Eurasian J Soil Sci 2018, 7 (2) 187 - 194

Eurasian Journal of Soil Science

Journal homepage : http://ejss.fesss.org

Response of three soils in the derived savanna zone of southwestern Nigeria to combined application of organic and inorganic fertilizer as affecting phosphorus fractions

Abigail O. Ojo [a,*], Michael T. Adetunji [b], Christopher O. Adejuyigbe [b], Ibukun O. Fademi [a]

[a] Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria
[b] Department of Soil Science and Land Management, Federal University of Agriculture, Abeokuta, Nigeria

Article Info

Received : 17.06.2017
Accepted : 17.01.2018

Abstract

Phosphorus inputs to the soil are primarily from the application of fertilizer P and organic resources. A ten week incubation study was carried out to determine the effects of organic and inorganic P sources on phosphorus fractions in three derived savanna soils. Poultry manure was applied at 0, 0.75g, 1.5g, 2.25g and 3g per 300g weight of soil while single superphosphate was applied at 0.0023g, 0.0046g, 0.0069g and 0.0092g per 300g of soil. Sampling was done at two weeks interval. At 0 week of the incubation study, Ekiti series had the largest amount of P fractions i.e. Fe-P, Al-P, residual P, reductant soluble P, occluded P, organic P and occluded P while Ca-P was high in Apomu series. However, increases in Fe-P, Al-P, Ca-P and organic P were observed in the three soil series evaluated and poultry manure was notably effective in reducing P occlusion. In conclusion, it was observed that irrespective of the soil series at different stages of the incubation studies, poultry manure and the combined application of poultry manure and Single superphosphate was highly effective in increasing P fractions.

Keywords: Poultry manure, single superphosphate, phosphorus fractions, derived savanna soils.

Introduction

Nigeria is located in the tropical zone (between latitude 9.0820°N, and longitude 8.6753°E), with a vast area having savanna vegetation. The soils found in this agroecological zone have coarse-textured surface soil and low in organic matter and the soil chemical properties. The lack of P availability in many agricultural soils has been described as the 'the bottle-neck of world hunger'. Even if P is supplied it may be rapidly and irreversibly fixed in usually strongly P-fixing soils (Brookes, 2001). In Nigeria, most of the soils especially in the southwestern part of the country are limiting in phosphorus (Nziguheba and Bunemann, 2005). Low availability of P is one of the main constraints to agricultural production under wet tropical conditions (Hinsinger, 2001). Manure and inorganic P fertilizers can supply phosphorus to the soil but most farmers in Nigeria are poor and cannot afford the high cost of the inorganic fertilizers. As a result a lot of research work (Omotayo and Chukwuka, 2009, Ayeni, 2010; Usman et al., 2015) has been carried out in Nigeria to find alternative source of P. Such as the use of different animal manures. . Many researchers have found that soil phosphorus availability would increase after long term fertilizer P application (Halvorson and Black;1985, Samadi and Gilkes, 1998; Fan et al., 2003; Lai et al., 2003; Zhang et al., 2004). However, such an effect of fertilizer P application varies with the climatic condition, soil type and soil test method employed as well as the rate of fertilizer P applied (Zhang et al., 2004). Manure on the other hand, contains significant proportion

* Corresponding author.
Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria
Tel.: +2348033563972
E-mail address: remia_ode@yahoo.com
e-ISSN: 2147-4249
DOI: 10.18393/ejss.393289

of organic P fractions and inorganic P forms. Different P fractions differ in mobility, bioavailabilty and chemical behavior (Jalali and Ranjbar, 2010) and the different P fractions could indicate distinct bioavailability to crops. Manure has been shown through incubation studies to have increased soil organic P fraction content (Reddy et al., 2000) and P from manure sources gradually turn into available forms over time (Halajnia et al., 2009). The inorganic P has been observed to be the largest fraction of manure, >75% of total P (Eghball, 2003). However, approximately two-third of inorganic P and one-third of organic P are not available in soil (Yu et al., 2006) while 70-90% of P that enters the soil is fixed, making it difficult for plants to absorb and use (Lei et al., 2004). If soluble fertilizer phosphorus is placed in the soil, it reverts into slowly soluble or insoluble forms, removing soluble phosphorus from the soil solution. This phenomenon is often called "fixation" and these phenomenon is common in most Nigeria soils where continuous fertilization is practiced. Application of organic and inorganic fertilizer affects the distribution of P fractions in soils, which determines the availability of P with reduction in P fixation and this will invariably affect the yield of crops and the order of abundance differs from soil to soil as a result of amendments (Verma et al., 2005; Kolawole and Tian, 2007). Therefore, this study intends to assess the effect of adding poultry manure and single superphosphate to soils in the derived savanna region as affecting soil phosphorus fractions over a period of time.

