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Changes in Phosphorus Fractions in Manure and Phosphorus Fertilizer Amended Soil of Southwestern Nigeria

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Authors' contributions

This work was part of my PhD research findings under the supervision of the three co-authors at the Federal University of Agriculture, Abeokuta, Nigeria.

Original Research Article

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ABSTRACT

Phosphorus (P) fractions are important forms of P in the soil which determines P availability, an important ion in the soil for plant use. Incubation study was conducted in the laboratory for ten weeks to study the changes in selected P fractions in an Alfisol (Iwo soil series) in the southwestern region of Nigeria amended with poultry manure and single superphosphate (SSP).

The soil was collected from the experimental field of the Institute of Agricultural Research and Training, Ibadan, Nigeria. Poultry manure at 0, 5, 10, 15 and 20 t ha^{-1} was applied in combination with single superphosphate (SSP) at 0, 15, 30, 45 and 60 kg P ha^{-1}. The treatments were replicated three times and phosphorus fractions (Organic P, Fe-P, Al-P, occulded P and residual P) were determined before and at two weekly interval during the incubation studies using the Chang and Jackson method.

Significant increases in Fe-P and Al-P fractions were observed to the 6th week of incubation after which it started decreasing when poultry manure was applied solely and in combination with SSP. The sole application of SSP i.e. at 30 kg P ha^{-1} of SSP increased the recalcitrant P fractions while poultry manure reduced it. When Fe-P

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extractable with NaOH i.e. NaOH-Pi builds up it acts as a sink for P and this is achieved more when the poultry manure was combined with SSP. Application of 20 t ha^{-1} of poultry manure in combination with 30 kg P ha^{-1} of SSP increased the Fe-P availability and therefore a potential sink for P.

Keywords: Iwo soil; poultry manure; singlesuperphosphate; phosphorus fractions.

1. INTRODUCTION

Phosphorus is an essential element, second to nitrogen as a macronutrient and needed for various metabolic processes in the plant. Soils in the southwestern part of Nigeria has been reported to be low in phosphorus [1]. Phosphorus deficiency can be attributed to loss due to erosion and phosphorus fixation or phosphorus uptake by plant [2,3]. Phosphorus fixation by ions in the soil is pH dependent i.e either it is an acidic or alkaline soil and these phosphorus forms determines the availability of phosphate in the soil solution. The release rate of adsorbed P directly affects the P supply to plants and this is important for long-term planning of crop production [4]. In the southwestern part of Nigeria, soils formed on the basement complex rock have been observed to have low levels of Fe-P and Al-P [5]. These two fractions determines the capacity of the soil to supply P into the soil solution. Apart from Fe-P and Al-P, the recalcitrant P fractions also exist which includes the occluded P and residual P fraction, which all exist in various level of abundance in Nigeria soils [6]**.** Increase or decrease in these P fractions is mostly affected by amendments which include both the organic and inorganic fertilizer [7]. Most farms in Nigeria are been cropped with the application of inorganic fertilizer but due to the high cost of purchasing these fertilizers, farmers are gradually adopting the use of organic fertilizers. Animal manure is a low-cost alternative to mineral fertilizers which provide a valuable source of nitrogen (N) and phosphorus (P) for crops [8]. Maintenance of adequate amounts of soil P through application of inorganic and/or organic P sources is critical for long-term agricultural productivity [9]. Organic and inorganic fertilizers have different effects on the organic and inorganic P fractions. For instance, the residual P pool may increase with increasing rate of fertilizer application [10] whereas P adsorption to soil particles can be greatly reduced through applying organic substances [11]. Adding P fertilizer or in combination with organic manure has been found to increase the concentrations of the labile inorganic pools as well as various nutrients in soils. However, this study was carried out to determine the changes in the organic and inorganic P fractions as a result of the sole and combined application of poultry manure and SSP.

2. MATERIALS AND METHODS

2.1 Characteristics of the Soil and Organic Amendment

Surface soil (0-20cm) formed on a basement complex rock located in the experimental field of the Institute of Agricultural Research and Training (Lat 7º 30', long 3º 54') in the southwestern part of Nigeria was used for the experiment. The soil was selected as it typifies soils that have received both poultry manure at 5, 7.5 and 10 t ha^{-1} while N.P fertilizer has been applied at 20, 40 and 60 kg P ha^{-1} over a long 10 years. A composite soil sample was taken from the surface layer (0-20 cm) of the soil, air dried and crushed to passed through a 2 mm sieve. Poultry manure cured for 2 months was collected from the Institute's poultry farm.

