Effect of Minjingu Phosphate Rock (MPR) and Farmyard Manure (FYM) Applied to an Oxic Haplustults on Bray -1-P and the Response of Maize to Applied MPR and FYM

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Abstract

A glasshouse pot experiment was carried out at SUA farm, Morogoro, Tanzania to investigate the effect of Minjingu phosphate rock (MPR) and farmyard manure (FYM) applied to an Oxic Haplustults on Bray 1-P and the response of maize (Zea mays (L.) variety staha) to the applied MPR and FYM in a 4^2 factorial experiment in a completely randomized block design. MPR was applied at the rates of 0,50,100 and 150mg P kg^{-1} soil and FYM at the rates of 0,7.5,15 and 30g kg^{-1} soil. The MPR and FYM were thoroughly mixed with 4.5 kg of 4mm sieved soil sample portions in 5-litre capacity plastic pots and incubated at 75% field capacity moisture content for 28 days before sowing four maize seeds and thinned to two plants one week after germination. The whole plant portions above the soil level in the pots were harvested at the age of 6 weeks for dry matter yields and P content determinations. The highest MPR and FYM combination increased the amounts of Bray – 1-P by 268%, and maize dry matter yields by 91%, compared to the control The above increases were attributed to the dissolution of the MPR and the decomposition and mineralization of the FYM hence releasing P and reducing the P-retention capacity of the soil and improvement soil physical, chemical and biological soil conditions by the applied FYM.

Key words: Minjingu phosphate rock farmyard manure Bray –1-P, dissolution, mineralization, decomposition.

Introduction

The majority of the soils in the humid tropics are highly weathered, leached, acidic and their clay fractions dominated by 1:1 clay minerals and hydrous oxides of Al and Fe. These soils are deficient in most of the major essential plant nutrients, phosphorus inclusive (Landon, 1991). The low available phosphorus contents in these soils could either be due to inherently deficient P contents in the soils parent materials or P occurring in forms that are not easily available to plants. In order to sustain plant growth and development in such soils, phosphorus has to be applied either in the form of inorganic fertilizers, manures or crop residues. However, most of the phosphorus added to such soils is converted into forms not easily available to plants. To attain adequate levels of available P for plants, substantial amounts of phosphate have to be applied so as to saturate the phosphate retention sites of the soils such that some of the applied phosphate remains labile in the soils.

It has been suggested that use of phosphate rock could be a viable and cheap alternative source of phosphate for the highly weathered and acid soils with high phosphate retention capacities (Burresh *et al.*, *1997)*. Most phosphate

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rocks (PR) are insoluble in water hence the P in PR is not immediately available to plants. However, the solubility of phosphate rock is enhanced when applied to highly weathered and acid soils. The enhanced solubility of PR is attributed to the presence of protons and sinks for phosphate and the calcium released during the PR dissolution process (Robinson and Syers, 1991; Robinson *et al.*, 1992). The congruent dissolution reaction of fluoro-apatite could be expressed by the chemical reaction equation (Rajan *et al.*, 1996).

$$Ca_{10}(PO_4)_6F_2+12H_2O \Leftrightarrow Ca^{2+} + H_2PO_4^{-1}+OH^-$$

In acid soils, the concentration of protons is high while the concentrations of phosphate and calcium ions are very low, hence the available sinks for OH^-, $H_2PO^-_4$ and Ca^{2+}, respectively. In acid soils, dissolution of phosphate rock is further enhanced by increased time of contact between the PR and soil (Chien, 1978) and the physical and chemical composition of the phosphate rock (Khasawneh and Doll, 1978; McClellan and Gremillion, 1980).

It has further been reported that use of phosphate rock together with manures and other organic soil amendments in acid soils enhanced the dissolution of phosphate rocks (Panda, 1990; Ikera *et al.*, 1994). However, positive and negative interactions between phosphate rock, organic soil amendments and soil with respect to phosphate rock dissolution have been reported (Chien *et al.*, 1990). The enhanced dissolution of phosphate rocks when applied together with manures was attributed to the release of simple organic acids during the decomposition and mineralization of the manures, thus releasing protons which enhanced the dissolution of phosphate rock. Further, the tendency for the formation of complex compounds between humic compounds and calcium creates a sink for the Ca^{2+} released during the dissolution of PR (Rajan *et al.*, 1996), further enhancing the dissolution of the phosphate rock.