Material and Methods

Background Information

The study area was located in Oniyo village situated between Ogbomoso and Kishi in the derived savanna region of Oyo, State, of southwestern part of Nigeria. The soils which have already been characterized to the series level were sampled on different farmers field in the region. Arable crops were planted solely and mixed cropped especially the maize/cassava intercrop. Most of the farmers in the locations by interviewing them was discovered to be subsistence farmers and therefore could not really afford buying inorganic fertilizers for use on their farm. However, some areas have received inorganic fertilizer over time while other areas received none.

Soil Characterization

Free survey method was employed to map the soils. Auger soil examinations were carried out on ten (10) farmers' field along different toposequences for soil type identification and boundary placement. Modal soil profile pits were dug based on the most representative auger examination. The soil profiles were described according to the FAO (2014). On the whole six modal soil profile pits (representing three soil types) were dug, described and sampled. The soils were classified into series level using the approaches of Moss (1957) and Murdoch et al. (1976).

Temidire series was described as been grey brown sandy soil, 50-100cm deep over hard iron pan. While Ekiti series was described as blackish sandy soil, stony, 50 cm deep over hard granite rock and Apomu series was described as very sandy in texture to a depth of 20 inches, free of stones and concretions to a similar depth with a pale greyish brown to reddish brown colour.

Table 1. Description of the soils used

Vegetation	Site Location		Soil series	Soil class (USDA)
Derived Savanna	Lat $8^0 17.66'$N	Log $4^0 10.86'$E	Temidire	Ferrudulf
Derived Savanna	Lat $8^0 17.80'$N	Log $4^0 10.90'$E	Ekiti	Ferrudulf
Derived Savanna	Lat $8^0 17.93'$N	Log $4^0 10.94'$E	Apomu	Hapludualf

Soil Chemical Analysis

Soil samples were collected at 0-20cm depth at five (5) different points around each profile pit and bulked into one sample. The soils were air dried and sub-samples were taken from each sampling bag for the various chemical analysis carried out. The pH of the soil was determined in distilled water (1:1 soil water ratio) with a pH meter. Exchangeable cations (K, Na, Ca, and Mg) by extraction, with ammonium acetate (pH= 7). Effective cation exchange capacity by summation of the exchangeable cations and exchangeable acidity. Available P was extracted with 0.03N NH_4F in 0.025N HCl solution (Bray and Kurtz, 1945) and P in the extract was analysed colorometrically by the molybdenum blue method at 660 nm. Soil organic carbon was determined by wet oxidation with sulphuric acid (Walkey and Black, 1934).

Incubation Studies

A ten week incubation study was conducted to determine the effect of fertilizer application i.e. both organic and inorganic fertilizer on phosphorus (P) forms in three different derived savanna soils. Single superphosphate (SSP) and poultry manure (PM) was applied, while P forms was monitored at two week interval. Poultry manure was applied at 0, 0.75g, 1.5g, 2.25g and 3g per 300g weight of soil while single superphosphate was applied at 0.0023g, 0.0046g, 0.0069g and 0.0092g per 300g of soil. Deionized water was added to the soil and the soil was kept moist throughout the period of the incubation studies. At two (2) weeks interval, soil samples were taken from each cup.

Fractionation of Inorganic Phosphorus

The procedure of sequential phosphorus fractionation is given Table 2. A summary of the procedure is as follows:

Table 2. Sequential P fractionation procedures and targeted P forms

Location	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 Residual P	0.25M H_2SO_4 + 25ml Sat. Nacl Conc. HNO_3 + HCl + 30% H_2O_2	1 hour Variable until complete	Saturated NaCl None	Ca-P Organically stable organic and inorganic P

Statistical Analysis

The experimental design was a 5 x 5 factorial experiment replicated three times. Data collected were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 4,10.3D Estatistical software, and where the F-value was significant, treatment means were separated at $P \leq 0.05$ level of significance using Fisher least significant differences (LSD) (GenStat, 2011).

Results

The pH of the soils varied between 6-6.5, organic matter between 5.16-10.32 g kg^{-1}, total N between 0.08-0.23g kg^{-1}, available phosphorus between 6.74- 14.5 mg kg^{-1}, exchangeable Ca between 0.62-2.06 cmol kg^{-1}, exchangeable Mg between 0.69-0.79 cmol kg^{-1}, exchangeable K between 0.08-0.31cmol kg^{-1} while exchangeable Na ranged between 0.06-0.1cmol kg^{-1}. Initial phosphorus fractions of the different soils are given in Table 3. Like soil properties, initial P fractions showed different values relative to different soil series.