The soil had a particle-size distribution of 740g kg^{-1} sand, 120g kg^{-1} silt and 140 g kg^{-1} clay as measured by the hydrometer method [12]. Soil pH was measuered using a 1:2 soil to water ratio. Organic C was measured by the wet oxidation method with sulphuric acid. Initial P fractions was determined and presented in Fig. 1. Available P using 0.03N NH_4F in 0.025N HCl as the extractant [13]. The soil was near neutral, low in N and organic matter but moderately high available P. The exchangeable cations was also low except Ca which was adequate in the soil and can be attributed to past fertilizer application (poultry manure and N.P.K fertilizer) on the soil (Table 2).

Analysis of the poultry manure (Table 3) used gave 5.82 % nitrogen, 12.74 % phosphorus (P) and 0.94 % potassium (K). Organic carbon content was slightly high in the manure (13.38 %) while the percentage Ca, Mg and Na in the organic manure were 8.04, 0.61 and 1.30 %. The C/N ratio was however low (2.3:1) while Fe was in abundance in the manure at 1555 mg kg^{-1}.

2.2 Incubation Experiment

The incubation study was conducted to determine the changes in P fractions from soil treated with poultry manure and single super phosphate. Surface soil from the Institute of Agricultural Research and Training, Ibadan, Nigeria was air-dried and passed through a 2 mm sieve. Poultry manure and SSP was ground before mixing with the soil. Three hundred grammes each of the soil was weighed into plastic cups and mixed thoroughly with 0.75g, 1.5g, 2.25g, 3g of poultry manure and 0.0022g, 0.0045g, 0.0067g, 0.009g of single super phosphate in three replicates. This corresponds to 5, 10, 15 and 20 t ha^{-1} of poultry manure and 15, 30, 45 and 60 kg P ha^{-1} of SSP. Treatment without SSP and poultry manure application was included for comparison. The treatments were arranged as a 5 x 5 factorial experiment in a completely randomized design (CRD). The incubation study was carried out in the laboratory with a temperature of 30ºC and 60% relative humidity. The temperature was maintained with the use of a regulated air-condition while a de-humidifier was used to regulate the relative humidity. The soil were moistened to field capacity with distilled water and left for ten weeks in a covered plastic cups. The plant available water was determined using a tension table at 0.1 bar suction. Soil samples were taken using a 10_cm diameter tube at two weeks interval and analysed for phosphorus fractions.

2.3 Phosphorus Fractionation

A 1g soil sample was placed ina 50ml centrifuge tube and was extracted sequentially with 1M NH_4Cl, 0.5M NH_4F, 0.1M NaOH, Sodium citrate/with sodium dithionite and 0.25M H_2SO_4 and this is tabulated below in Table 1. After the sequential extraction, residual P was extracted using the H_2O_2-H_2SO_4 wet oxidation technique [14]. The hours of shaking varied depending on the fraction which was been extracted after which the tubes were centrifuged and the supernatant decanted [15]. Inorganic P in the various soil extracts was determined colorimetrically using the ascorbic acid method [16]. An spectrophotometer was used to measure absorbance at wavelength of 882nm.

Table 1. Showing total amount of P applied in each treatment

Treatments	Inorganic	Organic	Total
No SSP, No PM	0	0	0
SSP 15	15	0	15
SSP 30	30	0	30
SSP 45	45	0	45
SSP 60	60	0	60
SSP 15 + PM 5	15	0.01	15.01
SSP 15 + PM 10	15	0.02	15.02
SSP 15 + PM 15	15	0.03	15.03
SSP 15 + PM 20	15	0.04	15.04
SSP 30 + PM 5	30	0.01	30.01
SSP 30 + PM 10	30	0.02	30.02
SSP 30 + PM 15	30	0.03	30.03
SSP 30 + PM 20	30	0.04	30.04
SSP 45 + PM 5	45	0.01	45.01
SSP 45 + PM 10	45	0.02	45.02
SSP 45 + PM 15	45	0.03	45.03
SSP 45 + PM 20	45	0.04	45.04
SSP 60 + PM 5	60	0.01	60.01
SSP 60 + PM 10	60	0.02	60.02
SSP 60 + PM 15	60	0.03	60.03
SSP 60 + PM 20	60	0.04	60.04

