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Influence of Organic Manure on Phosphorus and Potassium Fractions in Soil Planted with Soybean

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Authors' contributions

This work was carried out in collaboration with all the authors. This work was part of my PhD research work with authors MTA, COA and JGB as members of supervisory team. Author JOA provided valuable literature materials, helped in fractionation procedures, and preparation of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were carried out on the Research Farm of the Federal University of Agriculture Abeokuta, (FUNAAB), Ogun State, Nigeria to determine the effects of poultry manure (PM) on soil P and K fractions and nutrient availability to soybean plants. Treatments consisted of five rates of PM (0, 2.5, 5.0, 7.5 and 10 tha^{-1}) and 100 kg ha^{-1} of NPK 20:10:10 fertilizer as basal application. Soybean (TGx 1448-2E) was cultivated in two planting seasons. The experimental design was randomized complete block design with three replicates. During the second year (second season), treatments were not applied to evaluate residual effects. Results from phosphorus fractionation showed that residual P, redundant soluble P and occluded P had highest values of the inorganic P in the first planting season. Application of PM reduced P fixation, residual P and occluded P fractions in the soil in the second season. Available P significantly ($P \le 0.05$) increased in most treated soils and greater in second season. The values of total and mineral K were higher than

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those of the other forms. The abundance of soil K fractions in the soils followed the order: Total K > mineral K > non exchangeable K > 1N HCl K > 1N HNO_3 K > available K > exchangeable K > water soluble K. There were increases in all the K fractions. Application of PM significantly increased concentrations of N, P and K in plant tissue. The study concluded that application of 10 tha^{-1} PM minimised P fixation, increased available K, increased nutrient uptake and improved crop yield in soybean. Therefore, poultry manure is recommended for production of soybean in Abeokuta soil.

Keywords: Poultry manure; phosphorus fractions; potassium fractions; soybeans.

1. INTRODUCTION

Most of the agricultural lands in Nigeria have the proble m of low fertility status due to continuous cultivation [1,2]. Agbede TM. Mbah CN.This necessitates the use of soil amendment in forms of inorganic fertilizers, organic manures or combination of the two. The two major limiting nutrients in crop production after nitrogen are phosphorus and potassium and are obtainable in most organic manures.

There are many forms of P in the soil. These include: (i) primary mineral P (ii) secondary mineral P (iii) strongly sorbed inorganic P (iv) labile inorganic P (v) solution P (vi) microbial P (vii) labile organic P (viii) stable soil organic matter associated P [3,4]. The value of total P in soils is affected by parent materials, cropping history, applied soil amendment, and soil type. The total inorganic phosphorus is divided into active and inactive forms. The active P forms consist of Fe-P, Al-P, and Ca-P and the inactive forms consist of occluded P, reductant soluble P and residual P [5]. For efficient P management, it is essential to understand the relationships and interactions of the various forms of P in soils and the numerous factors that influence P availability [4,6].

Total organic P decreases steadily in continuous cropping situation without P fertilization [7]. Organic P generally accounts for 30% to 65% of the total P in soils [8]. The rate of mineralization of organic P generally increases with increasing soil temperature, often being quite rapid at temperature above 30℃ while below 30℃ little mineralization occurs [9].

Potassium exists in four forms in the soil. These include the solution, exchangeable, non-exchangeable or fixed and mineral or structural K forms [10,11,12]. The amount of each K fraction varies, depending on cropping history, as well as chemical fertilizer or organic manure application [13,14,15]. In some soils, non-exchangeable K becomes available as the exchangeable and solution K are removed by cropping or lost by leaching. In other soils, release from non-exchangeable K is slow to meet crop requirement. When there is surplus K in the soil solution (especially following the addition of fertilizer) the element is transferred to the exchangeable and non-exchangeable fractions through exchange and fixation process [14]. Soybean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and diverse domestic usage. Soybean has an average protein content of 40% and is more protein-rich than any of the common vegetable or animal food sources found in Nigeria. Soybean seeds also contain about 20% oil on a dry matter basis, and this is 85% unsaturated and cholesterol-free [16]. It is therefore important to understand the role of soil amendment in increasing the availability of phosphorus and potassium in soil cultivated with soya bean. Does application of PM to soil increase the availability of potassium and phosphorus and at what rate? What effects does this amendment have on P and K fractions, and concentrations of N, P and K in soybean tissue?

