European Journal of Agriculture and Forestry Research

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

TILLAGE AND FERTILIZER INTERACTIVE EFFECT ON PHOSPHORUS FRACTIONS IN AN ALFISOL

Ojo Abigail Oluremi

Institute of Agricultural Research and Training, Moor Plantation, Ibadan
Email: oluremiojo7@gmail.com
P.M.B 5029, Institute of Agricultural Research and Training, Moor Plantation, Apata, Ibadan, Nigeria

ABSTRACT: *Distribution of phosphorus (P) fractions is affected by the tillage system practiced as well as the type of fertilizer applied. A field study was conducted for two years to determine the effect of two tillage system and two fertilizer type on P distribution in a soil cropped with maize. Initial P fractionation studies showed a build-up of the recalcitrant P fraction with a low value observed for the labile P fraction. Combining zero tillage and poultry manure effectively increased the labile P fractions and this include the resin P fraction, the labile organic P fraction as well as the moderately organic P fraction. Land preparation using the conventional tillage system however increased both the conc. acid and residual P fractions, which are the recalcitrant fractions of P. Conclusively, adopting zero tillage with the application of poultry manure serves as an effective management strategy for a continuous flow of the plant available P through the build-up of the labile P fractions.*

KEYWORDS: tillage system; poultry manure; labile p fraction; non-labile p fraction

INTRODUCTION

Phosphorus is an essential element in the soil next to nitrogen that is needed in large quantities for normal plant growth and maturity. It exists in many complex chemical forms that differ markedly in their behavior, mobility, and resistance to bioavailability in the soils (Jalali and Matin, 2013). These different forms are identified through fractionation of the soil P, which is not only an effective approach for investigating soil P availability and transformation, but also can provide useful information for assessing the risk of soil P as the potential sources of eutrophication in aquatic systems (Jalali and Matin, 2013). The inorganic forms (Pi) can be found in solution (P-solution) and fixed through the adsorption phenomenon, with oxides of Fe and Al (of clay fraction). This process establishes either weak adsorption (labile P) or strong adsorption (moderately labile P) with these oxides (Azevedo et al., 2018) and, precipitated with Al, Fe and Ca, establishes insoluble forms (non-labile P). Phosphorus in soils is limiting and application of fertilizer phosphorus is essential for raising the available P content in soils in order to meet the crop requirements at different stages of growth (Shen et al., 2011). However, continuous application of P fertilizer may result in an accumulation of P associated with soil

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

organic matter (SOM), which further acts to reduce the availability of the added P (Velasques, G., 2016). Thus fertilization principally affect labile P and labile SOM forms, whereas recalcitrant forms of P and SOM remained unchanged (Velásquez et al., 2016). Different organic amendemnts have also been discovered to affect the various **P** fractions in **soils (**Kashem et al., 2004**)** and the combination of the inorganic and organic fertilizer has been reported to increase both the residual and Fe-P in a study conducted on a field for two years (Ojo et al., 2015). Land preparation methods, an important aspect of farming have great influence on P forms in soils (Halloran, 1993). No-till systems has been reported to accumulate P in the upper layer of the soil while conventional tillage tend to decrease the labile P fractions (Rotta et al., 2015). Furthermore, the combined effect of applying fertilizer under different tillage systems has been discovered to influence the distribution of P within the soil (Margenot et al., 2017). An experiment was conducted to study the effect of inorganic phosphorus fractions and tillage operations (conventional and zero tillage) on the yield of the crop (Mandal and Mukhopadhyay, 2015). The inorganic forms of phosphorus (Ca-P, Al-P, Fe-P, Re-P), in soils during the experimental period showed higher fractions in the conventional tillage than the zero tillage operation. The Al-P fraction of soil affected significantly (P=0.05) the yield of the crop (wheat) compared to other P-fractions (Mandal and Mukhopadhyay, 2015). In another study on the assessment of the effects of tillage and P fertilization on soil P fractions over 10- and 16-yr periods of cultivation, a long-term corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] rotational experiment was established and it was discovered that combined no-tillage and P fertilization enhanced soil inorganic P fractions, thereby improving soil P supplying capacity and P balance (Shi et al., 2015).

Tillage practices have been established to affect the soil physical, chemical and biological properties of the soil. Among the soil properties affected is the available P content of the soil. Tillage practices are broadly sub-divided into the conventional and conservation tillage systems. The conventional tillage practices have been found to improve the soil chemical properties (Alam et al., 2014). Highest total P has been recorded in zero tillage (Issaka et al., 2019). Fertilization on the other hand through several studies have been established to affect P availability as well as the distribution of P in the soil system. Organic manure application alone as well as the inorganic application especially with P fertilization has been observed to affect the distribution of P in the soil. However, the combined application has also been found to affect P forms distribution in different soil types. Studies have also shown that tillage practices as well as the type of fertilizer applied affect P forms distribution in the soil. Tillage practices combined with manure application have been observed to produce higher values of available P (Adeyemo and Agele, 2010). Changes in tillage and fertilization practices has also been found to alter the rate of nutrient cycling within the soil (Halloran, 1993). Evidences have also been found that the no-till system and P fertilization changed the distribution of P forms along the soil profile (Abdi et al., 2014).

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

Therefore, management practices have all been established to affect the availability of P in soils, The effect of tillage practices as well as fertilizer application has been assessed as regards P availability, which are strongly affected by P forms distribution. However, these effects have been studied differently and not interactively. There is therefore a need for a holistic approach to determining the overall factors for low P status of soils in the tropics. This study however aimed at determining the combined effect of different tillage methods on P fractions

Purpose/ Problem Statement

Low phosphorus status of tropical soils have been established and different management practices identified as the causes. Conventional method of tillage is posing a problem to soil productivity now while farmers are finding it difficult to embrace the conservation tillage system due to the labour intensiveness involved. Inorganic fertilizer application on the other hand has now been identified as a cause to soil degradation while organic manure is gradually increasing in its adoption by farmers. Availability of P in soils ultimately as a result of these factors is affected by the distribution of the P fractions in such soils. Therefore there is a need to evaluate the interactive effect of these two factors i.e. tillage methods and fertilizer types on not just P availability but on the P forms distribution.