Table 2. Sequential P fractionation procedures and targeted P forms

Fraction	Extractants	Equilibration	Washing	Targeted
NH_4Cl-P	IM NH_4Cl	30mins	None	Saloid-bound P
NH_4F-P	0.5M NH_4F	1 hour	None	Al-P
NaOH – P	0.1M NaOH Saturated Nacl + 5 drops of conc. H_2SO_4	15 mins	Saturated NaCl	Fe-P
Sodium + citrate Sodium dithionite P	0.3M sodium citrate + 1g solid Sodium dithionate + sat Nacl	Shake 15mins, preheat 15mins at 85^{0}C after sodium citrate, additional 15 mins after dithionte addition	Saturated NaCl	Reductant – Soluble P
NaOH-P	O.1M NaOH + few drops of conc. H_2SO_4 to remove colour	15 mins	Saturated NaCl	Occluded – P
H_2SO_4-P	0.25M H_2SO_4 + 25ml Sat. Nacl	1 hour	Saturated NaCl	Ca-P
Residual P	Conc. HNO_3 + HCl + 30% H_2O_2	Variable until complete	None	Organically stable organic and inorganic P

2.4 Statistical Analysis

The data collected were subjected to analysis of variance using the statistical analysis system (SAS) – General Linear Model [17]. Means were separated at 5% probability by Duncan Multiple Range Test.

3. RESULTS AND DISCUSSION

Initial phosphorus fractionation of the soil showed Al-P to be the most extractable P form in the soil followed by organic P and then Fe-P (Fig 1). The effect of the combined application of poultry manure and SSP was observed with the change in the order of abundance to organic P >Fe-P>Al-P (Tables 5, 7, 8).

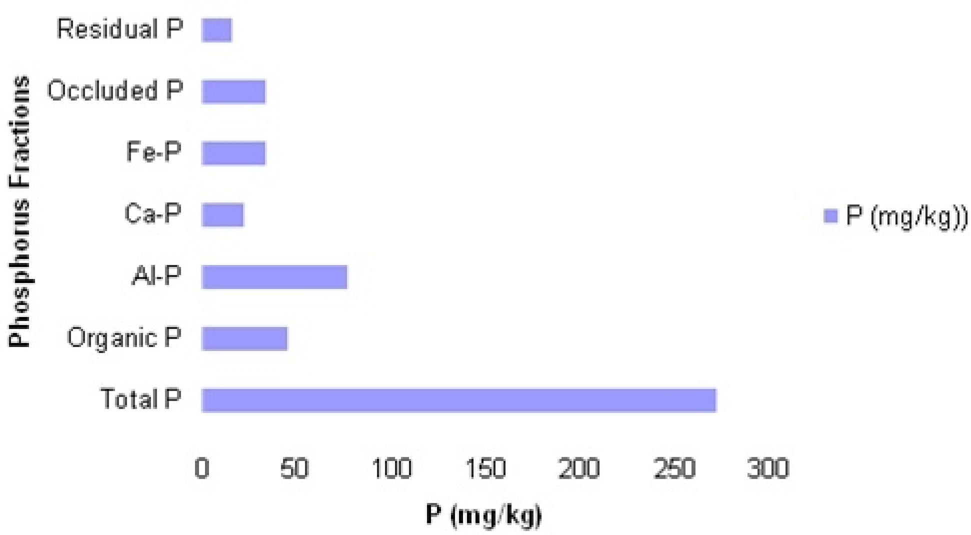

Fig 1. Initial Phosphorus Fractions of the soil

Table 3. Initial chemical properties of the soil

Parameters	Values
pH (H_2O)	6.40
Organic Matter (g kg^{-1})	24.08
N (g kg^{-1})	0.20
P (mg kg^{-1})	14.20
Exchangeable cations (c mol kg^{-1})	
Ca	1.14
Mg	0.82
K	0.47
Na	0.09
Particle size (g kg^{-1})	
Sand	740.00
Clay	120.00
Silt	140.00

Table 4. 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

3.1 Organic P

The effect of the sole and combined application of poultry manure and SSP is shown in Table 5. The organic P fraction was not increased when SSP was applied alone and this could be due to the fact that it is an inorganic fertilizer and will contribute to the inorganic pool rather than the organic pool. The result of the characterization of the poultry manure (Table 4) showed that the poultry manure had more of nitrogen and phosphorus and this would have contributed more to the organic P pool. Increase in organic P was however observed to the 4^{th} week when poultry manure was applied in combination with SSP but decreased at 6WAI when poultry manure was applied alone. The largest extractable P was however obtained when poultry manure was applied at 20 t ha^{-1} in combination with 45 kg P ha^{-1} of SSP. About 36 years ago, a similar result was obtained [18].