The main objective of the current study was to investigate the effects of various combinations of MPR and FYM, on the dissolution and decomposition of MPR and FYM, respectively and the response of maize to the MPR-FYM treatment applied to an Oxic Haplustults in a glasshouse pot experiment. The specific objectives were to study the influence of the MPR-FYM treatments on the amounts of Bray-I-P, yields of maize and phosphorus contents in the maize plants.

Materials and methods

A glasshouse pot experiment study was conducted at the Sokoine University of Agriculture (SUA) Morogoro, Tanzania, to evaluate Minjingu PR as a source of phosphate for maize (*Zea mays L var staha*) plants when applied in combination with kraal manure (FYM) to a highly weathered acid soil. A composite soil sample for the pot experiment was collected from the SUA farm. Twenty soil samples from an area covering about 2.5 ha were collected randomly at a depth of 0-30cm and composited. The composited soil was airdried and ground to pass through a 4mm sieve. A small portion (200g) of the 4mm sieved composite soil sample was further ground to pass through a 2mm sieve and used for the determination of the soil's physical and chemical properties while the rest of the soil was used for the glasshouse pot experiment. The soil used in this study was classified as an Oxic Haplustults (Kaaya *et al.*, 1994) equivalent to Dystric Nitosols (FAO – UNESCO, 1988).

The FYM was collected from a cattle kraal at Sangasanga village, Morogoro. The FYM was air dried ground and sieved using a 2mm. sieve. The Minjingu phosphate was obtained from Minjingu, Arusha, Tanzania.

The soil pH was measured in a soil water suspension (1:2.5 soil:water) based on the procedure of Dewis and Freitas (1970) while the cation exchange capacity was determined by the neutral amminium acetate saturation method (Thomas., 1982). The quantities of exchangerable Ca, Mg, K and Na ions in the ammonium acetate filtrate were measured by atomic absorption spectrophotometry (Thomas, 1982). Organic carbon was determined by the wet oxidation method of Walkey and Black (Nelson and Sommers, 1982). Total nitrogen was determined by the micro-Kjeldahl digestion-distillation method (Bremner and Mulvaney, 1982). Plant available P was extracted by the Bray-I-P- procedure (Bray and Kurtz, 1945) and the P in the extract determined by the procedure of Murphy and Riley (1962) as modified by Watanabe and Olsen (1965). The particle size analysis was determined by the Bouyoucous hydrometer method (Day, 1965).

The chemical composition of the Minjingu phosphate rock was analysed at IFDC, Muscles Shoals, Alabama. USA by X-ray fluorescence. Total analysis of the kraal manure (FYM) included total organic carbon. N. P. Ca and K were determined using the procedures of Okalebo *et al.* (1993).

Glasshouse pot experiment

Five litre plastic buckets with drainage holes at the bottom were used for the experiment. Forty eight. 4.5 kg soil sample portions of the 4mm sieved composite soil were weighed into the five litre capacity plastic buckets and mixed thoroughly with the weighed amoamounts of MPR and FYM, in three replicates of the MRP-FYM combinations. A 4^2 factorial combination in a randomized complete block design was used with rates of 0, 50. 100, and 150 mg Pkg $^{-1}$ soil (equivalent to 0. 100, 200 and 300kg Pha^{-1} as MPR) and 0, 7.5 15 and 30g FYMkg^{-1} soil (equivalent to 0, 15, 30 and 60 tons FYM ha^{-1}). The soil-MPR-FYM treatments were incubated for one month at 75% field capacity moisture content (using distilled H_2O). After the incubation period. four maize seeds were sown in each pot and thinned to two plants per pot one week after germination. Nitrogen fertilizer equivalent to 100kgNha^{-1} as $(NH_4)_2SO_4$ was added to each pot two weeks after germination. Soil sampling from the potted soil was done twice. first immediately after the incubation (before planting) and the second, seven weeks from the planting (immediately after harvesting). Whole plant samples above the soil levels in the pots were harvested seven weeks from planting for dry matter determination and P in the maize plants. The % P contents in the maize plant samples were determined following the procedure of Okalebo *et al.* (1993).