The objectives of this study are to evaluate the effects of poultry manure application on phosphorus and potassium fractions, nutrient bioavailability, and yield of soya bean.

2. MATERIALS AND METHODS

2.1 Field Experiments

The field experiments were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta. Soybean was cultivated in two planting seasons at this location. The experimental design was randomised complete block design with three replicates and plot size was 4 m by 4 m. 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 plots. Organic manure was applied two weeks before planting. Inorganic fertilizer was applied two weeks after planting. Soybean seeds (TGx 1448-2E) were treated with fungicide (Apron plus) to prevent fungal attack prior to germination and soon after germination. Application of treatment and planting were preceded by land preparation which included ploughing and harrowing. Land preparation was not done the second growing season. Plant spacing was 60 cm between rows and drilling of seeds at 5 cm along the rows. Thinning of seedlings was done after two weeks to ensure one plant per stand. Weeds were controlled by pre-emergence herbicides after planting. Soybean was grown to maturity, allowed to dry and harvested. For plant samples, upper mature leaves were taken prior to initial seed set after planting [17]. The plant samples were chemically analysed for N, P and K. Soil samples were taken before planting and at harvest. Soil samples were taken, air-dried and analysed for soil pH, P and K fractions, pH, available P, exchangeable bases, organic C and effective cation exchange capacity was determined. Plant height, dry matter yield and grain yield were collected as agronomic data.

2.2 Characteristics of the Soil Used

The field site is located in Abeokuta, Nigeria, at longitude N 7° 14.30ˡ and latitude E 3° 26.21ˡ. The soil was classified as Typic Paleustalf .The soil is a loamy sand with sand, silt, and clay having values of 772, 88, and 140 g kg^{-1} respectively. The soil pH (in water) was slightly acidic with the value of 6.3 and organic C was 29.0 g kg^{-1}. Available P, 12.7 mg kg^{-1}; nitrogen, 1.7 g kg^{-1}; Ca, Mg, K, Na were 1.88, 1.25,0.34 and 0.29 cmol kg^{-1} respectively. This showed that the cations order of abundance was: Ca > Mg > K > Na. Exchangeable acidity and ECEC were 0.1 and 3.86 cmol kg^{-1} respectively.

2.3 Poultry Manure Analysis

Total analysis was done by wet digestion. This involved addition of 10ml of HNO3/$HClO_4$ (2:1) to 0.5 g of poultry manure and digested at 150℃. After heating for 90 minutes the temperature was increased to 230℃ and 2 ml of HCl/H_2O (1:1) was added. The digestion was allowed to continue for 30 minutes [18].The results are shown in Table 1.

2.4 Chemical Composition of Poultry Manure

The chemical composition of poultry manure used is shown in Table 1. Nitrogen was higher than other macro nutrients. Phosphorus was 14.9 g kg^{-1}% and potassium was 14.2 g kg^{-1}. Organic carbon was 128.4 g kg^{-1} and C: N was 5.44.

2.5 Soil Physical and Chemical Analysis

Particle size distribution was determined by the hydrometer method [19]. Soil pH was determined in 1:1 (soil-water ratio) using electrode pH meter [20]. Nitrogen was determined by Kjeldahl method [20]. Organic matter was determined by the wet digestion method by Walkley and Black [21]. Exchangeable sodium, potassium, calcium and magnesium in the soils were extracted with neutral ammonium acetate (1M NH_4OAC). Extracted K and Na were determined by flame photometry while Ca and Mg were determined by atomic absorption spectrophotometry [22]. Available phosphorus was determined by Bray 1 P extraction method and analysed colorimetrically by molybdenum blue procedure [23]. Soil exchangeable acidity was determined by titration of normal KCl extracted acidity against 0.05 N sodium hydroxide solution [24].