3.2 Residual P

The residual P fraction of the soil as a result of the amendment is shown in the Table 6 and increased by both the sole application and the combined application of poultry manure and SSP. Although the sole application of SSP was more effective in increasing the residual P fraction than the sole application of poultry manure, the combined application of poultry manure at 15 t ha^{-1} and SSP at 15 kg P ha^{-1} gave the most significant increase and this occured at the initial stage of the incubation studies i.e. 2 weeks after incubation .After the initial increase, the residual P fraction started decreasing which signifies the release of P from the non-labile pool into the labile pool due to mineralization and hereby shows the importance of combining poultry manure with an inorganic fertilizer like SSP in increasing P availability in the soil. An increase in residual P fraction in a study on sequential changes in soil (Humic Gleysol) organic P and inorganic P has been reported [19]. While another study on continuous cultivation with cow dung and P fertilizer gave a decrease in the residual P fraction in a study on the dynamic of inorganic P and organic P pools of a savanna Alfisol [20].

Table 5. Effect of treatments on organic P in the incubation experiment

	2WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	48.98u	60.23r	59.78s	46.57u	51.88t
5	110.75h	87.23n	86.95n	80.92o	63.45q
10	175.63c	117.50g	69.76p	93.75m	250.20a
15	148.13d	98.75j	81.13o	128.25e	96.88l
20	100.03i	184.38b	118.13f	100.04i	98.01k

	4WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	34.50u	56.72q	53.75r	50.20t	38.13u
5	46.25s	291.25i	168.73l	341.85e	241.88j
10	227.50k	309.34h	133.62n	185.03l	388.13c
15	107.50p	125.10o	352.50d	166.85m	337.75f
20	313.13g	105.56p	226.50j	590.43a	390.66b

	6WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	22.78t	44.38s	22.50t	48.38s	53.13r
5	123.75m	110.13n	75.00p	140.63k	387.50b
10	106.25o	216.88i	73.13q	318.75d	286.10e
15	356.25c	128.79l	149.38j	264.38g	223.21h
20	431.24a	128.84l	216.88i	275.03f	148.13j

	8WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	36.40s	40.56r	18.72t	38.90s	40.20r
5	48.90q	123.10k	186.25e	148.13h	225.03c
10	672.88a	130.00j	85.63n	146.88h	85.63n
15	101.22m	180.12f	202.50d	68.75p	356.25b
20	75.63o	118.72l	140.63i	170.21g	107.50m

	10WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	22.72s	34.56r	18.02t	34.32r	38.76q
5	128.70l	118.86m	184.20f	138.12k	94.70o
10	267.50b	147.50j	132.22k	193.10e	196.88d
15	100.05n	150.22i	171.25g	76.42p	105.15n
20	278.13a	98.20o	154.38h	232.45c	109.38n

Means with the same letter are not significantly different from each other

Table 6. Effect of treatments on Residual P in the incubation experiment

			2WAI		
			P rates (kg P/ha)		
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	34.50l	116.25e	61.25i	72.50h	157.50b
5	71.88h	45.63k	99.38f	49.38k	90.00f
10	50.63j	83.13g	51.23j	140.00c	125.63d
15	91.25f	242.50a	80.63g	115.63e	81.25g
20	79.99g	41.88k	68.13i	42.50k	48.13k

			4WAI		
			P rates (kg P/ha)		
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	36.90h	76.88e	72.50e	35.63h	98.13d
5	77.50e	38.75h	50.63f	54.85f	219.38a
10	93.13d	71.25e	57.50f	116.25c	98.13d
15	76.88e	38.75h	96.25d	71.88e	57.50f
20	59.97f	79.38e	126.26c	41.25g	156.85b

			6WAI		
			P rates (kg P/ha)		
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	30.34m	136.23g	122.50h	84.38k	153.13e
5	84.38k	218.19b	69.38l	130.63g	121.88h
10	116.25i	231.25a	69.33l	86.88k	160.03d
15	144.38f	89.38k	209.38b	168.13d	195.00c
20	86.20k	103.13j	135.63g	130.63g	181.23c

			8WAI		
			P rates (kg P/ha)		
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	22.50l	50.00h	45.03j	44.71j	80.03e
5	43.75j	112.50d	162.50b	39.38k	41.88j
10	72.50f	56.25h	82.50e	76.88f	48.13i
15	60.42g	55.03h	44.38j	40.03j	48.14i
20	66.25g	221.88a	45.63j	140.63c	35.63k