METHODOLOGY

Land preparation methods

Prior to planting, two land preparation methods employed namely the zero and conventional tillage systems. For the zero tillage plots, the soil was not disturbed and the use of herbicide was employed to bring down the vegetation in the plot. The conventional plots had ploughing done twice and then harrowed.

Field Trial

Interaction between fertilizer and tillage systems was evaluated on the field. Experimental plots had combinations of two tillage systems as described above, poultry manure at 5 t/ha and application of N.P.K 15-15-15 applied at 120 kg/ha due to the low nutrient status of the soil used for the field trial.

Different combinations were employed and this include zero tillage with no treatments, conventional tillage with no treatments, zero tillage with the application of poultry manure, conventional tillage with the application of poultry manure, zero tillage with the application of NPK as well as conventional tillage with the application of NPK. These treatments were arranged on the field in a randomized complete block design and replicated three times.

Phosphorus Fractionation studies

Tiessen and Moir (1993) method for fractionation of P in soils was employed for the study. 1g of soil was weighed and 1 anion exchange resin bag was added. 60 ml of distilled water then added and shaked for 16 hrs. The resin bags was retrieved and adhering soil washed with distilled water

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

into the centrifuge tube. Then 50ml 0.5M HCl was added to the residue and shaked for 16 hrs. The soil suspension was then centrifuged @ 2000rpm for 10 min . Then it was decanted and the filtrate kept for reading **[Resin P]**

In continuation of the step-wise extraction, 50ml 0.5M $NaHCO_3$ was added to the residue [pH 8.5] and shaked for 16hrs, It was then centrifuged @ 2000rpm for 10 min The supernatant was decanted and the filtrate kept for reading on the spectrophotometer **[$NaHCO_3$ Pi]**

50ml 0.1M NaOH was then added to the residue and shaked for 16 hrs. Centrifuging of the soil suspension was done @ 2000rpm for 10min. The supernatant was decanted and the filtrate kept for reading on the spectrophotometer **[NaOH Pi]**

For the next stage, 50ml 1M HCl was added to the residue and shaked for 16 hrs. It was then centrifuged i.e. soil suspension @ 2000rpm for 10min. The supernatant was decanted and the filtrate kept for reading on the spectrophotometer for analysis **[Dilute Acid P]**

To the residue, 2ml of conc HCl was added. It was poured in small beakers and placed in the water bath @ 80^{o}C for 10 min. It was then removed, allow to cool for 1hr. It was later transfered back into the centrifuge tubes and the tubes shaked every 15 min. 1ml conc HCl was then added to the tubes and centrifuged @ 2000rpm for 10 min. The supernatant was then decanted into 10 ml volumetric flasks. 2ml of distilled water was then added to make up with distilled water **[Conc HCl P]**

In preparation for ignition of the soil, 3 ml conc HNO_3 and 1 ml conc $HClO_4$ was added to the residue [Ignited soil] and transferred to a crucible. It was then placed in a muffle furnace @ 200^{o}C for 16 hrs. It was allowed to cool and 2 ml of 5M HNO_3 added to the crucible. It was then filtered into 10 ml volumetric flask. This was made up to volume with 5M HNO_3 [Residual P]

For the NaOH and $NaHCO_3$ extract

1.2 and 0.3 ml of 0.1M H2SP4 respectively was added to 2 ml of the NaOH and $NaHCO_3$ extract. It was centrifuged @ 4000rpm for 20 min. and cooled in a refrigerator for 30min

Inorganic P in the resin-, dilute-acid-, acid-, and residual-P extracts was measured directly using the molybdate ascorbic acid method (Murphy and Riley 1962) on a spectrophotometer at 712nm.

In order to get the organic P fractions for $NaHCO_3$ and NaOH P fractions, the total P fraction was determined as stated below and the inorganic P fractions determined above was subtracted from the total P to get the organic fractions.

For total P analysis

1 ml of $NaHCO_3$ or NaOH extract was taken and 0.1g of ammonium persulfate added. Then add 2 ml of 0.9 M H_2SO_4 in an autoclave for 2hrs

Organic P in the NaHCO3 and NaOH was calculated by the difference between total P and inorganic P.

Op = Tp – Ip

Op = Ignited P – Unignited P

Sum of inorganic and organic P = Total P

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

Statistical Analysis

The data collected were subjected to analysis of variance using the statistical analysis system (SAS) – General Linear Model (SAS, 2000). Means were separated by Duncan Multiple Range Test

RESULTS

There were significant differences in the values obtained for resin P as affected by the interactive effect of the land preparation methods and fertilizer type (Fig 1). After the first year, the highest value for resin P was observed when both zero and conventional tillage was combined with poultry manure. After the first year trial, plot that had only conventional tillage practiced on it had the lowest value for resin P. However, in the second year, the most significant increase in resin P was observed in the plot that zero tillage was practiced in combination with poultry manure. In terms of abundance of resin P, the plot that had a combination of conventional tillage and poultry manure was next in abundance as regards increase in resin P fraction. Values for resin P however decreased in the second year in other treatment combinations. Irrespective of the year of cropping, the plot that received no fertilizer and conventional tillage was practiced on it had the lowest value for resin P.