2.6 Phosphorus Fractionation Study

Phosphorus fractionation procedure by Chang and Jackson [5] and Peterson and Corey [25] was 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 soil. Saloid P was extracted by 50 ml of NH_4Cl and Al-P by 50 ml of 0.5 NH_4F. This was followed by Fe-P extraction using 0.1M NaOH, saturated NaCl and 5 drops of concentrated H_2SO_4. Reductant soluble P was extracted by 25 ml of 0.3M sodium citrate, 1g solid sodium dithionate and saturated NaCl. Occluded P by

Table 1. Some chemical properties of the poultry manure used

Parameter	Value	Parameter	Value
Nitrogen	23.6 g kg^{-1}	Iron	7.0 g kg^{-1}
Phosphorus	14.9 g kg^{-1}	Sulphur	5.7 g kg^{-1}
Potassium	14.2 g kg^{-1}	Zinc	53.50 mg kg^{-1}
Calcium	4.3 g kg^{-1}	Organic carbon	128.4 g kg^{-1}
Magnesium	1.8 g kg^{-1}	C : N	5.44

50 ml of 0.1 M NaOH and concentrated H_2SO_4. Extraction of Ca-P was by 50 ml 0.25M H_2SO_4. Residual P extracted by combination of concentrated HNO_3, HCl and 30% H_2O_2. The different fractions of P were determined in all the samples taken from the soil before and after organic amendment. Organic P was determined by ignition method [26,27].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. Bray 1 P not included in Total P calculation.

2.7 Potassium Fractionation Study

For K fractionation, each of the K fractions was determined separately (non-sequential procedures). Fixed K in the soil samples was extracted by 1N HNO_3 in 1: 10 soil - acid suspension with boiling for 10 minutes [28,29]**.** Similarly, 1N HCl extractable K was obtained in 1: 10 soil - acid suspension with boiling for 60 minutes [28,30,31]**.**Total K was determined by digesting the soil sample in combination of concentrated perchloric acid ($HClO_4$) and concentrated nitric acid (HNO_3) using a soil - acid ratio of 1: 10 [32]. Available K was extracted with 1M NH_4OAc (at pH 7.0) [33]. Water-soluble K was extracted with distilled, deionised water in 1: 10 soil-water suspension [31,34]**.** Exchangeable K was obtained by subtracting water-soluble K from 1M NH_4OAc (at pH 7.0) extractable K (Available K). Non-exchangeable K was obtained by deducting available K from total K. Mineral K was obtained by the difference between non-exchangeable K and the fixed K (1N HNO_3 K) [35]. The K in the extracts was determined by flame photometry.

The data collected were subjected to analysis of variance (ANOVA) using GENSTAT. Means were separated by Least Significant Difference and Regression analysis conducted.

3. RESULTS AND DISCUSSION

3.1 Effects of Organic Manure Application on Phosphorus Fractions and Available P in Field Experiments

The P fractions and available P are shown in Table 2. Application of manure treatment had significant effect on all the phosphorus fractions in both first and second seasons. In first season, the order of abundance of P fractions was: Organic P > residual P > reductant soluble P > occluded P > saloid P > Fe-P > Al-P > Ca-P. In second season, the order of abundance of P fractions was: organic P > residual P > Fe-P > saloid P > Ca-P > reductant soluble > Al-P > occluded P. This indicated high reduction in occluded P and reductant soluble P. Out of the three active inorganic P fractions (Al-P, Fe-P and Ca-P), Fe-P was observed to be the highest in the soil. This supported the observations earlier made that most Nigerian soils are dominated by Fe-P fraction [36,37,38,39]. 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 before plants could use it [40].

