.10
5	0	364.21	120.62	8.04	4.45	131.92	18.52	25.43	15.23
	15	411.08	159.73	5.95	5.01	128.21	79.71	17.66	14.80
	30	426.82	183.73	4.82	4.12	165.98	15.77	23.30	29.10
	45	398.63	101.88	5.96	4.85	141.74	105.55	13.83	24.82
	60	402.76	123.73	5.73	5.15	131.40	99.59	11.72	25.43
10	0	421.72	128.89	5.60	5.21	161.73	20.23	19.37	20.70
	15	433.88	173.12	5.18	4.90	140.98	51.29	36.39	22.02
	30	506.40	318.13	6.05	5.06	117.57	29.47	12.98	17.15
	45	373.35	80.15	4.90	4.75	132.47	98.53	29.79	22.75
	60	332.92	150.80	6.92	5.20	99.59	11.60	30.54	28.28
15	0	340.87	279.35	4.95	5.04	162.79	17.46	13.73	16.45
	15	373.69	175.60	4.27	4.74	94.48	60.41	16.39	17.80
	30	434.77	180.17	4.74	5.09	169.18	44.46	6.92	24.20
	45	454.56	166.25	6.97	5.02	161.73	71.71	13.62	29.27

20	60	441.21	145.25	7.03	4.45	139.92	74.27	41.19	29.10
	0	424.80	137.50	5.73	4.94	153.22	17.46	4.79	21.15
	15	446.77	210.20	4.05	5.06	146.83	52.46	20.11	8.06
	30	513.48	206.25	5.03	4.83	137.26	110.87	21.92	27.32
	45	361.43	110.63	6.02	4.55	127.15	82.14	12.87	18.08
	60	365.30	147.50	6.86	5.75	124.49	40.47	30.64	9.59
LSD(p≤0.05)									
	SSP	*	*	*	*	*	*	*	*
	PM	*	*	*	*	*	*	*	*
	SSPXP	*	*	*	*	*	*	*	*

* - significant at p <0.05, NS – Not significant

3.4. Effect of the combined application of poultry manure and SSP on the various P fractions in Temidire Series during the second greenhouse studies

In the second greenhouse studies, the total P in the soil reduced as compared to the first greenhouse studies when the treatments was applied alone and in combination (Table 5). Organic P decreased when SSP was applied alone (19) but increased with the sole application of 5 t ha⁻¹ poultry manure and when it was combined with SSP. A similar trend was observed also for the inorganic P fractions. In other words, plant removal without further amelioration of this soil type will result into the reduction of both the organic and inorganic P fractions (20). However, mineralization of the organic P fraction which increased with some combined application is a major contributor to the release of P into the soil solution during the second cycle of cropping.

Table 5 : Effects of treatments on phosphorus fractions in the second greenhouse studies using soil samples from Ogbomosho I

(Temidire Series)

Treatments		Phosphorus Fractions (mg kg ⁻¹)							
PM	P rates	Total P	Organic P	Al-P	Ca-P	Fe-P	Occluded P	Reduc	Residual
t ha ⁻¹	Kg P ha ⁻¹							Soluble P	P
0	0	242.23	48.90	60.15	23.22	30.52	24.22	28.18	11.04
	15	361.33	130.63	6.28	5.31	37.24	98.95	30.64	23.30
	30	267.23	67.23	6.92	5.11	30.00	65.01	9.58	18.73
	45	403.32	80.63	5.43	4.78	29.37	100.23	5.96	16.92
	60	275.40	140.38	5.43	5.64	27.24	73.84	6.38	16.49
5	0	316.28	135.00	8.06	4.89	22.56	15.12	31.07	29.58
	15	374.39	120.02	8.19	10.75	42.32	95.87	70.97	26.28
	30	329.99	158.67	5.53	5.12	51.92	81.08	9.27	18.41
	45	366.30	210.20	4.79	5.00	46.82	73.42	9.15	16.92
	60	298.20	144.30	5.40	4.89	22.56	91.08	15.64	14.33
10	0	314.52	118.75	6.60	5.21	47.77	11.93	15.85	28.41
	15	279.33	122.50	7.55	5.43	43.73	75.76	7.87	16.49
	30	413.23	249.35	8.09	5.03	27.13	92.46	9.04	22.13
	45	270.21	107.50	6.60	5.11	22.98	92.69	20.11	15.22
	60	284.66	170.02	5.19	4.05	15.22	60.21	13.09	16.89
15	0	343.21	180.63	7.34	4.89	37.24	18.95	30.64	33.52