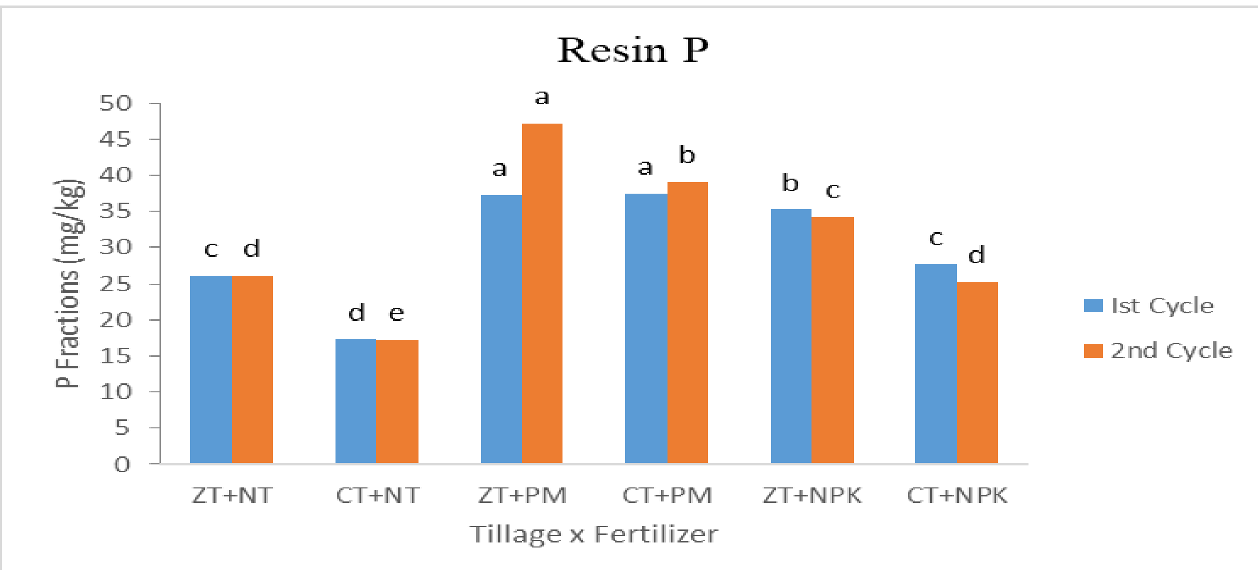

Fig 1: Effect of land preparation methods and fertilizer type on resin P fraction during the first and second year field trial

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

There was a build-up of the bicarbonate organic P fraction in the plot that zero tillage was practiced on it without fertilizer application in the first year of cropping (Fig 2). In terms of abundance of this P fraction, the second most abundant value was obtained for the plot that zero tillage was practiced on it and poultry manure was applied. During this first year of cropping, the least value for the bicarbonate organic P fraction was observed in the plots that had zero and conventional tillage practiced on it and NPK fertilizer was added. However, in the second year, an increase in the bicarbonate organic P fraction was observed in the plot that zero tillage was practiced and poultry manure applied. Decreases in the P fraction was however observed for other combinations in the second year of cropping.

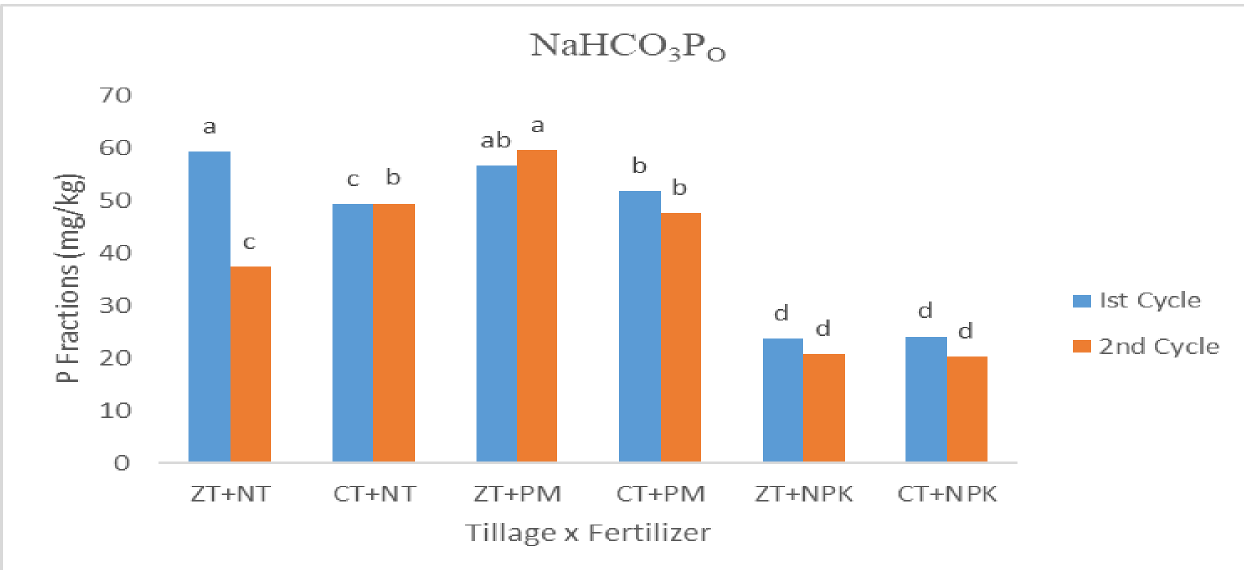

Fig 2: Effect of land preparation methods and fertilizer type on Bicarbonate organic P fraction during the first and second year field trial

In the first year of cropping, the most significant increase in the bicarbonate inorganic P fraction was observed in the plot that received NPK fertilizer and zero tillage was practiced (Fig 3). In terms of abundance as regards this inorganic P fraction, the combined effect of conventional tillage with poultry manure was next in the values obtained. After the first year of cropping however, the plot that had zero tillage practiced on it with no fertilizer had the least value. In the second year, the bicarbonate inorganic P fraction significantly increased in the plot that zero tillage was practiced on it with no treatments. Increases in this inorganic P fraction was also observed in the plots that had conventional tillage practiced on it and in the plot that had a combination of zero tillage and applied poultry manure.

