Eurasian J Soil Sci 2016, 5 (2) 84 - 88

Eurasian Journal of Soil Science

Journal homepage : http://fesss.org/eurasian_journal_of_soil_science.asp

Dissolution of rock phosphate in animal manure soil amendment and lettuce growth

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Abstract

A study was conducted in pots on the field to assess the effect of different quantities of poultry manure (PM), cattle manure (CM) and pig manure (PG) on the release of available phosphorus from Togo rock phosphate (RP) and lettuce growth. There were eleven (11) treatments which were: Control (soil only); 2.5g RP; 2.5g CM; 2.5gRP + 2.5g CM; 2.5gRP + 5gCM; 2.5gPM; 2.5gRP + 2.5gPM; 2.5gRP + 5gPM; 2.5gPG; 2.5gRP + 2.5gPG; 2.5gRP + 5gPG, applied per kg soil, using the Completely Randomized Design (CRD) with three replications. Available phosphorus and other parameters were assessed using standard methods. Results were statistically analyzed using the the GenStat (11th Edition) statistical software package. The amount and type of animal manure in the amendment affected the amount of the available P released. The addition of 2.5g manure to 2.5g RP in a kg of soil significantly ($P<0.05$) increased available P by 4 to 7 times over the sole 2.5g RP/kg soil treatment. Doubling the amount of manure in the amendment (5g manure + 2.5g RP) almost doubled the amount of P released, with the poultry manure combinations being more significant. The amount of available P in the soil positively related to the plant height (R^2=63), leaf area (R^2=0.55), dry weight (R^2=0.73) and the percentage P in the leaf (R^2=0.88) of lettuce. The PM at 2.5gRP + 5gPM recorded the highest significant ($P<0.05$) values. The study has provided further basis for manure selection and quantities to be used in enhancing the release of P from rock phosphate. However, investigations need to be continued using nuclear techniques.

Article Info

Received : 30.08.2015
Accepted : 15.10.2015

Keywords: Available phosphorus, manure, rock phosphate, soil amendment

Introduction

In comparison with other parts of the world, most soils of Africa are considered as inherently poor. Nutrient mining combined with the inherently low soil fertility has been blamed for the low crop yields in Africa (Shepherd et al. 1996).

It is generally viewed that substantial increases in inorganic fertilizer use are necessary to restore and maintain the fertility of African soils and enhance their productivity (Minot and Benson, 2009). Though inorganic fertilizers have dramatically increased food production worldwide, high costs, poor distribution systems and lack of manufacturing capacity are some of the factors preventing farmers from accessing the fertilizers they need to maintain the health of their farmland (Eurekalert, 2006).

With the rise in costs of industrial fertilizers of which phosphorus fertilizers are integral part in developing countries, it has become necessary to look for alternative phosphorus sources for farming operations.

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e-ISSN: 2147-4249 DOI: http://dx.doi.org/10.18393/ejss.2016.2.084-088

Rock phosphate, a naturally occurring mineral source of phosphate, could serve as an alternative source of phosphorus in developing countries. It has been found to be much less expensive than soluble phosphorus fertilizers (Lorion, 2004). However, rock phosphate material has poor solubility when used as a fertilizer in soils.

Treating rock phosphate with organic materials is found to be a technique for enhancing the solubility and the subsequent availability to plants of phosphorus (Zapata and Roy, 2004).

Several studies have been conducted on amending rock phosphates to enhance their rate of dissolution after application to soils. The incorporation of agricultural wastes like poultry manure and cow dung with rock phosphate significantly improved the release of P and performance of crops (Singh and Amberger, 1990; Akande et.al. 2005; Akande et.al. 2008).

In the quest to delve more into the use of organic manure to ease the release of available phosphorus from rock phosphate, the present study was conducted with the objective of assessing the effect of different kinds and quantities of poultry manure, cattle manure and pig manure on the release of available phosphorus and growth of lettuce using Togo rock phosphate.

Material and Methods

An experiment was carried out at the College of Agriculture Education (latitude 07° 04'N; longitude 01° 24'W), University of Education, Winneba Ghana, from May to July, 2014. The soil of the area is classified by the FAO-UNESCO legend as Chromic Luvisol (Asiamah, 1988).

Soil was sampled from the top layer (0 – 15cm) of the College's experimental field and sieved through a 2mm sieve. The sieved soil was amended with dried and ground poultry manure (PM), cattle manure (CM), pig manure (PG) and rock phosphate (RP), which were also sieved through a 2mm sieve at various proportions in pots (diameter - 10cm; 5kg soil capacity). The physical and chemical properties of the soil, animal manures and the rock phosphate are presented in Tables 1 and 2.