3.5 Effect of the combined application of poultry manure and SSP on the various P fractions in Apomu series during the first greenhouse studies

Effect of the sole and combined application of the two treatments on the various P fractions was significant. There was an increase in total P over the initial value when SSP was applied alone and in combination with SSP (Table 6). The largest total P fraction was observed with the application of 45 kg P ha⁻¹ of SSP. Organic P increased when the treatments were applied solely and when combined. However, the most significant increase in organic P was observed with the combined application of poultry manure with SSP. Al-P, Ca-P, Fe-P, occluded P and the reductant soluble P fractions reduced when compared to the initial values. Phosphorus adsorption to soil particles can be greatly reduced with the application of organic substances (3). In the first greenhouse studies it was observed that there was an increase in the residual P fraction as compared to the control.

Table 6 : Effects of treatments on phosphorus fractions in the first greenhouse studies using soil samples from Ogbomosho III(Apomu

Series)									
Treatments		Phosphorus Fractions (mg kg ⁻¹)							
PM	P rates	Total P	Organic P	Al-P	Ca-P	Fe-P	Occluded P	Reduc	Residual
t ha ⁻¹	Kg P ha ⁻¹							Soluble P	P
0	0	187.13	42.34	42.82	26.16	7.78	43.85	10.12	14.06
	15	177.50	99.38	3.88	6.17	5.11	19.47	0.53	33.30
	30	194.48	96.88	3.86	7.77	5.21	42.13	3.74	24.89
	45	380.41	96.25	4.20	6.81	4.93	31.18	11.28	25.76
	60	266.36	59.38	5.15	7.66	7.77	33.62	11.60	41.18
5	0	225.40	81.50	3.08	25.96	4.89	13.49	35.75	42.98
	15	224.03	141.25	4.05	8.30	4.89	31.49	5.11	28.94
	30	165.85	70.04	3.70	6.28	4.89	43.81	5.53	31.60
	45	232.26	122.50	4.85	6.59	4.79	52.35	11.60	29.58
	60	174.38	95.04	4.20	6.81	7.87	31.71	6.60	22.15
10	0	177.50	88.13	4.20	5.96	5.03	17.66	4.79	41.73
	15	202.34	123.68	3.94	6.70	5.11	30.22	4.89	27.79
	30	221.95	121.88	3.90	6.59	5.00	41.50	4.89	38.19
	45	221.17	113.75	6.05	6.70	4.56	51.39	5.53	33.19
	60	184.53	80.63	4.40	8.10	7.66	31.81	5.97	45.96
15	0	255.27	158.75	3.93	6.72	5.43	12.03	0.53	33.30

20	15	248.05	156.81	6.00	7.66	5.12	31.28	3.62	37.56
	30	185.17	80.21	6.65	6.81	4.79	42.13	5.64	38.94
	45	238.59	117.50	4.47	7.66	7.45	52.03	5.97	43.52
	60	212.79	110.63	4.35	7.48	7.45	36.07	7.34	39.47
	0	244.43	159.38	4.08	7.34	5.53	14.05	13.62	30.43
	15	213.51	110.56	4.17	7.87	5.11	40.89	5.21	39.69
	30	179.09	88.43	5.10	6.28	5.01	42.45	5.96	25.86
	45	364.97	242.50	4.60	8.30	7.34	51.71	10.94	39.58
	60	240.40	138.03	4.02	8.06	16.38	22.60	10.55	40.75
	LSD(p≤0.05)								
	SSP	*	*	*	*	*	*	*	*
	PM	*	*	*	*	*	*	*	*
	SSP×PM	*	*	*	*	*	*	*	*

* - significant at p <0.05, NS – Not significant

3.6 Effect of the combined application of poultry manure and SSP on the various P fractions in Apomu series during the second greenhouse studies

In the second greenhouse studies, total P increased as compared to the first greenhouse studies (Table 7). Sole application of poultry manure accounted for more of total P than when SSP was applied alone. The highest extractable total P fraction was observed with the combined application of 10 t ha⁻¹ of poultry manure and 45 kg P ha⁻¹ of SSP. Organic P also increased as compared to the first greenhouse studies and this was observed with most treatment combinations. There was more of the organic P fraction when poultry manure was applied alone than with the sole application of SSP. Manure contains large amount of organic P (21) and can be released to increase soil phosphorus concentrations by mineralization. The combined application of 10 t ha⁻¹ of SSP and 45 kg P ha⁻¹ of SSP gave the largest organic P fraction. There were significant increases in Al-P and Ca-P fractions as compared to the first greenhouse studies. Both the sole application of SSP and poultry manure as well as the combined application were effective in increasing the soil Fe-P in the second greenhouse study. When Fe-P builds up it can act as a sink of P (22) and can serve as a source of P for plants if the resin and Bic-Pi are extremely low. Although occluded P increased, poultry manure reduced the P occlusion when applied solely. There was a slight increase in reductant soluble P fraction while residual P, the recalcitrant P fraction decreased.