European Journal of Agriculture and Forestry Research

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

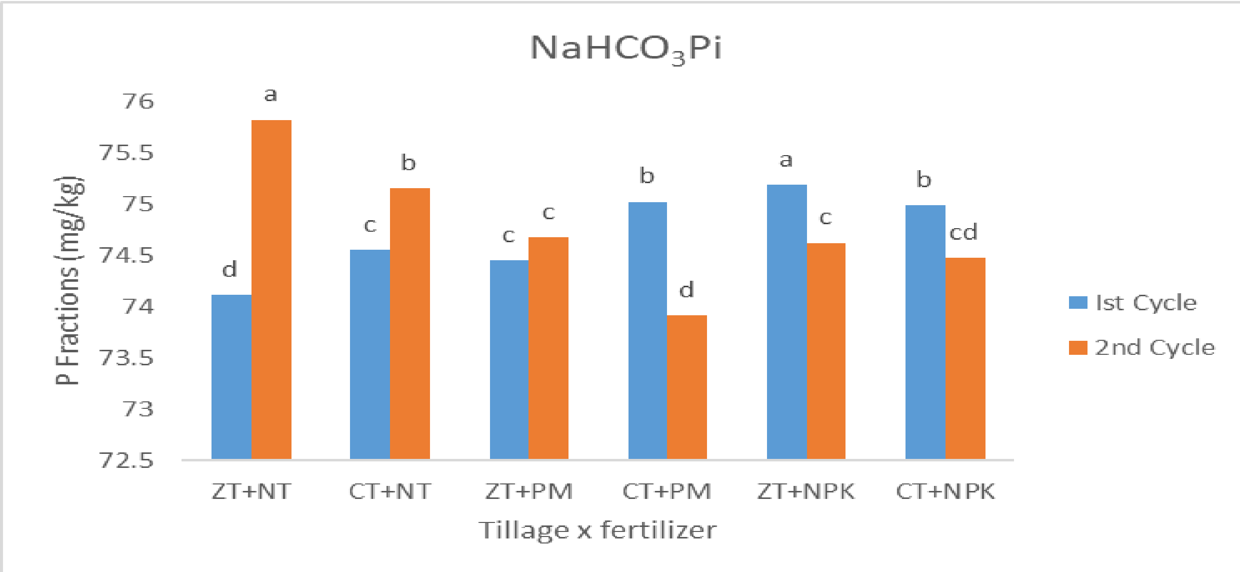

Fig 3: Effect of land preparation methods and fertilizer type on Bicarbonate inorganic P fraction during the first and second year field trial

The most significant increase in the hydroxide organic P fraction after the first year was observed for the plot that had a combination of zero tillage and poultry manure applied (Fig 4). Next in trems of the abundance of this organic P fraction was observed in the plot that had a combination of conventional tillage and poultry manure. After the first year cropping, the plot that received no fertllizer and conventional tillage was practiced on it had the least value. After the second year of cropping, the plot that had a combination of conventional tillage and poultry manure applied had the highest value for hydroxide organic P fraction. However, decreases in the organic P fraction was observed in other plots.

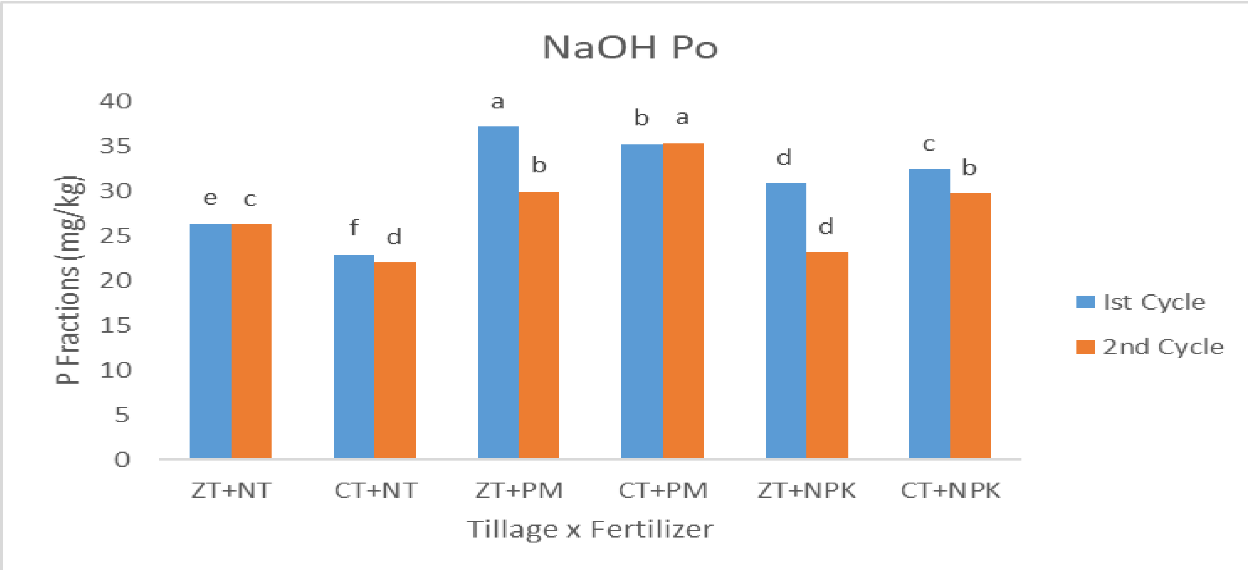

Fig 4: Effect of land preparation methods and fertilizer type on Hydroxide organic P fraction during the first and second year field trial