Significant decrease in occluded P in soils could be attributed to organic compounds and enzymes contained in organic manure which caused the release of some occluded P held up. Similar results were reported [41,42]. Total P ranged from 504.40 to 555.16 mg kg^{-1} in first season and from 182.59 to 283.08 mg kg^{-1} in second season. This significant reduction in total P could be the results of plant uptake, mineralisation, run off, erosion and leaching. Organic P ranged from 119.46 to 196.14 mg kg^{-1} in first season and from 89.94 to 156.23 mg kg^{-1} in second season. Reduction in organic P is attributed to its conversion to inorganic P by micro organisms. This resulted in increase in available P in the soil. Complexing of metal cations (Fe, Al, Ca, and Mg) which bind phosphates by organic anions, and the displace of phosphates from the soil matrix by process of ligand exchange has been reported [43,44]. Bray 1 P increased with increase in rate of treatment.

In first season, highest value of Fe-P (53.70 mg kg^{-1}) obtained was observed at 7.5 t ha^{-1}. This showed 307% increase over the control (13.20 mg kg^{-1}). In second season, Fe-P obtained at 10 t ha^{-1} was significantly higher than all treatment rates. In first season, occluded P ranged from 50.95 to 98.38 mg kg^{-1}, while there was decrease in second season, it ranged from 0.88 to 2.53 mg kg^{-1}. In first season, residual P at 5.0 t ha^{-1} increased significantly over other treatment rates, while in second season, the value in control experiment was significantly higher than other treatment rates. Lowest value was recorded at the highest rate of poultry manure. Reduction in residual P had been reported [42,45]. In both first season and second season, saloid P increased significantly when 10 t ha^{-1} of poultry manure was used. This is attributed to formation of loosely bond P from P released during the process of mineralisation. Similarly, there was general decrease in Al-P and reductant soluble P in second season compared to first season due to the effect of poultry manure application. Bray 1 P in second season was greater than first season. The highest value was 79.28 mg kg^{-1} at 7.5 t ha^{-1} indicating 499 % increase over the control. Increase in Ca-P at some treatment rates could be attributed to build up of Ca-P due to fixation of released inorganic P from mineralization of organic P by Ca compounds.

Application rate of 10 t ha^{-1} of poultry manure significantly increased organic P compared to other treatment rates in both first and second seasons since poultry manure is a rich source of organic P. Influence of soil pH, organic matter, activities of microorganisms, rate of application of soil amendments on soil P fractions has been reported [46,47].

3.2 Effects of Organic Manure Application on Potassium Fractions in Field Experiments

Effects of organic manure application on K fractions in Abeokuta field experiments are shown in Table 3. In both seasons application of manure treatment had significant effects on all the K fractions except 1N HNO_3 K. Increase in available K in treated soils compared to control was observed. In second season, there was 55% increase in available K in treated soil with 10 t ha^{-1} of poultry manure over the control. Values of 1N HNO_3 K were less than 1N HCl K in both years. Similar trend had been reported [48,49]. Highest exchangeable K and non exchangeable K in second season were 0.25 and 69.77 cmol kg^{-1} respectively.

Increase in available K, water soluble K and exchangeable K in the second season compared to first season was as a result of the residual effects of poultry manure applied to the soil. There was more release of organically bound K from poultry manure following its mineralisation to inorganic forms. This supported results earlier reported [50,51]. Water soluble K in the soil was generally low probably because of leaching and erosion. High values of mineral and non exchangeable K are the indications that the soils can supply K in long term cultivation.

A large percentage of soil K was in unavailable forms. Exchangeable K was less than non-exchangeable K. Similar situations had been reported [52,53,54]. Increase in total K in treated soils compared to control could be attributed to increase in water soluble K and exchangeable K as well as non exchangeable K, since total K consisted of these forms of K and mineral K. Earlier work also observed increase in soil total K following the use of inorganic and organic manures [52,55]. This was attributed to fixation of added soluble K by clay mineral [55]. Water soluble K was lower than exchangeable K. These two fractions have been reported to be the forms easily absorbed by plants [15,56.57]. Benefit of high non exchangeable K in this soil is their high potential K supplying power. When there is depletion in exchangeable K and water soluble K due to plant uptake or leaching, non exchangeable K replenishes the lost K and therefore maintaining the natural balance.