Table 7 : Effects of treatments on phosphorus fractions in the second greenhouse studies using soil samples from Ogbomosho III(Apomu Series)

Treatments		Phosphorus Fractions (mg kg ⁻¹)							
PM	P rates	Total P	Organic P	Al-P	Ca-P	Fe-P	Occluded P	Reduc	Residual
t ha ⁻¹	Kg P ha ⁻¹							Soluble P	P
0	0	193.65	42.52	45.10	24.15	11.56	51.01	9.94	9.37
	15	422.09	88.75	5.85	10.11	105.76	108.95	40.75	11.92
	30	466.84	52.42	5.85	12.04	125.02	146.83	9.04	15.64
	45	419.10	68.13	5.43	9.07	91.72	120.17	9.79	14.79
	60	411.93	45.04	7.66	11.13	106.19	110.46	11.23	20.22
5	0	469.32	188.15	5.11	29.10	106.83	27.04	10.64	12.45
	15	501.50	195.64	6.38	12.02	120.76	145.77	8.16	12.77
	30	574.54	180.07	5.75	8.45	118.10	169.18	84.69	8.30
	45	444.79	149.38	5.32	11.90	110.23	98.05	49.37	20.54
	60	408.53	150.05	6.60	10.04	117.57	99.27	7.87	17.13
10	0	495.40	168.77	6.19	8.05	101.29	25.02	73.42	12.66
	15	406.67	124.38	5.85	11.50	103.85	140.98	6.70	13.41
	30	411.97	102.50	5.53	12.93	118.64	144.17	17.77	10.43
	45	643.73	376.23	6.99	8.05	107.89	110.20	20.85	13.51
	60	620.58	276.08	5.53	14.20	105.97	144.95	9.69	22.03
15	0	576.06	252.06	5.85	10.15	125.02	16.66	12.13	10.28
	15	463.94	103.13	7.24	10.02	120.76	167.05	44.79	10.96

20	30	414.42	135.03	8.51	10.38	113.32	101.40	26.49	19.28
	45	386.35	108.73	5.53	13.43	128.74	95.95	19.47	14.50
	60	568.09	290.08	6.17	13.00	100.87	120.11	7.66	30.20
	0	467.29	175.63	5.84	8.22	101.72	23.85	52.35	9.68
	15	463.43	123.14	5.64	13.10	116.51	158.54	34.26	12.24
	30	390.49	137.48	5.96	9.23	99.38	95.55	29.05	13.83
	45	413.45	143.75	5.85	10.20	116.51	105.37	15.32	16.46
	60	593.78	303.13	5.35	14.97	120.50	114.97	9.69	25.17
LSD(p≤0.05)									
	SSP	*	*	*	*	*	*	NS	*
	PM	*	*	*	*	*	*	*	*
	SSPXP	*	*	*	*	*	*	*	*

* - significant at p <0.05, NS – Not significant

4. Conclusion

The distribution of the phosphorus fractions after the application of poultry manure and single superphosphate was site specific. Organic P has observed by previous authors was the largest extractable P fraction. However, application of poultry manure in combination with SSP at different rates effectively increased organic P in Temidire series and Apomu series. The inorganic P fractions either increased or decreased in the two soil series depending on the treatment application. The buildup of the inorganic P fractions especially the recalcitrant P fractions was observed in the two series while there were reductions in some soil P fractions. However, the decrease in the inorganic P fractions in two soil series signifies an immediate mineralization in the second greenhouse studies while the decreases observed in the P fractions during the studies is important for maintaining equilibrium between the less available P fractions and the readily available for the sustainability of P in the soil solution.

COMPETING INTERESTS

Authors have declared that no competing interest exists.