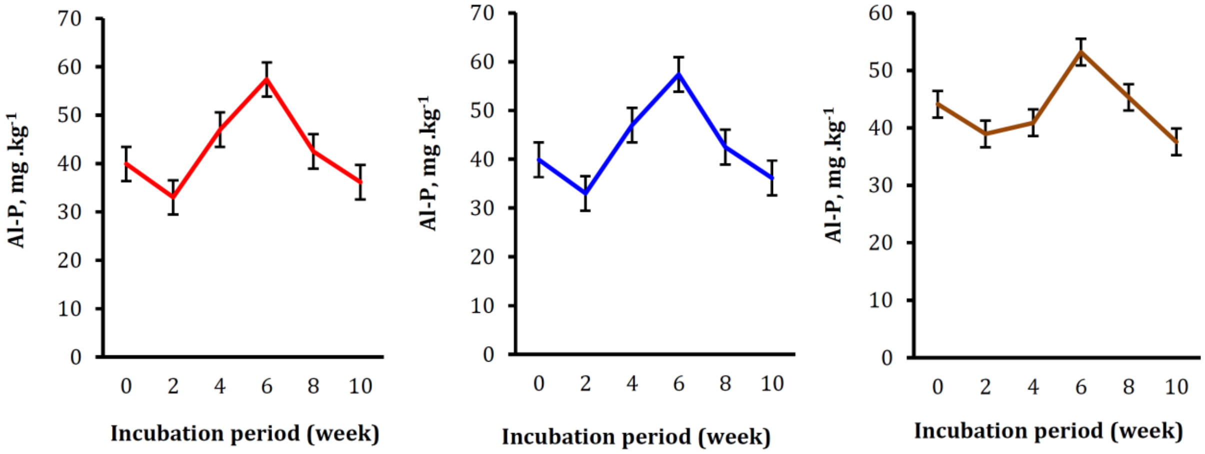
Table 3. Initial soil phosphorus fractions of the different soil series (mg kg^{-1})

	Organic P	Fe-P	Al-P	Ca-P	Occluded P	Reductant Soluble P	Residual P
Temidire Series	52.09	38.96	27.83	22.10	87.83	30.32	33.39
Ekiti Series	68.72	46.87	34.52	24.10	108.39	50.20	55.05
Apomu Series	44.52	7.79	34.52	27.90	94.52	25.70	12.56

Effect of addition of organic manure to P fertilizer followed a similar trend in the three soil series identified. Al-P was initially high at 0 week then decreased at the 2nd week. A gradual increase was observed from the 2nd to the 6th week after which a decrease was observed till the 10th week of incubation (Figure 1).

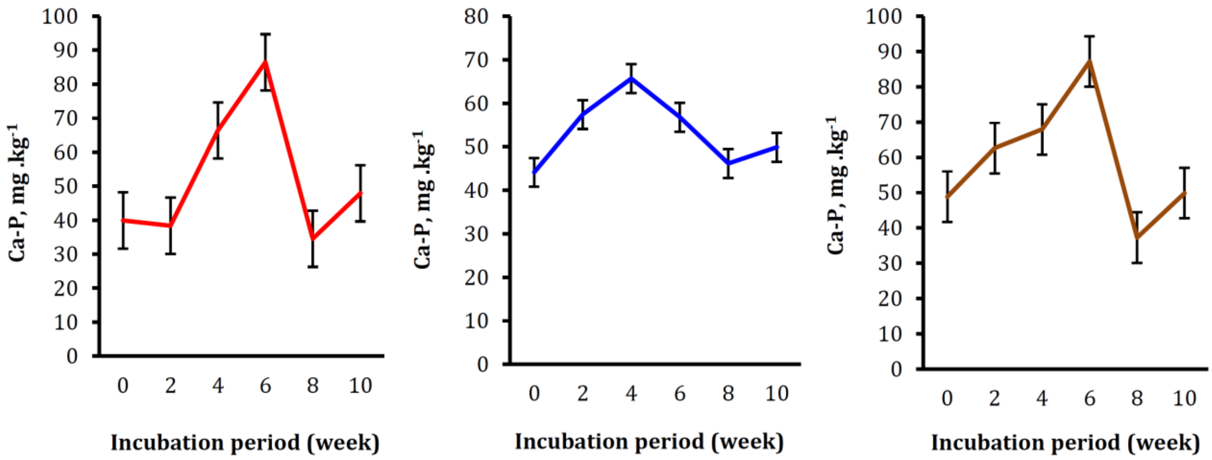
Effect of addition of organic manure to P fertilizer followed a similar trend in Apomu and Ekiti series. Ca-P was low at the beginning of the incubation studies and then increased from the 2nd to the 6th week and later decreased. However, in Temidire series, a steady increase was observed from the 1st week of the incubation studies to the 4th week and later then decreased to the 8th week (Figure 2).