3.3 Effects of organic manure application on concentrations of N, P and K in plant tissue and some agronomic parameters in field experiments

Some agronomic parameters and concentrations of N, P and K in plant tissue observed in the Abeokuta field experiments are indicated in Table 5.Highest plant heights of 70.67 and 72.33 cm were obtained in first season and second season respectively. Both were obtained at 10 t ha^{-1}. Application of organic manure had significant effect on dry matter yield in second season. However, highest dry matter yields were obtained at treatment rate of 10 t ha^{-1} in both years. Dry matter yield in second season was higher than first season. Application of organic manure had significant effect on grain yield in second season. Highest seed yields for both years were obtained at treatment rate of 10 t ha^{-1}. More seeds were obtained in second season than first season.

Higher concentrations in plant tissue of the three nutrients were observed in second season than first season. Plant height, dry matter yield, grain yield, and number of pods per plant increased in the second season more than the first season because of residual effect of organic manure. Strong residual effect has been reported in second planting season following the use of manure [58]. These increases in agronomic parameters nitrogen uptake could also be attributed to increase in nitrogen uptake facilitated by symbiotic fixation of N by Rhizobia bacteria in the root nodules of soybean. Following decomposition and mineralisation, other essential nutrients must have increased in the soils because organic manure is known to be reservoir of macro and micro nutrients.

Table 2. Initial phosphorus values (pre cropping) and effects of organic manure on phosphorus fractions and Bray 1 P in Abeokuta field experiments

Season	**Manure rate (t ha^{-1})**	**Phosphorus fractions (mg kg^{-1})**									
		Saloid P	**Al –P**	**Fe- P**	**Ca- P**	**Occluded P**	**Reductant Soluble P**	**Residual P**	**Organic P**	**Total P**	**Bray 1 P**
Initial value		24.22	19.22	63.82	26.44	94.44	70.74	121.33	115.32	535.53	12.70
First season	0	36.74 b	10.48 b	13.20 d	5.77 c	98.38 a	93.80 ab	124.57 c	119.46 c	502.40 b	10.89 c
	2.5	34.38 b	17.66 a	20.69 cd	2.88 c	85.60 a	91.47 ab	117.33 cd	125.86 bc	495.87 b	18.19 bc
	5	32.84 b	16.89 ab	31.25 b	11.06 b	82.87 a	97.68 a	167.53 a	147.23 bc	587.35 a	27.95 a
	7.5	13.34 c	15.98 ab	53.70 a	20.67 a	50.95 b	80.43 ab	147.20 b	158.16 b	540.43 ab	22.86 ab
	10	56.44 a	16.44 ab	25.09 bc	20.19 a	63.07 b	74.03 b	103.77 d	196.14 a	555.16 ab	23.48 ab
Second season	0	8.64 d	0.44 c	7.56 c	4.64 c	1.14 a	8.22 a	67.32 a	89.94 c	187.90 c	13.24 d
	2.5	12.60 cd	0.83 bc	9.83 c	8.87 bc	0.92 ab	4.43 b	48.58 bc	96.54 c	182.59 c	41.43 c
	5	15.60 bc	1.53 ab	17.49 b	12.74 b	0.98 ab	3.16 bc	51.87 abc	129.90 b	233.27 b	62.90 b
	7.5	20.27 ab	1.90 a	29.11 a	25.17 a	0.60 b	2.04 c	59.21 bc	144.79 a	283.08 a	75.06 a
	10	24.45 a	1.16 bc	30.04 a	24.56 a	0.76 ab	1.92 c	38.02 c	156.23 a	277.14 a	79.28 a

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

Table 3. Initial potassium values (pre cropping) and effects of organic manure on potassium fractions in Abeokuta field experiments