			10WAI		
			P rates (kg P/ha)		
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	22.78h	47.83f	117.50c	40.12f	65.00d
5	56.88e	38.75g	161.25b	36.25g	54.38e
10	42.50f	53.13e	45.63f	191.25a	63.13d
15	69.25d	46.88f	55.03e	51.25e	36.88g
20	59.38e	58.75e	50.03e	190.06a	47.50f

Means with the same letter are not significantly different from each other

3.3 Fe-P

Effect of the amendments on Fe-P in the soil is shown in Table 7. This particular soil was formed on a basement complex rock and Fe-P alongside Al-P signifies the capacity of the soil to supply P into the soil solution. In Iwo soil, a soil formed on the basement complex rock, most of the mineralized P were converted to Fe-P and Al-P [21]. Most amendments increased the Fe-P fraction to the 6th week of incubation with a decrease at 8WAI. Availability of P is determined by the dynamic relationship between labile P and the solution P. As Fe-P decreases at 8WAI, phosphorus will become available in the soil solution. However, at 10WAI, Fe-P later increased as a result of most amendments with the largest extractable Fe-P obtained when PM was applied at 20 t ha^{-1} with 30 kg P ha^{-1} of SSP. Increases in Fe-P during an incubation studies have been observed on some calcareous soils [22]. A high significant increase in Fe-P as a result of the application of organic manure and inorganic fertilizers have also been reported [23].

3.4 Al-P

The effect of sole application of single superphosphate and the combined application of poultry manure and single superphosphate on the Al-P fraction was significant.(Table 8) The sole application of poultry manure though significant did not increase the Al-P fraction . During the incubation study, Al-P increased to the 6th week of incubation before decreasing, indicating immobilization of P before the 6th week and invariably inavailabilty of P in the soil solution. The highest significant increase was obtained with the sole application of 30 kg P ha^{-1} of SSP at 6WAI (390.63 mg kg^{-1}). Similar results were obtained in a study on an andosol to evaluate wheat yield, P and N uptake and soil P fraction in a long term fertilization [24].

3.5 Occluded P

The effect of the sole and combined application of poultry manure and SSP on the occluded P fraction is shown in Table 9. The sole application of SSP highly increased the occluded P fraction while the application of poultry manure decreased it. The decrease in this fraction indicates the ability of poultry manure to decrease P fixation and increase P availability in the soil solution [25]. Application of 30 kg P ha^{-1} of SSP gave the largest value of 327.50 mg kg^{-1} at 6WAI. Increase in occluded P have been observed in a calcareous soil as a result of fertilization [26].

Table 7. Effect of treatments on Fe-P in the incubation experiment

	2WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	35.67o	68.13e	70.63d	75.63c	50.63l
5	66.25f	62.50g	60.62h	53.10j	59.38i
10	46.88n	30.61p	69.20e	50.63l	131.25a
15	50.63l	88.75b	51.88k	77.50c	61.88g
20	47.50n	45.63n	88.75b	48.75m	59.38i

	4WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	47.80l	85.63c	68.75i	71.88h	81.25d
5	73.13g	61.88j	56.85k	80.19d	58.75k
10	75.63f	78.13e	97.50a	70.73h	71.25h
15	84.42c	70.51h	91.88b	81.88d	56.25k
20	73.13g	68.75i	98.75a	77.50e	76.88e

	6WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	26.57p	75.03k	101.25b	90.57g	80.63j
5	96.25d	79.38k	90.11g	89.38h	78.21k
10	70.63n	76.25l	71.25n	92.50f	102.50b
15	71.88n	98.22c	105.03a	73.75m	66.25o
20	94.38e	92.86f	98.91c	81.88i	92.23f

	8WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	31.20n	59.21g	59.38g	61.05f	47.50j
5	90.23b	92.70a	41.25l	55.03h	51.25i
10	38.75m	54.38h	75.00d	81.25c	55.03h
15	59.21g	65.63e	93.75a	72.35d	59.38g
20	50.63i	60.03f	45.00k	82.95c	48.75j

	10WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	29.80p	25.03q	45.03l	100.20c	62.42i
5	62.50i	51.88k	38.75n	73.13g	147.50b
10	34.38o	46.88l	40.63m	63.75i	73.13g
15	70.63h	88.91d	44.38l	79.38f	71.25h
20	54.38j	85.03e	151.25a	36.25n	50.11k

