Tropentag 2017, Bonn, Germany
September 20-22, 2017

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Bonn, Bonn, Germany

Phosphorus Fractionation and Sorption Characteristics of Biochar Amended Soils of Ghana

Joseph Osafo Eduah[1*], Mark Kofi Abekoe[1], Henrik Breuning-Madsen[2], Mathias Neumann Andersen[3]

[1]University of Ghana, Department of Soil Science, Ghana
[2]University of Copenhagen, Department of Geosciences and Natural Resource Management, Denmark
[3]Aarhus University, Department of Agroecology and Environment, Denmark

Abstract

The high phosphorus fixing capacity of tropical soils including Ghanaian soils has restrained the development of economically sustainable crop production. The application of biochar can change surface chemical properties of highly weathered tropical soils, and hence affect phosphate sorption and distribution of P pools in soils. The study therefore aimed at the effect of corn cob and rice husk biochar on P sorption and fractions in two acid and one alkaline soil of Ghana. The biochars were produced at varying pyrolytic temperatures (300^{O}C, 450^{O}C and 650^{O}C) and applied at a rate of 1% (w/w) to the soils and incubated for 60 days. Phosphorus fractions of biochars and soil-biochar mixtures was assessed by a modified Hedley method whiles sorption of P was studied by fitting the equilibrium solution and adsorbed P concentrations using Langmuir and Freundlich sorption isotherms. Amending the acid soils with biochar increased the equilibrium P concentration in solution significantly at decreasing pyrolytic temperature for the two biochar types. There was however, an increase in P sorption with increasing charring temperatures in the alkaline soil. The interaction of biochar with soils resulted in an increase in the readily available P (Resin-P & $NaHCO_3$-Pi) fractions making P more available for plant uptake. The increase in the readily available P pool was more significant at relatively lower temperature (300^{O}C) than higher charring temperatures for both biochar types. Calcium-bound P (HCl-P) of the soils increased sharply upon biochar addition but the Al & Fe-bound P (NaOH-Pi, moderately labile P) decreased. The study thus showed that biochar pyrolysed at 300-450^{O}C could be used to reduce P sorption and increase P bioavailability especially in acid soils.

Keywords: Acid soils, adsorption, alkaline soil, desorption, phosphorus

*Corresponding author email: jo.eduah@yahoo.com

Introduction

The high phosphorus (P) fixing capacity of highly weathered tropical soils including Ghanaian soils has restrained the development of economically sustainable crop production (Brady and Weils, 2001). Geochemical processes such as dissolution, complexation, adsorption and precipitation undergone by P in soils determine its mobility and fate (Gérard, 2016). Amending tropical soils with biochar has reportedly improved P bioavailability and plant growth. Biochar reduces soil acidity and hence controls P complexation with Fe^{3+}, Al^{3+} and Ca^{2+} (Xu et al. 2014). Due to its large surface area and high negative surface charge, biochar alters the surface chemistry of tropical soils, and therefore affect P distribution in soils (Liang et al., 2014). The Interactive effect of biochar at varying pyrolytic temperatures with Ghanaian soils on P sorption and pools is less explored even though the information will be useful for the effective management of P for sustainable crop production in the country. The study therefore investigated biochar effect on P sorption and P fractions in some soils of Ghana.

Materials and Methods

Two biochar types at three different pyrolytic temperatures (300°C, 450°C and 650°C) were produced from corn cob (C) (*Zea mays*) and rice husk (R) (*Oryza sativa*). Two acid soils namely Typic Plinthustult (U), Plinthic Acrudox (O) and one alkaline soil, (Quartzipsamment (A)) were sampled from different agro-ecological zones of Ghana. The biochar types were mixed with the soils at a rate of 1% (30.4 g/kg) and incubated for 60 days. Phosphorus adsorption studies were conducted by shaking soil/biochar mixture in various concentrations of P solution. The Langmuir and Freundlich sorption isotherms were used to describe P adsorption data**.** Soil-biochar P fractions were partitioned by sequential chemical extraction using modified Hedley's fractionation procedure that consisted of four inorganic P (Resin-P, $NaHCO_3$-Pi, NaOH-Pi & HCl-Pi), two organic P ($NaHCO_3$-Po & NaOH-Po) and occluded P (Residual P) (Hedley et al. 1982a).