There were more of the hydroxide inorganic P fraction in the first year as compared to the values obtained for the second year (Fig 5). After the first year of cropping, the plot that received poultry manure and zero tillage was practiced on it had the highest hydroxide inorganic P fraction. Next in abundance was the values obtained for the plot that only had zero tillage practiced on it. The lowest value was obtained in the plots that had combinations of conventional tillage and poultry manure as well as plots that a combination of zero tillage and NPK fertilizer. After the second year cropping, decreases in the hydroxide inorganic P fraction was observed for most treatment combination. However, an increase in the inorganic P fraction was observed in the plot that zero tillage was practiced on it and NPK fertilizer applied.

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

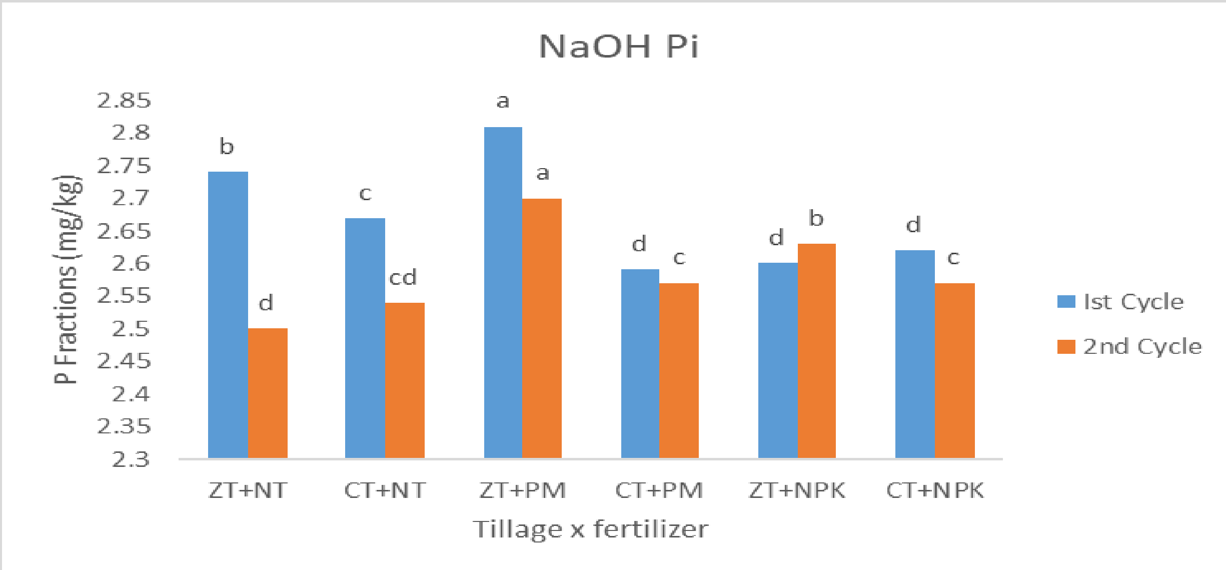

Fig 5: Effect of land preparation methods and fertilizer type on Hydroxide inorganic P fraction during the first and second year field trial

There were significant differences in the values obtained for the dilute acid P in both years of cropping (Fig 6). After the first year of cropping, the highest value for this P fraction was observed for the plots that zero tillage was practiced on it and poultry manure applied and was not significantly different from values obtained from the plot that had conventional tillage practiced on it and poultry manure applied. The least value was observed in the plots that had a combination of conventional tillage been practiced and NPK fertilizer applied and was not significantly different from values obtained from the plot that had no treatments and conventional tillage was practiced on it. Increases was observed in the second year of cropping with the combination of zero tillage and poultry manure having the highest value followed by values obtained for the combination of conventional tillage and poultry manure. Decreases was however observed for other treatments and after the second year of cropping, the least value was observed in the plots that conventional tillage was practiced and NPK fertilizer applied.