Season	**Manure rate (t ha^{-1})**	**Potassium fractions (cmol kg^{-1})**							
		Avail. K (1M NH$_4$OAc)	**H$_2$O soluble K**	**Exchangeable K**	**1N HNO$_3$ K**	**1N HCl K**	**Non Exch. K**	**Mineral K**	**Total K**
Initial value		0.34	0.03	0.31	0.45	0.96	36.38	35.93	36.72
First season	0	0.22 d	0.05 bc	0.17 d	0.59 a	2.20 c	52.12 b	51.53 b	52.34 b
	2.5	0.32 c	0.04 c	0.28 c	0.61 a	2.89 b	55.47 ab	54.86 ab	55.79 ab
	5	0.28 cd	0.05 bc	0.23 c	0.63 a	3.20 a	57.07 a	56.44 a	57.35 a
	7.5	0.63 a	0.07 ab	0.56 a	0.70 a	2.99 b	58.71 a	58.01 a	59.34 a
	10	0.54 b	0.08 a	0.46 b	0.66 a	2.89 b	57.91 a	57.25 a	58.45 a
Second season	0	0.20 c	0.04 bc	0.16 c	0.51 a	2.01 a	54.74 b	54.23 b	54.94 b
	2.5	0.21 c	0.03 c	0.18 bc	0.55 a	1.98 ab	53.50 b	52.95 b	53.71 b
	5	0.23 bc	0.04 bc	0.19 bc	0.56 a	1.95 ab	66.47 a	65.91 a	66.70 a
	7.5	0.25 b	0.05 ab	0.20 b	0.58 a	1.94 b	67.27 a	66.69 a	67.52 a
	10	0.31 a	0.06 a	0.25 a	0.54 a	2.00 a	69.77 a	69.23 a	70.08 a

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

Table 4. Effects of organic manure on some agronomic parameters and concentrations of N, P and K in plant tissue in Abeokuta field experiments

Season	Manure rate (t ha^{-1})	Plant height (cm)	Dry matter yield (t ha^{-1})	Grain yield (t ha^{-1})	No of pods per plant	Tissue concentrations		
						N %	P %	K %
First season	0	48.67 d	1.66 a	0.73 a	111.33 c	0.54 c	0.10 b	0.89 ab
	2.5	55.67 cd	1.69 a	0.75 a	121.33 bc	0.74 bc	0.12 ab	0.75 b
	5	60.67 bc	1.78 a	0.76 a	157.67 ab	0.72 bc	0.14 ab	0.95 ab
	7.5	65.00 ab	1.99 a	0.70 a	176.67 a	0.89 ab	0.19 a	1.05 a
	10	70.67 a	2.05 a	0.99 a	137.00 abc	1.03 a	0.17 ab	1.02 a
Second season	0	46.00 c	2.03 b	0.86 d	145.33 c	0.82 b	0.15 d	0.87 c
	2.5	56.67 b	2.93 a	1.26 b	173.67 bc	0.96 ab	0.09 d	0.97 bc
	5	65.33 ab	2.49 ab	1.14 c	212.00 ab	0.91 b	0.23 c	0.96 bc
	7.5	68.33 a	3.01 a	1.33 b	238.67 a	1.03 ab	0.30 b	1.13 ab
	10	72.33 a	3.18 a	1.46 a	205.00 ab	1.15 a	0.39 a	1.29 a

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

Table 5 shows the potential yield effects of switching each of the soil P and K fractions on variation in grain yield using regression analysis. Table 6 shows percentage variance accounted for by soil P and K fractions with the most potential effects on grain using regression equation. Saloid P had the highest potential change effects on grain yield in first season followed by water soluble K. Only saloid P contributed significantly ($p<0.001$) to the variation in grain yield among the first three variable involved in the equation. With additional increase in number of parameters with higher potential effects added to the equation there was gradual increase in percentage variance accounted for by the variables from 44.4 to 50.2% (with addition of water soluble K), but a reduction in % variance accounted for with addition of organic P.

In the second season Bray 1 P (available P) contributed most to the variation in grain yield and accounted for 74.4% of the total variation. This was followed by reductant soluble P. With addition of reductant soluble P, the % variation in grain yield accounted for by the variables increased from 74.4 to 75.6%. Bray 1 P contributed significantly ($p<0.001$) to variation in grain yield when involved alone in the equation. With addition of other variable with high potential change (saloid P), no significant contribution of the Bray 1 P was observed.