Table 1. Some chemical and physical properties of the soil used for the study

pH (1:1)	OC, %	N, %	Ca	Mg	K	Na	OM, %	P, mg/kg	Exch. A(Al+H)	TEB, me/100g	BS, %	Sand, %	Silt, %	Clay, %
			(me/100g)											
6.33	1.18	0.12	4.63	1.6	0.16	0.09	2.04	28.14	0.10	6.48	98.47	78.28	2.21	19.51
												Loamy Sand		

Table 2. Some chemical properties of rock phosphate and animal manures used for the study

	Ca	Mg	K	P	N
	(%)				
Poultry manure	2.14	0.65	0.90	1.77	4.27
Cattle manure	1.98	0.64	0.26	0.71	2.06
Pig manure	0.26	1.40	0.48	1.57	2.13
Rock phosphate	46.82	0.03	0.02	11.04	0.04

The treatments per kg soil were: Control (soil only); 2.5g RP; 2.5g CM; 2.5gRP + 2.5g CM; 2.5gRP + 5gCM; 2.5gPM; 2.5gRP + 2.5gPM; 2.5gRP + 5gPM; 2.5gPG; 2.5gRP + 2.5gPG; 2.5gRP + 5gPG.

There were three replications for the treatments. The Completely Randomized Design (CRD) was used to assign treatments on the field. The treatments were placed on the field for two weeks under rainfall conditions. Samples of soil from the treatments were taken for chemical analyses before two weeks old lettuce (leaf lettuce) seedlings (4plants/pot) were transplanted on them.

The physical and chemical properties of soil samples, animal manures, rock phosphate and plant samples were assessed using standard methods which involved; organic matter (Walkley and Black, 1934), particle size analysis (Bouyoucos, 1962), total nitrogen and total phosphorus (Anderson and Ingram, 1989), total K (IITA, 1985), available phosphorus (Bray and Kurtz, 1945), exchangeable Ca, Mn, K and Na (IITA, 1985) and Al (McLean, 1982).

At 30 days after transplanting the lettuce plants were harvested. Plant heights were measured with a meter rule and a string. The leaf area of the plants was measured by the grid counting method and the dry matter of the plant assessed by the oven dying method. Values of parameters were subjected to analysis of variance (ANOVA) and the Least Significant Difference Test (P<0.05) for the separation of means using the GenStat (11th Edition) statistical software package.

Results and Discussion

Table 3 indicates available P, exchangeable Ca, Fe, Mn and Al released from the rock phosphate soil amendment with different types of animal manure after two weeks of incubation under natural conditions on the field. At the same RP level of 2.5g/soil the animal manure soil amendments recorded significantly (P<0.05) higher values of available P than the RP + Soil and the control.

Table 3. Available P levels and other nutrients after soil amendment

Treatment (per kg soil)	PO_4, mg/kg	Ca, me/100g	Fe, mg/kg	Mn, mg/kg	Al, me/100g
Control	141.96	5.11	66.04	1.43	0.00
2.5g RP	149.29	5.13	66.98	1.44	0.00
2.5g CM	183.56	5.16	70.00	1.45	0.00
2.5gRP + 2.5g CM	212.94	5.15	69.58	1.45	0.00
2.5gRP + 5gCM	298.62	5.20	69.48	1.47	0.00
2.5gPM	208.05	5.47	68.40	1.44	0.00
2.5gRP + 2.5gPM	256.99	5.40	70.71	1.47	0.00
2.5gRP + 5gPM	389.19	5.61	67.97	1.47	0.00
2.5gPG	200.72	5.34	68.01	1.46	0.00
2.5gRP + 2.5gPG	253.32	5.31	70.50	1.47	0.00
2.5gRP + 5gPG	323.09	5.47	69.00	1.48	0.00
LSD	29.19	0.61	8.30	0.50	NA
CV	12.40	4.11	3.22	10.00	NA

Figure 1 shows the estimated amount of available P released from the RP alone in the various treatments. The amount and type of animal manure in the amendment affected the amount of the available P released. The addition of 2.5g manure to 2.5g RP in a kg of soil significantly (P<0.05) increased available P by 4 to 7 times over the sole 2.5g RP/kg soil treatment. Doubling the amount of manure in the amendment (5g manure + 2.5g RP) almost doubled the amount of P released, especially for the poultry and the cattle manures. Significant differences were seen among the different types of animal manures in the P released, especially, at 5g manure amendment, the poultry manure released the highest amount of P which was almost 1.6 and 1.8 times greater than the amount released under the cattle and pig manures respectively. In a similar study using palm oil mill effluent, the release of available P from RP was found to increase with the application of the effluent and the amount applied (Oviasogie and Uzoekwe, 2011), which is observed in the current study.