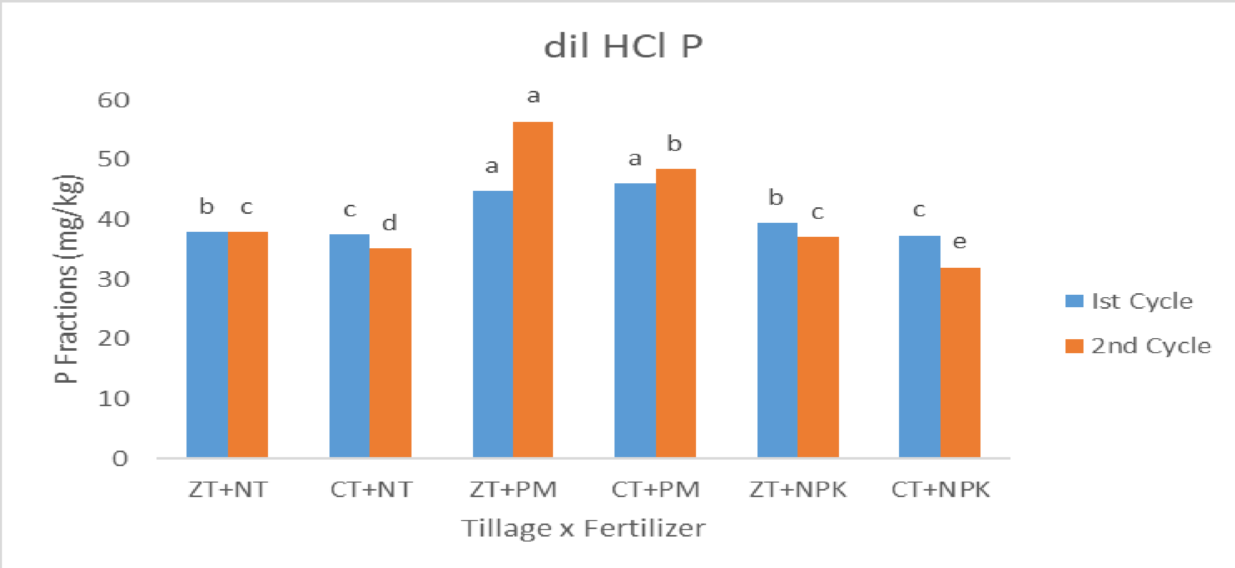

Fig 6: Effect of land preparation methods and fertilizer type on Dilute Acid P fraction during the first and second year field trial

The P fraction extracted using concentrated acid after the first year of cropping was observed to be significantly higher in the plots that zero tillage was practiced and poultry manure applied (Fig 7). Next in terms of abundance of the P fraction was the plot that zero tillage was practiced but no fertilizer applied. The least value was obtained in plots that had the combination of conventional tillage and NPK and which was not significantly different from the plot that conventional tillage was also practiced but poultry manure applied. Decreases in the P fraction was observed for most treatment combination after the second year of cropping. However an increase in the conc. Acid P fraction was observed in the plot that had conventional tillage practiced on it but no fertilizer was applied.

European Journal of Agriculture and Forestry Research

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

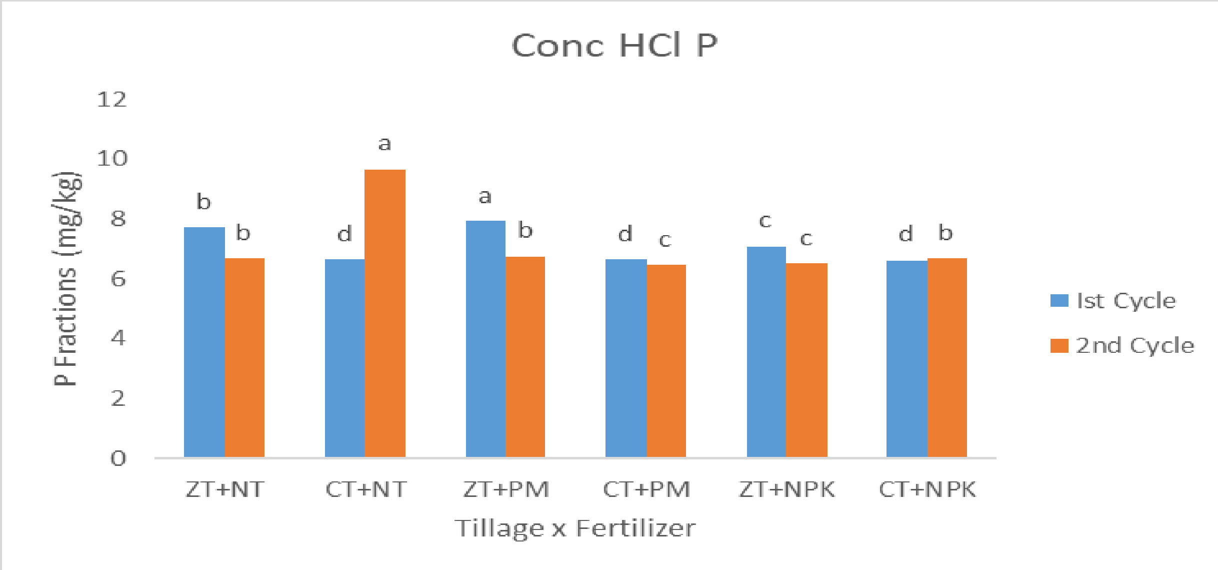

Fig 7: Effect of land preparation methods and fertilizer type on Conc Acid P fraction during the first and second year field trial

Significant differences in the values obtained for residual P was observed for both years of cropping (Fig 8). However, in the first year, the highest value, which is the largest buildup of residual P fraction was observed in the plot that conventional tillage was practiced on it but no fertilizer applied. The least value was however obtained in the plot that conventional tillage was practiced on it but NPK fertilizer applied. However, irrespective of the combination of the tillage system and fertilizer type, there was a decrease in the residual P fraction in the second year of cropping