Effect of addition of poultry manure to single superphosphate on Fe-P followed a similar trend in Apomu and Temidire series. The inorganic P fraction was however higher in Temidire series than in Apomu series at the beginning of the incubation studies. Intermittent decrease and increase was observed to the 8th week of incubation and then decreased towards the 10th week of the incubation studies. Fe-P was also higher at the beginning of the incubation studies in Ekiti and Temidire series. A decrease was observed down to the second week after which a steady increase was then observed to the 8th week but later decreased while tending towards the 10th week (Figure 3).



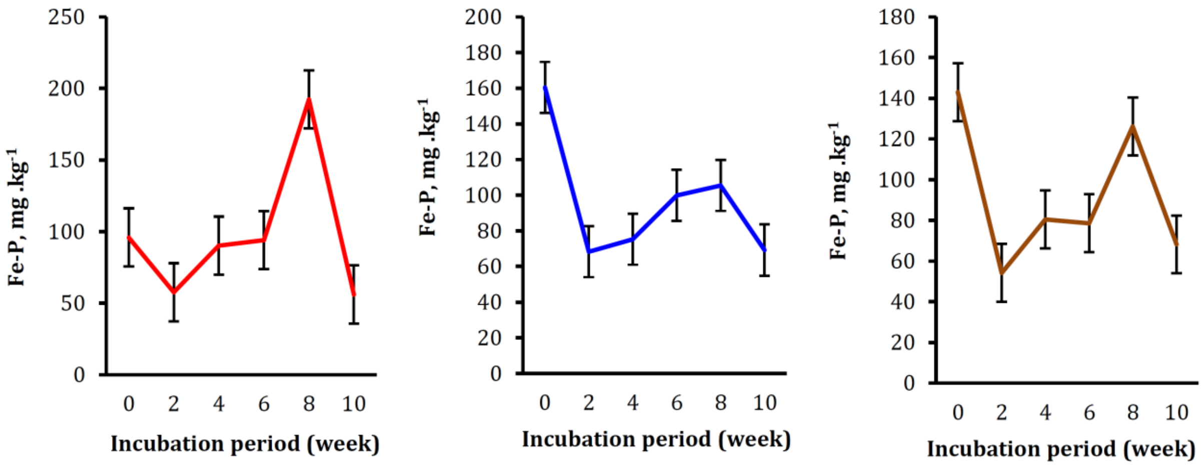
(a) (b) (c)

Figure 1. Al-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.



(a) (b) (c)

Figure 2. Ca-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.

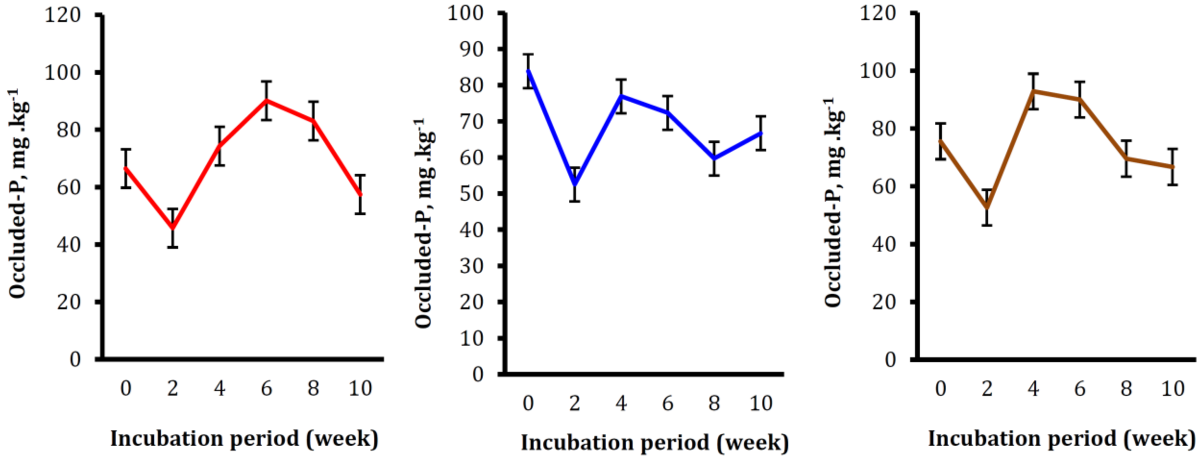


(a) (b) (c)

Figure 3. Fe-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.