Results and Discussion

Sorption characteristics of soils and soil-biochar mixture

The Langmuir equation effectively explained P sorption by the three soil types, showing an increase in P sorption with increasing P concentration but at decreasing increment (Fig. 1). The sorption capacity of the two acid soils, Typic Plinthustult (U) (384.5 mg kg^{-1}) and Plinthic Acrudox (O) (333.3 mg kg^{-1}) was relatively higher than the alkaline soil, Quartzipsamment (A) (104.2 mg kg^{-1}) (Fig.1). The relatively high P sorption capacity of the former is due to the high content of amorphous and crystalline Fe and Al oxides (Jiang et al., 2015). Incorporating the two biochar types into the acid soils significantly ($p < 0.05$) decreased P sorption. The result of the present study is consistent with those of Morales et al. (2013) who found that biochar reduces P fixing capacity of degraded tropical acid soils. The inhibitory effect of biochar produced at 300^{O}C (UR3, UC3, OR3, OC3) on P adsorption onto the acid soils was relatively greater than at 450^{O}C and 650^{O}C. Adding biochar to the soils raised the CEC, but decreased with increasing pyrolytic temperature. This may have led to an increase in electrostatic anion repulsion between the negatively charged soil-biochar surfaces and the negatively charged P ions (HPO_4^{2} / $H_2PO_4^{-}$). Unlike the decrease in P sorption in the Typic Plinthustult and Plinthic Acrudox amended with the biochar types, the Quartzipsamment showed increase in P sorption with increasing charring temperatures probably due to the formation of Ca and Mg phosphate precipitates (Chintala et al. 2014).

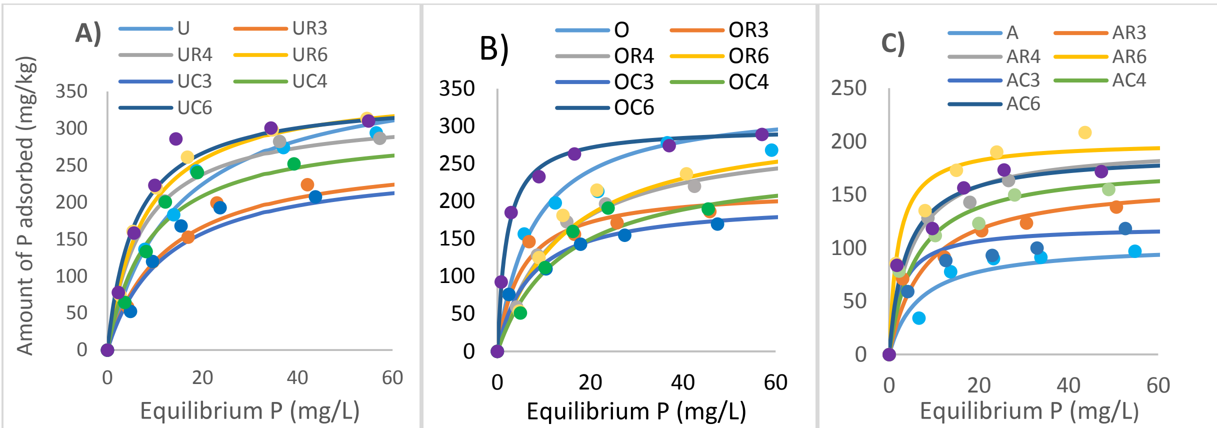

Fig 1. Phosphorus sorption isotherm for A) Typic Plinthustult (U), B) Plinthic Acrudox (O) and C) Quartzipsamment (A) amended with corn cob biochar and rice husk biochar at 300ºC, 450ºC and 650ºC pyrolytic temperature.

Phosphorus fractions of soils and soil-biochar mixture

The readily labile P (Resin-P & $NaHCO_3$-Pi) and the Ca-bound Pi (HCl-Pi) of the three soils increased significantly ($p < 0.05$) upon biochar amendment making P available for plant uptake (Fig. 2). This observation is similar to that of Ch'ng et al. (2014) who also reported a significant increase in Ca-P and Resin-P fractions upon the application of biochar. The increase in the labile P pool was more significant at relatively low temperatures (300^{O}C and 450^{O}C). There was no significant ($p > 0.05$) effect of the biochar types on the moderately labile P (NaOH-Pi) and the residual P of the soils.

Conclusion and Outlook

The study indicated that biochar influences P cycling and distribution in tropical soils. Phosphorus availability increased in the acid soils but decreased in the alkaline soil. Biochar produced at low temperatures (300^{O}C and 450^{O}C) can be considered as appropriate amendments in acid soils to make P more available for plant uptake. Future studies should focus on the long term effect of biochar at various pyrolytic temperatures on P sorption and fractions in tropical soils.