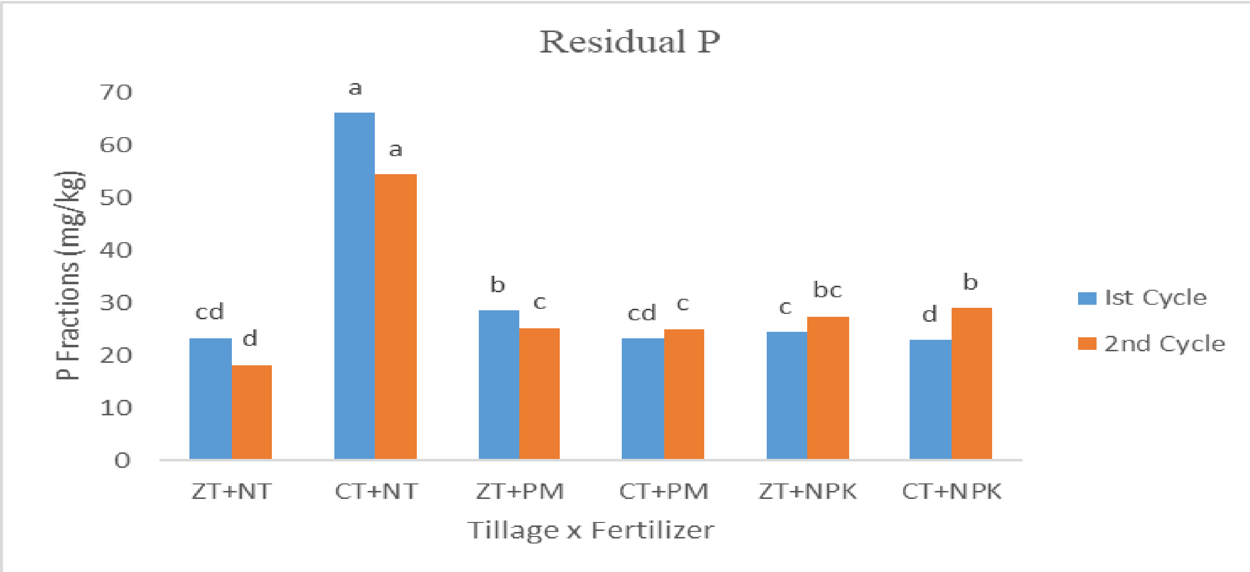

Fig 8: Effect of land preparation methods and fertilizer type on residual P fraction during the first and second year field trial

DISCUSSION

The results of the phosphorus fractionation studies carried out before the field trial was carried out showed that there was more of the recalcitrant P fractions in the degraded soil and therefore a need for amendment especially an organic source. Degraded soils especially for the top soils have been found to be highly depleted in P and this invariably would have resulted from more of P in the bound form (Dalhatu and Garba, 2012). However, after the first year of cropping, combined use of poultry manure with either zero or conventional tillage gave the highest value of resin P and this could have been due to the P solubilizing effect of poultry manure as reported by past research work (Khan et al., 2016). The increase observed in resin P after the second year of cropping as a result of the combined use of poultry manure and zero tillage could be attributed to the fact that build-up of nutrients occurs using zero tillage (Gattinger et al., 2011) and its ability to increase resin P was further aided by its combination with poultry manure.

Land preparation using the zero tillage method was able to increase the labile organic P fraction (Selles and Faganello, 1997). Zero tillage has the ability to improve the organic matter level in the soil and invariably the organic P fraction. Increase in the labile P fraction after two cycles of cropping could only be achieved with the combination of zero tillage and poultry manure. In other words, sustainability of plant available P through the labile P fraction would be achieved when zero tillage is combined with poultry manure application (Suner and Galantini , 2016) was found not to only increase Distribution of P into the resin P fraction and the moderately labile organic and inorganic P fraction was achieved by the combination of zero tillage with poultry manure. Application of NPK fertilizer in combination with NPK was also found to effectively increase the moderately inorganic P fraction and this could have been due to the ability of NPK fertilizer to increase the inorganic form of P (Caldecott, 2009).

The increase in the dilute acid P fraction as result of the combination of zero tillage and poultry manure after each year of cropping invariably means the rate of application of poultry manure should be reduced to prevent a build-up of Ca-P (Ojo et al., 2015), which also increase the exchangeable Ca level in the soil. However, increase in the recalcitrant P fraction as a result of this combination will be necessary to maintain a balance between the labile and non-labile forms of P in the soil (Zapata and Roy, 2004), which will facilitate a continuous release of P over time. Evidence of a reversible reaction occurring between the labile and non-labile P fractions as reported in past research work (Buehler et al.,2002) was further confirmed in the decreases in values observed in the second year of cropping when zero tillage was combined with poultry manure application. Land preparation method of using conventional tillage however further build up the recalcitrant P fraction (Carvalho et al., 2014).

CONCLUSION

Application of fertilizer either organic or inorganic when combined with either zero or conventional tillage was found to affect the distribution of P forms in a maize-potato cropped soil. Combining zero tillage with the application of poultry manure was found to significantly increase both labile and non-labile P fractions. However, the largest P fraction observed as a result of this combination was obtained for resin P, followed by the labile organic P fraction. A necessary caution was however observed for Ca-P and therefore would require a reduction in the rate of application for poultry manure in future research work.However, conventional tillage system with no fertilizer application continued to build-up the recalcitrant P fraction and not reduce it as observed after the second year of cropping.

Implication to Research and Practice

Combined application of organic manure and the conservation tillage system was established to be effective in the buildup of the labile P fractions which invariably determines the availability of P in the soil. However, this for a farmer cultivating a large area of land running into hectares seems unachievable most times especially in the developing countries such Nigeria where this study was carried out. There is therefore a need to research more into land preparation methods especially as regards the conventional method suitable for use in combination with organic manure application for the sustainability of P turnover through the distribution of the labile P forms in the soil.

Vol.8, No.1, pp.1-15, February 2020

Published by ECRTD-UK

Print ISSN: ISSN 2054-6319 (Print), Online ISSN: ISSN 2054-6327(online)

Reference

Abdi, D., Cade-Menun, B.J., Ziadi, N and Parent, L.E. (2014). Long term impact of tillage practices and phosphorus fertilization on soil phosphorus forms as determined by P nuclear magnetic resonance spectroscopy. Environmental Quality, 43(4) 1431-1441.

Adeyemo, A.J and Agele, S.O. (2010). Effect of tillage and manure application on soil physicochemical properties and yield of maize grown on a degraded intensively tilled alfisol in Southwestern Nigeria. Journal of Soil Science and Environmental Management, 1(8) 205-216.

Alam, M.K., Islam, M.M, Salahin, N and Hasanuzzaman. (2014). Effect of tillage practices on soil productivity and crop productivity in Wheat- Mungbean-Rice cropping system under sub-tropical climatic conditions. The Scientific World Journal. Volume 2014, Article ID 437283, 15 pages.