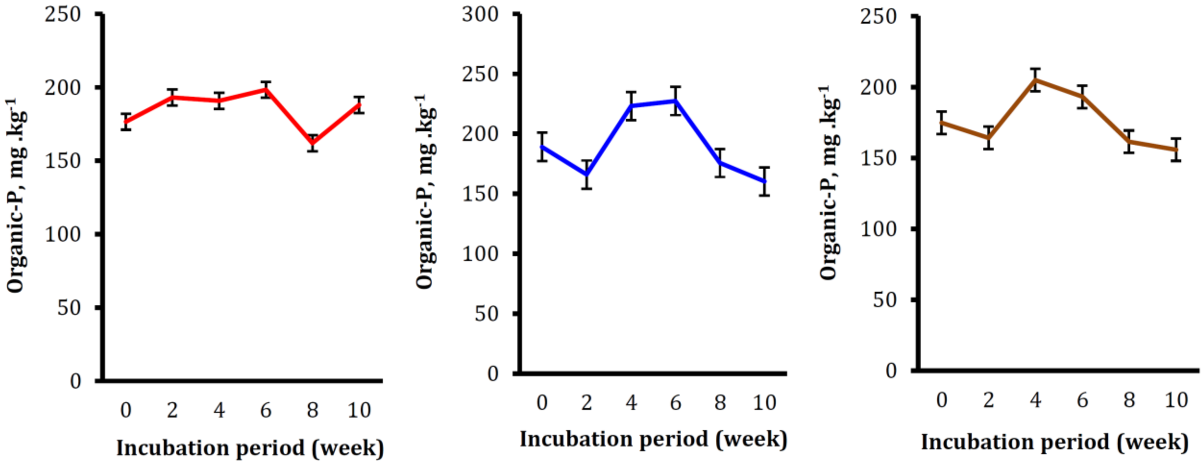
A similar trend was observed in the three soil series identified as affected by poultry manure and SSP. A decrease was observed at the 2nd week of incubation and then later increased to the 4th week. A subsequent decrease in occluded P was observed from the 4th week in Temidire and Ekiti series while this observation was noticed at the 6th week in Apomu series (Figure 4).

A steady increase in organic P as affected by the treatments applied was observed in Apomu series from the beginning of the incubation studies to the 6th week of the incubation studies while a decrease was then observed at the 8th week. An increase in organic P was observed to the 4th week in Ekiti and Temidire series and later decreased from the 4th to the 10th week of incubation in Temidire series. However, in Ekiti series, a decrease in organic P was observed from the 6th week to the 10th week (Figure 5).



(a) (b) (c)

Figure 4. Occluded-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.



(a) (b) (c)

Figure 5. Organic-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.

The reductant soluble P fraction was observed to increase from the beginning of the incubation studies to the 2nd week in Apomu and Ekiti series, then a decrease was observed to the 8th week and then an increase from the 8th to the 10th week of the incubation studies. However, in Temidire series, the increase observed at the 2nd week of incubation was higher than what was observed in the two other series. A decrease in organic P was later observed to the 8th week and an increase was then observed from the 8th to the 10th week (Figure 6).

Intermittent increase and decrease in residual P was observed in Apomu series to the 10th week of the incubation studies. A steady increase was however observed in Temidire series to the 6th week and then a decrease to the 10th week. In Ekiti series, an intermittent increase and decrease in residual was observed to the 6th week of incubation and later decreased to the 10th week (Figure 7).

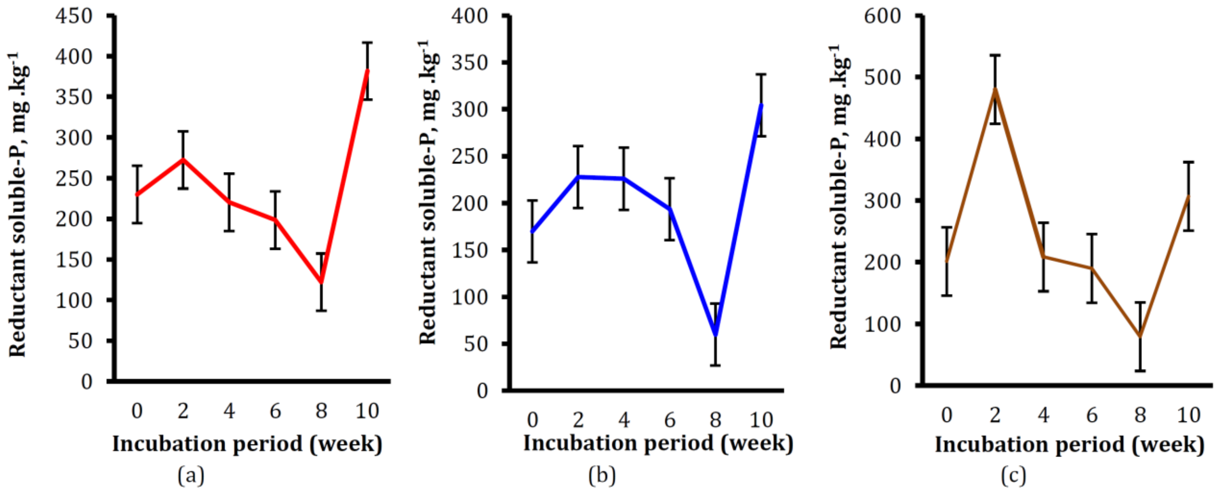


Figure 6. Reductant soluble-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.