References

1. Giwa David D. Ojeniyi SO. Comparative effect of pig manure and N.P.K fertilizer on soil fertility and performance of tomato (*lycopersicum lycopersicon mill*). Thesis and Dissertations. Crop, Soil and Pest Management. Federal University of Technology, Akure; 2004.
2. Nwoke OC, Vanlauwe B, Diels J, Sanginga N, Osonubi O. The distribution of phosphorus fractions and desorption characteristics of some soils in the moist savanna zone of West Africa. Nutrient Cycling in Agroecosystems. 2004; 69(2):127-141.
3. Faridullah A, Waseem A, Alam A, Irshad M, Sabir M, Umar M. Leaching and mobility of heavy metals after burned and unburned poultry litter application to sandy and masa soils. Bulgaria Journal of Agricultural Science. 2012; 18: 733 – 741.
4. Jianbo S, Lixing Y, Junling Z, Haigang L, Zhaocha B, Xinping C, Weifeng Z, Fusuo Z. Phosphorus dynamics: From Soil to Plant. Plant Physiology. 2011; 56: 997--1005.
5. Hansen JE, Cade-Menun, BJ, Strawn,DG. Phosphorus speciation in manure amended alkaline soils. Journal of Environmental Quality. 2004; 33:1521-1527.

- 190 6. Harrison AF. Soil Organic Phosphorus-A review of world literature. CAB International,
191 Wallingford, Oxon, UK, p 257;1987.
- 192 7. Sharpley AN, Smith, SJ. Nitrogen and phosphorus forms in soil receiving manure. Soil Science.
193 1995; 159(4): 253--258.
- 194 8. Zhang TQ, Mackenzie, AF. Change of soil phosphorus fractions under long-term corn
195 monoculture. Soil Science Society of America Journal. 1997; 61:485-493.
- 196 9. Kolawole GO, Tijani – Eniola H, Tian G. Phosphorus fractions in fallows of West Africa: Effect of
197 residue management. Plant and Soil. 2004; 263: 113-120.
- 198 10. Smyth AJ, Montgomery RF. Soil and land use in Central Western Nigeria. Govt. Printer, Ibadan,
199 Nigeria. 1962; 265pp.
- 200 11. Murphy J, Riley JP. A modified single solution method for the determination of phosphate in
201 natural waters. Anal Chim Acta. 1962; 27:31–36.
- 202 12. Udo EJ, Ogunwale, JA. Manual of Soil, Plant and Water Analysis. Department of Agronomy,
203 University of Ibadan, Nigeria; 1978.
- 204 13. Chang SC, Jackson ML. Fraction of soil phosphates. Soil Science.1957; 83: 133—144.
- 205 14. SAS Institute. SAS for linear models. A guide to the ANOVA and GLM procedures. SAS Inst.,
206 Cary, N.C; 2000.
- 207 15. Amhakhian SO, Osemwota IO. Characterization of phosphorus status in soils of the Guinea
208 Savanna zone of Nigeria. Nigerian Journal of Soil Science. 2012; 22 (1): 37-43.
- 209 16. Ullah F, Amir W, Muhammed I, Qaisar M, Muhammed A, Arif A. Leachability of phosphorus in
210 soils after application of burned and unburned poultry litter. 2012; 7(5): 834-840.
- 211 17. Sylvia DM, Hartel PG, Fuhrmann JJ, Zuberer DA. Principles and applications of soil microbiology.
212 Pearson Education Inc., NJ; 2005.
- 213 18. Morgan MA. The behavior of soil and fertilizer phosphorus. In phosphorus loss from soil to water.
214 Cab International NY: USA. 137-150; 1997.
- 215 19. Zhang TQ, Mackenzie AF, Liang BC, Drury CF. Soil test phosphorus and phosphorus fractions
216 with long-term phosphorus addition and depletion. Soil Science Society of American Journal.
217 2004; 68:519--529.

- 218 20. He Z, Griffin, JA, Honeycutt CW. Evaluation of soil phosphorus transformations by sequential
219 fractionation and phosphatase hydrolysis. Soil Science. 2004; 169: 515-527.
- 220 21. Turner BL, Leytern, AB. Phosphorus compounds in sequential extracts of animal manures :a
221 chemical speciation and a novel fractionation procedure. Environmental Science and Technology.
222 2004; 38:6101-6108.
- 223 22. Kuo S, Huang B, Bembene. Effects of long-term phosphorus fertilization and winter cover
224 cropping on soil phosphorus transformations in less weathered soil. Biology and Fertility of Soils.
225 2005; 41:116--123.