Azevedo, R.P., Salredo, J.H., Lima, P.A, Fraga, V. and Quintao Lana, R.M. (2018). Mobility of phosphorus from organic and inorganic source materials in a sandy soil. International Journal of Recycling in Organic Waste Agriculture, 7(2) 153-163.

Buehler S., Oberson A., Rao I.M., Friessen D.K and Frossard E. (2002). Sequential phosphorus extraction of a 33P-labeled oxisol under contrasting agricultural systems. Soil Science Society of Aerican Journal, 66 868-877.

Carvallo, A.M., Bustamante, M.C., Almondes, Z.A.P. and Figueiredo, C.C. (2014). Forms of phosphorus in an oxisol under different soil tillage systems and cover plants in rotation with maize. R. Bras. Ci. Solo, 38 972-979.

Dalhatu, S and Garba, J. (2012). Soil resources degradation and conservation techniques adopted among the small holder farmers in Gusau, North-Western Nigeria. Nigerian Journal of Basic and Applied Science, 20(2) 134-141.

Gattinger, A., Jawtusch, J., Muller, A and Mader, P. (2011). No-till agriculture- a climate smart solution? Bischofliches Hilfswerk MISEREOR e.V. Mozartstrabe 9, 52064 Achen, Germany. Eds Piepenbrink, Schroeder, A., MISEREOR.

Halloran. (1993). Effect of tillage and fertilization on inorganic and organic soil phosphorus. Canadian Journal of Soil Science, 73 359-369.

Issaka, F., Zhang, Z, Zhao, Z.Q, Asenso, E., Li, J.H., Li, Y.T and Wang, J.J. (2019). Sustainable conservation tillage improves soil nutrients reduces nitrogen and phosphorus losses in Maize farmland in Southern China. Sustainability, 11 1-13.

Jalali, M and Matin N.H. (2013). Soil phosphorus forms and their variations in selected paddy soils of Iran. Environmental Monitoring and Assessment, 185 8557–8565.

Kashem A., Akinremi O.O and Racz G.J. (2004). Phosphorus fractions in soil amended with organic and inorganic phosphorus sources. Canadian Journal of Soil Science, 84(1) 83-90.

Khan, M.Y., Asghar, H.N and Akhtar, M.J (2016). Combined use of phosphate solubilizing bacteria and poultry manure to enhance the growth and yield of mung bean in calcareous soil. Soil and Environment, 35(2) 146-154.

Mandal, K. and Mukhopadhyay, D. (2015). Effects of inorganic phosphorus fractions under different tillage practices on wheat (Triticum aestivum) in an acid soil of West Bengal (India). Tropical Agricultural Research and Extension, 18(3) 102–106.

Margenot, A.J., Paul, B.K., Sommer, R.R., Pulleman, M.M., Parikh, S.J., Jackson, L.E and Fonte, S.J (2017). Can conservation agriculture improve phosphorus (P) availability in weathered soils. Effects of tillage and residue management on soil P status after 9 years in a Kenyan Oxisol. Soil and Tillage Research, 166 157-166.

Murphy J and Riley J.P (1962). A modified single solution method for the determination of phosphate in natural water. Anal Chim Acta, 27 31–36.

Ojo, A.O, Adetunji, M.T., Okeleye, K.A and Adejuyigbe, C.O (2015). Soil fertility, phosphorus fractions and maize yield as affected by poultry manure and single superphosphate. International Scholarly ResearchNotices. Vol. 2015, Article ID 616213, 8 pages.

Rotta, L.R., Paulino, H.B., Anghinoni, I., Souza, E.D., Lopes, G and Carueiro, A.C (2015). Phosphorus fractions and availability in a haplic plinthosol under no-tillage system in the Brazilian Cerrado. Cienc Agrotec, Lavras, 39(3) 216-224.

SAS Institute (2000). SAS for linear models. A guide to the ANOVA and GLM procedures. SAS Institute, Cary, NC.

Selles, F and Faganello, A (1997). Distribution of phosphorus fractions in a Brazilian Oxisol under different tillage systems. Soil and Tillage Research, 44(1-2) 23-34.

Shen J., Yuan L., Zhang J., Li H., Bai Z., Chen X., Zhang W and Zhang, F (2011). Phosphorus dynamics: from soil to plant. Plant Physiology, 156 997–1005.

Shen, J., Yuan, L., Zhang, J., Li, H, Bai, Z., Chen, X., Zhang, W and Zhang, F (2011). Phosphorus dynamics: From soil to plant. Plant Physiology, 156(3) 997-1005.

Shi, Y.C., Ziadi, N., Messiga, A.J., Lalande, R. and Hu, Z (2015). Soil phosphorus fractions change in winter in a corn-soybean rotation with tillage and phosphorus fertilization. Pedosphere, 25(1) 1-11.

Sunar, L and Galantini, J.A (2015). Phosphorus dynamic in the soil-plant system under different management practices in semiarid pampas. International Journal of Plant and Soil Science, 7(2) 109-120.

Tiessen, H and Moir, J.O (1993). “Characterization of Available P by Sequential Extraction,” In: M. R. Carter, Ed., Soil Sampling and Methods of Analysis, Lewis Publishers, Bo-ca Raton, pp. 75-86.

Velasquez, R.., Calabi-Floody, M., Poblete-Grant, P., Rumpel, C., Denamet, R., Condron, L and Merci, M.L (2016). Fertilizer effects on phosphorus fractions and organic matter in Andisols. Journal of Soil Science and Plant Nutrition, 16(2) 294-304.

Zapata, F and Roy, R.N (2004). Use of phosphate rocks for sustainable agriculture. FAO Fertilizer and Plant Nutrition Bulletin, 13 1–148.