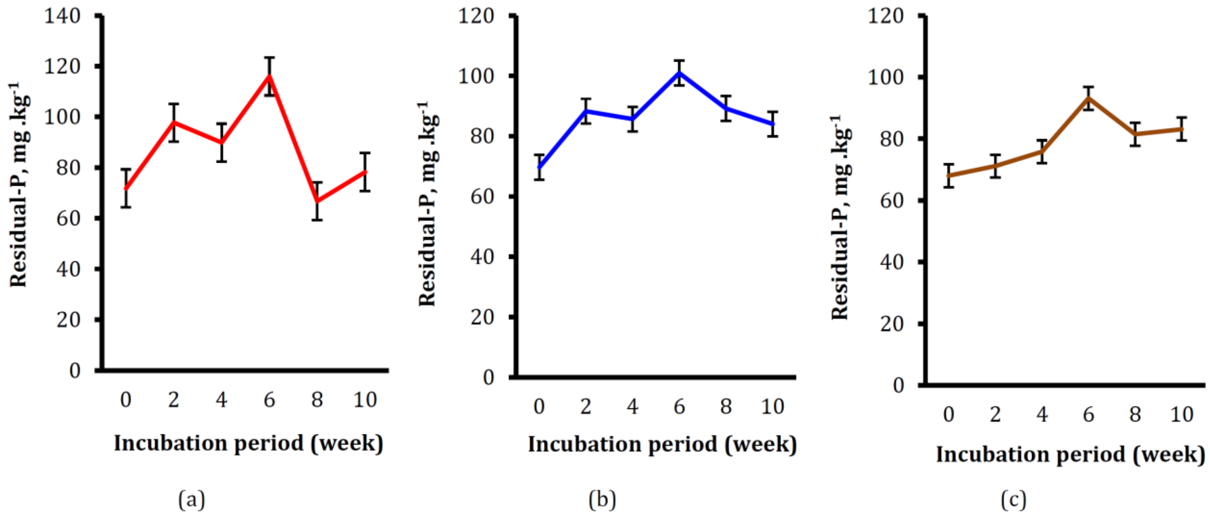


Figure 7. Residual-P as influenced by Single superphosphate (SSP) and poultry manure (PM) on soil series (a) Apomu (b) Ekiti (c) Temidire.

Discussion

Soil phosphorus (P) management requires a more targeted and soil specific approach (Daly et al., 2015). Limited availability of P in many tropical soils can be attributed to dominance of Al-P and Fe-P in the soils evaluated (Kiflu et al., 2017). Presence of Al-P in the soil at 0 week could be attributed to significant amount of Al oxides in soils found in the south western part of Nigeria (Gideon et al., 2016). Increase in Al-P at week two (2) would invariably lead to release of P into the soil solution while the build-up later observed could be attributed to the effect of P fertilizer in the soils (Ibrikci et al., 2005). However, Ca- P was low at the 0 week of the incubation studies due to the acidic nature of the soils evaluated while the increase observed later would probably be due to the liming ability of the poultry manure added to the single superphosphate (Ojo et al., 2015). Effect of added poultry manure was later observed at the 10th week of the incubation studies and this was probably due to the residual effect of the poultry manure added (Amanullah et al., 2010) .This observation was however not seen in Temidire series where an increase in Ca-P was observed from the beginning of the incubation studies to the 4th week and this could have been to the effect of past application of fertilizer that could have increased Ca-P (Song et al., 2017) in Temidire series. High Fe-P at the beginning of the incubation studies could probably be due to the presence of Fe oxides in the soils evaluated (Gikonyo et al., 2011). The intermittent increase and decrease observed in Temidire and Apomu series would have been due to individual effect of poultry manure and SSP at different stages of the incubation studies. However, a decrease in Fe-P was observed at the beginning of the incubation studies in Apomu series and this could probably be due to the characteristic of Apomu series with high sand fraction (Adesanwo et al., 2013) and therefore prone to leaching compared to Temidire and Ekiti series. Effect of poultry manure in reducing P occlusion in soils was observed in the three soil series evaluated (Ojo et al., 2016). However, the increase later observed could be due to the effect of SSP added to the soils. Effectiveness of added poultry manure to P fertilizer was later observed with a decrease in occluded P (Ojo et al., 2016) from the 4th week of the incubation studies. Addition of poultry manure to SSP was more effective in Apomu series and this was evident in the build-up of organic P (Waldrip et al., 2011) from the beginning of the incubation studies to the 6th week. An increase in organic P was observed in Ekiti and Temidire series till the 4th week of incubation while later added poultry manure became less effective with an evident decrease in organic P. A build-up of the reductant soluble P observed in Apomu and Ekiti series would probably be due to the effect of the inorganic fertilizer added (Soremi et al., 2017) while the decrease later observed signified the effectiveness of poultry manure in reducing P fixation in soils. The intermittent increase and decrease in residual P also signifies the individual effect of poultry manure and SSP at different stages of the incubation studies. However, effect of the P fertilizer i.e. SSP added was more evident in Temidire series where a steady build-up of residual P was observed (Sattari et al., 2012).