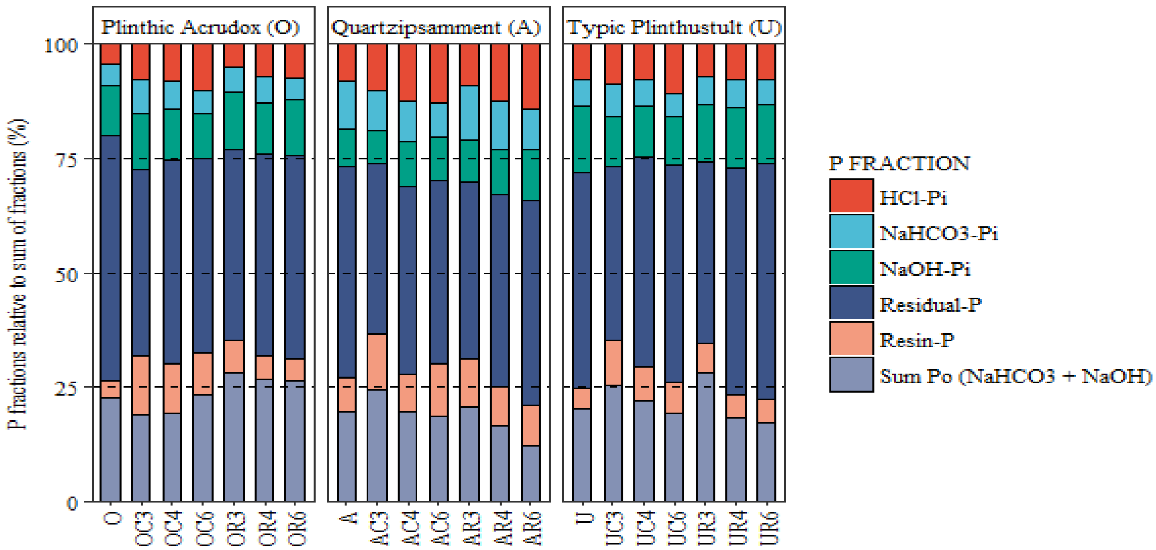

Fig 2. Percentage distribution of P fractions in the biochar amended soils

References

1. XU, G., SUN, J., SHAO, H., AND CHANG, S.X. (2014). Biochar had effects on phosphorus sorption and desorption in three soils with differing acidity. Ecological Engineering. 62: 54– 60
2. BRADY, N.C., AND WEIL, R.R., 2002. The nature and properties of soils. Prentice Hall, Upper Saddle River, NJ.
3. MORALES, M. M., COMERFORD, N., GUERRINI, I.A., FALCAO, N.P.S., AND REEVES, J.B. (2013). Sorption and desorption of phosphate on biochar and Biochar-soil mixtures. Soil Use and Management. 29, 306-314
4. GÉRARD, F., (2016). Clay minerals, iron/aluminum oxides, and their contribution to phosphate sorption in soils-A myth revisited. Geoderma 262: 213-226
5. LIANG, Y., CAO, X., ZHAO, L., XU, X., AND HARRIS, W., (2014). Phosphorus Release from Dairy Manure, the Manure-Derived Biochar, and Their Amended Soil: Effects of Phosphorus Nature and Soil Property. J. Environ. Qual. 43:1504-1509
6. JIANG, J., YUAN, M., RENKOU, X., AND BISH, D.L., (2015). Mobilization of phosphate in variable-charge soils amended with biochars derived from crop straws. Soil & Tillage Research. 146: 139-147
7. CHINTALA, R., SCHUMACHER, T.E., MCDONALD, L.M., CLAY, D.E., MALO, D.D., PAPIERNIK, S.K., CLAY, S.A., JULSON, J.L., (2014). Phosphorus Sorption and Availability from Biochars and Soil/Biochar Mixtures. Clean-Soil, Air, Water. 42 (5), 626-634
8. HEDLEY, M.J., STEWART, J.W.B., CHAUHAN, B.S., (1982a). Changes in inorganic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. Soil Science Society of America Journal 46, 970-976.
9. CH'NG, H.Y., OSUMANU HARUNA AHMED O.H., NIK MUHAMAD AB MAJID, N.M.A., (2014). Improving Phosphorus Availability in an Acid Soil Using Organic Amendments Produced from Agroindustrial Wastes. Scientific World Journal.