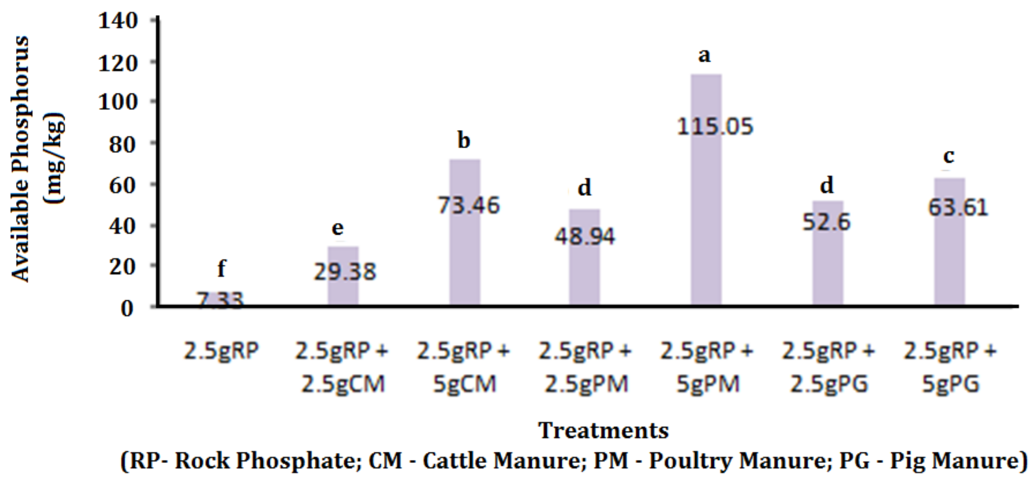

Figure 1. Estimated amount of available phosphorus released from only rock phosphate (RP) under different soil manure amendment (Figures with the same letters are not significantly (P<0.05) different from each other)

The ability of organic manure in enhancing the release of available P from RP has been related to increase in microbial activities and the acidic soil conditions created by the decay of the organic manure (Kim et al. 1997; Rashid et al. 2004; Chen et al. 2006; Nishanth and Biswas, 2008; Kumari et al. 2008). Different organic materials will create different soil environmental conditions (Bangar et al. 1985; Nair and Ngouajio, 2012) and hence leading to differences in the release of available P from RP in soil amendments. Such situations might be the reasons behind the significant performance of the PM in enhancing higher release of available P in the amendments than the rest of the organic materials, because PM has been found to produce higher microbial biomass and hence acidic conditions in soil amendments (Lin et al. 2010).

Available P in the soils may be converted into insoluble complexes (Mehta et al. 2015) through precipitation reactions with Ca^{2+} in calcareous soils and Mn^{3+}, Al^{3+} and Fe^{3+} in acidic soils (Khan et al. 2009). The effect of Ca^{2+}, Mn^{3+}, Al^{3+} and Fe^{3+} impacting differences among the treatments may be considered as insignificant as the concentrations in the treatments were not significantly different (Table 3).

The RP treated with different combinations of the organic manures significantly ($P < 0.05$) increased the growth and yield characteristics of lettuce (Table 4) as well as the percentage N, P and K contents of the lettuce leaves (Table 5) in comparison to the sole RP and the control treatments. The amount of available P in the soil positively related to the plant height (R^2=63), leaf area (R^2=0.55), dry weight (R^2=0.73) and the percentage P in the leaf (R^2=0.88) of lettuce. The PM at 2.5gRP + 5gPM recorded the highest significant ($P<0.05$) values of the parameters than the other treatments, bearing the same trend as the available P released in the soil discussed above.

Table 4. Growth and yield parameters of lettuce after soil amendment

Treatment (per kg soil)	Plant Height (cm)	Leaf Area (cm²)	Dry weight (g)
Control	9.20	38.18	11.36
2.5g RP	11.90	40.50	12.23
2.5g CM	12.30	49.02	14.11
2.5gRP + 2.5g CM	15.70	79.75	16.58
2.5gRP + 5gCM	15.70	75.46	17.53
2.5gPM	16.70	75.40	18.12
2.5gRP + 2.5gPM	19.50	78.02	19.21
2.5gRP + 5gPM	21.30	80.80	23.62
2.5gPG	13.10	59.64	14.51
2.5gRP + 2.5gPG	13.60	65.28	15.40
2.5gRP + 5gPG	15.55	69.84	16.62
LSD	1.51	2.44	1.60
CV	4.50	12.00	9.70

Table 5. Nutrient content of lettuce after soil amendment

Treatment (per kg soil)	N (%)	P (%)	K (%)
Control	1.40	0.37	1.23
2.5g RP	1.54	0.40	1.97
2.5g CM	1.75	0.40	1.28
2.5gRP + 2.5g CM	1.88	0.44	1.64
2.5gRP + 5gCM	1.90	0.48	1.91
2.5gPM	1.71	0.43	2.00
2.5gRP + 2.5gPM	1.93	0.50	1.34
2.5gRP + 5gPM	2.03	0.56	2.03
2.5gPG	1.88	0.42	1.80
2.5gRP + 2.5gPG	1.89	0.45	1.82
2.5gRP + 5gPG	1.92	0.47	1.68
LSD	0.77	0.10	0.85
CV	3.22	5.10	2.00

Conclusion

The application of poultry manure, cattle manure and pig manure in rock phosphate soil amendment improved the dissolution of P from the rock phosphate, with the poultry manure being much more effective. The dissolution increased with the quantity of manure applied. The growth, yield and percentage P content of lettuce increased relative to the available P in the amended soil. Repetition of the experiment using nuclear techniques is imperative as this will give more accurate results.

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