Conclusion

Effect of combined application of poultry manure and single superphosphate was evident in the increases in the labile P fractions i.e. the NaOH-P fractions notably Al and Fe-P determined. Poultry manure ability to lime and increase Ca was evident in the increases observed in Ca-P and this particular treatment was effective in the reduction of P occlusion and in the build-up of organic P in most of the soils evaluated. Conclusively, irrespective of the soils series, the effectiveness of poultry manure and SSP, solely and in combination was evident in all the P fractions determined.

References

Adesanwo, O.O., Odu, U.V., Thompson, O.F., 2013. Dynamics of potassium in representative soil series of southwestern Nigeria. *Communications in Soil Science and Plant Analysis* 44(22): 3259-3266.

Amanullah, M.M, Sekar, S., Muthukrishnan, P., 2010. Prospects and potential of poultrymanure. *Asian Journal of Plant Sciences* 9(4): 172-182.

Ayeni, L.S., 2010. Integrated application of cocoa pod ash and NPK fertilizer: Effect on soil and plant nutrient status and maize performance-Field experiment. *Journal of American Sciences* 6(6): 96-102.

Bray, R.H., Kurtz, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Science* 59 (1): 39–45.

Brookes, P., 2001. The soil microbial biomass: Concept, measurement and applications in soil ecosystem research. *Microbes and Environments* 16(3): 131-140.

Chang, S.C., Jackson, M.L., 1957. Fractionation of soil phosphates. *Soil Science* 84 (2): 133-144.

Daly, K., Styles, D., Lalor, S., Wall, D.P., 2015. Phosphorus sorption, supply potential and availability in soils with contrasting parent material and soil chemical properties. *European Journal of Soil Science* 66(4): 792-801.

Eghball, B., 2003. Leaching of phosphorus fractions following manure or compost application. *Communications in Soil Science and Plant Analysis* 34(19-20): 2803-2815.

FAO, 2014. World Soil Resources Reports No. 106. Food and Agriculture Organization of the United Nation (FAO), Rome, Italy. Available at [access date: 17.06.2017]: http://www.fao.org/3/a-i3794e.pdf

Fan, J., Hao., M.D., Wang, Y.G., 2003. Effects of rotation and fertilization on soil fertility on upland of Loess Plateau. *Research in Soil Water Conservation* 10(1) : 31–36 [in Chinese].

GenStat., 2011 GenStat Discovery Edition 4, Release 10.3DE (PC/Windows 7). VSN International Ltd., Rothamsted Experimental Station, Hemel, Hempstead, UK.

Gideon, I.K., Ogbonna, A.N., Nzegbule, E.C., 2016. Soil physico-chemical properties in three land use systems (Theobroma Cacao, Gmelina Arborea and Secondary Forest) in Umuahia, North of Abia State, Nigeria. *Canadian Journal of Agriculture and Crops* 1(1) : 19-29.

Gikonyo, E.W, Zaharah, A.R, Hanafi, M.M., Anuar, A.R., 2011. Degree of phosphorus saturation and soil phosphorus thresholds in an ultisol amended with triple superphosphate and phosphate rocks. *The Scientific World Journal* 11: 1421-1441.

Halajnia, A., Haghnia, G.H., Fotovat, A., Khorasani, R., 2009. Phosphorus fractions in calcareous soils amended with P fertilizer and cattle manure. *Geoderma* 150(1-2): 209-213.

Halvorson, A.D., Black, A.L., 1985. Long-term dryland crop responses to residual phosphorus fertilizer. *Soil Science Society of America Journal* 49(4): 928–933.

Hinsinger, P., 2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: A review. *Plant and Soil* 237(2): 173-195.

Ibrikci, H., Ryan, J., Ulger, A.C, Buyuk, G., Cahir, B., Korkmaz, K., Karnez, E., Ozgenturk, G., Konuskan., 2005. Maintenanace of phosphorus fertilizer and residual phosphorus effect on corn production. *Nutrient Cycling in Agroecosystems* 72(3): 279-286.

Jalali, M., Ranjbar, F., 2010. Aging effects on phosphorus transformation rate and fractionation in some calcareous soils. *Geoderma* 155 (1-2): 101-106.

Kiflu, A, Beyene, S., Jeff, S., 2017. Fractionation and availability of phosphorus in acid soils of Hagereselam, southern Ethiopia under different rates of lime. *Chemical and Biological Technologies in Agriculture* 4(21): 1-7.