Table 5. The potential effects of switching each of the soil P and K fractions on variation in grain yield using regression equation

Soil fractions	DF	Mean square	
		First season	Second season
Saloid P	1	0.1010	0.4509
Al P	1	0.0005	0.1607
Fe P	1	0.0128	0.2892
Ca P	1	0.0332	0.4352
Occluded P	1	0.0178	0.2272
Reductant soluble P	1	0.0115	0.4805
Residual P	1	0.0418	0.2511
Organic P	1	0.0503	0.3683
Total P	1	0.0024	0.2874
Bray 1 P	1	0.0025	0.4944
Available soluble K	1	0.0145	0.2534
Water soluble K	1	0.0524	0.0609
Exchangeable. K	1	0.0106	0.2218
1N HNO_3 K	1	0.0002	0.0177
1N HCl K	1	0.0004	0.0029
Non Exch. K	1	0.0040	0.0974
Mineral K	1	0.0041	0.0974
Total K	1	0.0043	0.0982

Table 6 shows percentage variance accounted for by soil P and K fractions with the most potential effects on grain yield using regression equation. Bray 1 P had greatest effect on grain yield in the second season. This supported well known that phosphorus is needed for the formation of seeds in crops.

Table 6. Percentage variance accounted for by soil P and K fractions with the most potential effects on grain yield using regression equation

Season	Parameter	Estimate	S.E	% variance accounted for	T pr.	F. pr
First season	Constant	0.5917	0.0602	44.4	<0.001	0.004
	Saloid P	0.0056	0.0016		<0.004	
	Constant	0.4956	0.0834	50.2	<0.001	0.006
	Saloid P	0.0048	0.0016		<0.011	
	H_2O soluble K	2.1800	1.3800		0.14	
	Constant	0.4680	0.1140	46.3	0.002	0.020
	Saloid P	0.0047	0.0017		0.018	
	H_2O soluble K	1.6400	2.0500		0.441	
	Organic P	0.0004	0.0011		0.718	
Second season	Constant	0.8213	0.0665	74.4	<0.001	<0.001
	Available P	0.0072	0.0011		<0.001	
	Constant	1.1100	0.2360	75.6	<0.001	<0.001
	Available P	0.0043	0.0025		0.117	
	RSP	-0.0332	0.0261		0.227	
	Constant	1.0550	0.2400	76.0	0.001	<0.001
	Available P	0.0031	0.0031		0.476	
	RSP	-0.0321	0.0259		0.241	
	Saloid P	0.0097	0.0089		0.299	

RSP- Reductant soluble P

Available P, saloid P and water soluble K contributed in greater proportion to grain yield. However, non labile or recalcitrant P and K are also important because interrelationship/ dynamics between the labile and non-labile P and K affects the equilibrium of these two nutrients in the soil.

4. CONCLUSION

There was significant decrease in total P, occluded P, residual P and reductant soluble P in 2012 compared to first season experiments. There was general increase in available P in most of the plots considered despite increase or decrease in other forms of P. Poultry manure contributed to the reduction in fixation of P and release of fixed forms of P. Organic manure initially increased soil K fractions, but these K fractions slightly decreased with time due to crop uptake, leaching and release from non exchangeable K to soil exchangeable K. Most of the soil K forms are in non available forms; and the exchangeable forms are less than non exchangeable forms. Poultry manure significantly improved soil nutrient status as shown in increased plant tissue concentrations, dry matter yields, and grain yields in second season field experiments compared to first season. This also indicated residual effects of poultry manure in this soil. Soil test should be done before next application of poultry manure in order to reduce pollution or chemical toxicity in the soil. It was concluded that poultry manure improved availability of soil P and K and crop yield.

COMPETING INTERESTS

We hereby declare that there is no competing interest among the authors or with any organization.

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