Means with the same letter are not significantly different from each other

Table 8. Effect of treatments on Al-P in the incubation experiment

	2WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	78.20a	31.25d	37.50d	28.10f	31.25d
5	36.88d	34.38d	22.25h	28.13f	30.32e
10	25.50g	22.24h	15.50i	25.63g	36.25d
15	27.50f	36.88d	30.12e	37.50d	61.20b
20	41.88c	24.38g	35.63d	29.38f	15.63i

	4WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	88.45a	36.88h	59.23e	60.78e	63.73d
5	73.75c	71.25c	60.23e	73.75c	60.63e
10	66.25d	58.73e	32.91h	42.14g	75.63c
15	65.60d	38.21h	59.38e	40.33g	74.45c
20	77.50b	65.03d	39.02h	60.36e	51.62f

	6WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	112.40d	378.77b	390.63a	148.15c	78.75i
5	96.25f	103.29e	81.25h	94.22f	68.88j
10	64.21j	83.25h	71.25i	108.75e	90.21g
15	81.88h	78.75i	73.73i	62.24j	96.25f
20	88.13g	82.50h	105.63e	105.03e	92.64f

	8WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	103.50a	35.63e	51.25c	34.38e	41.10d
5	40.70d	56.25c	34.38e	50.63c	29.38f
10	54.60c	31.25e	35.63e	38.75e	40.63d
15	31.07e	52.50c	40.22d	31.88e	59.38c
20	31.25e	30.03e	43.75d	63.14b	31.25e

	10WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	105.26b	28.13h	55.03e	42.50f	28.13h
5	26.89h	45.63f	56.88e	93.13c	38.75g
10	43.75f	133.13a	43.75f	41.88f	54.38e
15	37.50g	41.88f	26.25h	41.88f	68.75d
20	30.63g	68.75d	50.03e	52.50e	41.88f

Means with the same letter are not significantly different from each other

Table 9. Effect of treatments on Occluded P in the incubation experiment

	2WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	22.98f	59.38c	46.25d	57.50c	37.50e
5	20.07f	38.75e	45.03d	91.25a	41.25d
10	16.25g	57.50c	36.25e	56.88c	58.23c
15	16.88g	39.38e	42.50d	56.88c	37.50e
20	20.03f	54.38c	75.63b	57.50c	52.50c

	4WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	36.74i	92.50d	65.01f	75.03e	69.38f
5	18.63j	66.88f	72.25e	79.21e	58.13h
10	14.22j	74.12e	67.50f	60.73g	71.56e
15	12.10j	68.73f	113.13b	136.88a	58.75h
20	19.63j	58.13h	60.63g	103.92c	117.50b

	6WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	38.98i	61.88h	327.50a	63.13h	98.05e
5	16.25j	105.03d	101.62d	65.00h	62.50h
10	12.75j	61.88h	61.85h	61.25h	68.75h
15	13.75j	90.89f	66.88h	106.88d	75.03g
20	17.50j	111.78c	141.78b	65.63h	102.60d

	8WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	27.30g	108.13b	140.06a	98.60c	35.03f
5	21.63g	88.75d	38.75f	40.75e	93.75c
10	17.50h	35.00f	101.25b	83.13d	39.38f
15	19.40h	109.38b	109.38b	139.38a	30.03f
20	25.63g	42.50e	39.38f	104.76b	37.50f

	10WAI				
	P rates (kg P/ha)				
Poultry manure (t/ha)	**0**	**15**	**30**	**45**	**60**
0	39.10f	51.88d	53.75d	58.13d	54.38d
5	28.75g	51.88d	51.25d	82.15a	51.88d
10	29.38g	58.13d	55.00d	50.00d	55.03d
15	26.25g	51.88d	49.38e	83.91a	61.25c
20	24.38g	71.88b	46.88d	39.38f	42.50d

Means with the same letter are not significantly different from each other

4. CONCLUSION

Fractionation of P at the initial stage showed Al-P to be the largest fraction in the soil used. However, during incubation, application of 30 kg P ha^{-1} of SSP highly increased the Al-P fraction which was the same rate that led to the most significant increase in the occluded P fraction and therefore not a suitable treatment for P availabilty because occluded P is a non-labile P fraction which is not easily made available in the soil solution for plant use. The amount of P in solution at a given time is based on P sorption of P to Al/Fe and soil surfaces. The most significant increase in Fe-P which will invariably increase the solution P was observed with the application of 20 t ha^{-1} of poultry manure in combination with 30 kg P ha^{-1} of SSP and therefore a recommended rate of application.

COMPETING INTERESTS

Authors have declared that no competing interest exits.

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