Kolawole, G. O., Tian, G.. 2007. Phosphorus fraction and crop performance on an alfisol amended with phosphate rock combined with or without plant residues. *African Journal of Biotechnology* 6(16): 1972-1978.

Lai, L., Hao, M. D., Peng, L. F., 2003. The variation of soil phosphorus of long-term continuous cropping and management on Loess Plateau. *Research in Soil Water Conservation* 10(1) : 68–70 [in Chinese].

Lei, H., Zhu, C., Liu, X., Zhou, W., Hong, L., 2004. Phosphorus adsorption-desorption characterization in acid soils under amendment. *Acta Pedologica Sinica* 41: 636-640.

Nziguheba, G., Bunemann, E., 2005. Organic phosphorus dynamics in tropical agro-ecosystems, In: Organic Phosphorus in the Environment, Turner, B.L, Frossard, E., Baldwin, D.S. (Eds.). CAB International, Wallingford UK, pp. 243-268.

Moss, R. P., 1957. Report on classification of soils found over sedimentary rocks in Western Nigeria. WSMANR. Ibadan, Nigeria. 88p

Mudorch, G., Ojo-Atere, J. O., Colborne, G., Olomu, E. I., Odugbesan, E. M., 1976. Soils of the Western State Savanna in Nigeria . Land Resources Division, Ministry of Overseas Development, Tolworth Tower, England. 145p.

Reddy, D.D., Subba, R.A., Rupa, T.R., 2000. Effects of continuous use of cattle manure and fertilizer phosphorus on crop yields and soil organic phosphorus in a vertisol. *Bioresource Technology* 75(2): 113-118.

Samadi, A., Gilkes, R. J., 1998. Forms of phosphorus in virgin and fertilized calcareous soils of Western Australia. *Australian Journal of Soil Research* 36 (4): 585–601.

Sattari, S.Z, Bouwman, A.F, Giller, K.E., Ittersum, M.K., 2012. Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. *Proceedings of the National Academy of Sciences of the United States of America* 109 (16): 6348-6353.

Song, K., Xue, Y., Zheng, X., Weiguang, L, Qiao, H., Qin, Q., Yang, J., 2017. Effects of the continuous use of organic manure and chemical fertilizer on soil inorganic phosphorus fractions in calcareous soil. *Scientific Reports* 7 : Article number: 1164.

Soremi, A.O., Adetunji, M.T., Adejuyigbe, C.O., Bodunde, J.G., Azeez, J.O., 2017. Influence of organic manure on phosphorus and potassium fractions in soil planted with soybean. *International Journal of Plant and Soil Science*. 14(2): 1-11.

Ojo, A.O, Adetunji, M.T, Okeleye, K.A., Adejuyigbe, C.O., 2015. Soil fertility, phosphorus fractions and maize yield as affected by poultry manure and single superphosphate. *International Scholarly Research Notices* Article ID 616213.

Ojo, A.O, Adetunji, M.T, Okeleye, K.A., Adejuyigbe, C.O., 2016. The effect of poultry manure and P fertilizer on some phosphorus fractions in some soils of southwestern Nigeria: An incubation. *Communications in Soil Science and Plant Analysis*. 47(21): 2365-2377.

Omotayo, O.E, Chukwuka, K.S., 2009. Soil fertility restoration technoques in sub-Saharan Africa using organic resources. *African Journal of Agricultural Research* 46(3): 144 – 150

Usman, A.R.A., Abduljabbar, A., Vithanage, M., Ok, Y.S., Ahmad, M., Ahmad, M., Al- Wabel, M.I., 2015. Biochar production from date palm waste: charring temperature induced changes in composition and surface chemistry. *Journal of Analytical Applied Pyrolysis* 115: 392-400.

Verma, S., Subehia, S.K., Sharma, S.P., 2005. Phosphorus fractions in an acid soil continuously fertilized with mineral and organic fertilizers. *Biology and Fertility of Soils* 41(4): 295-300.

Waldrip, H., He, Z., Erich, S., 2011. Effects of poultry manure amendment on phosphorus uptake by ryegrass, soil phosphorus fractions and phosphatase activity. *Biology and Fertility of Soils* 47(4): 407-418.

Walkey, A., Black, I.A., 1934. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science* 63: 251-263.

Yu, S., He, Z.L., Stoffella, P.J., Calvert, D.V., Yang, X.E., Banks, D.J., Baligar, V.C., 2006. Surface runoff phosphorus (P) loss in relation to phosphatase activity and soil P fractions in Florida sandy soils under citrus production. *Soil Biology and Biochemistry* 38(3): 619-628.

Zhang, T.Q., MacKenzie, A.F., Lang, B.C., Drury, C.F., 2004. Soil test phosphorus and phosphorus fractions with long term phosphorus addition and depletion. *Soil Science Society of America Journal* 68(2): 519-528.