Results and discussion

Soil properties

Some of the physical and chemical properties of the Oxic Haplustults (Dystric Nitosols) are presented in Table 1. From the data in Table 1. the Oxic Haplustults could be taken to be highly weathered and leached based on the low CEC, low percentage base saturation and the low soil pH. According to Landon (1991) the Oxic Haplustults would be rated as of low fertility status with respect to the low amount of Bray – 1-P. total nitrogen. and exchangeable bases namely. Ca, Mg and K. To optimize on crop production. in this case maize, the deficient nutrients have to be applied to the soil in the form of fertilizers or manures to meet the crop requirements

Table 1: Some physico-chemical properties of the Oxic Haplustults

Parameter	Value
pH in water (1:2:5)	5.0
Organic carbon (%)	1.7
Organic matter (%)	3.0
CEC (Cmol (+) kg^{-1})	12.5
Exchangeable bases (Cmol kg -1 soil)	
Na^{+}	0.45
K^{+}	0.94
Ca^{+2}	4.0
Mg^{2+}	2.0
Total N%	0.07
(Bray -1-P (mg Pkg^{-1} soil)	3.55
Particle size distribution,	
Sand (%)	65.8
Coarse silt (%)	2.0
Fine Silt (%)	2.2
Clay (%)	30.0
Textural Class	Sand Clay Loam

Properties of the manure

Some roperties of the FYM are presented in Table 2. The FYM contained low amounts of total N. P and Ca. The low amounts of total N,P and Ca in the FYM could be due to their low contents in the feeds given to the animals. The FYM (kraal manure) was collected from an open kraal (boma) with no concrete floor. hence the FYM was a mixture of soil. cow dung and minimal amounts or urine. The FYM used in the study was rated as of low quality.

Table 2: Some chemical properties of the farmyard manure (FYM)

Constituent	Value
Total Organic Carbon (%)	20.20
Total Nitrogen (%)	0.98
Total Phosphorus (%)	0.18
Total Calcium (%)	3.54
Total Potassium (%)	4.70
pH (in H_2O)	8.50

Chemical composition of the Minjingu phosphate rock

The chemical constitution of the Minjingu phosphate rock is presented in Table 3. The contents of P and Ca in the MPR were high hence the MPR could be rated as a potentially good fertilizer material based on the P and Ca contents.

Table 3: Chemical composition of the Minjingu phosphate*

Major Constituent	% Content (Weight basis)
P_2O_5	29.0
CaO	41.7
Al_2O_3	1.2
Fe_2O_3	0.4
MgO	3.2
Na_2O	1.3
K_2O	0.8
F	3.1
S	0.1
SiO_2	9.4
CO_2	3.1

* Analysed at IFDC, Muscle Shoals, Alabama USA.

Effect of incubating + MPR + FYM on Bray-I-P

The effect of one month period of incubation (equilibration) of the soil, MPR and FYM together on Bray-1-P is presented in Table 4. Both the FYM and MPR when applied singly or in combination significantly (P= 0.05) increased the amount of Bray-1-P. The more pronounced increase in Bray –1-P. for the MPR x FYM combination, could be attributed to the P released from the dissolution of MPR and decomposition of the FYM. Decomposition of FYM may have enhanced dissolution of the MPR by the organic acids produced during its decomposition. The above results conform to those reported by (Ikera) *et al.* (1994). The amounts of P released based on the amounts of MPR and FYM mixed with the soil in the posts suggest that the dissolution of the MPR and the decomposition rates of the FYM are slow and gradual, hence extended reaction (contact) time between the MPR-FYM- soil is essential for the release of P from MPR.

The amounts of Bray – 1- extractable phosphate at harvesting time, that is 11 weeks of contact between MPR-FYM in the soil are presented in Table 5. The effect of FYM alone at different rates had no significant effect on the amounts of Bray- 1-P. and this could be attributed to the low content of P in the FYM, loss of the released P through plant uptake, fixation of the phosphate released from the FYM by the soil colloids. The differences in amounts of Bray- 1-P in Table 4 and Table 5 confirm the gradual release of P from MPR and FYM through the processes of dissolution and decomposition (mineralization), respectively. Further, the positive influence of MPR x FYM- interaction on the amount of Bray – 1 extractable P could be attributed to the sustenance of the P and Ca sinks in the soil through formation of complexes between the simple organic compounds and phosphate and Ca ions released during the decomposition and dissolution of the FYM and MPR, respectively (Chien, 1978).

Table 4: Effect of 28 days of incubating soil, Minjingu rock phosphate and farmyard manure together on Bray -1-extractable P

FYM-rates	Minjingu Phosphate rock rates (mg P kg^{-1})				
gkg^{-1} soil	0.0	50.0	100.0	150.0	Marginal means
	Bray -I-P-(mgPkg^{-1} soil)				
0.0	3.53i	4.80gh	5.90ef	8.85c	5.78
7.5	4.50h	5.50fg	46.30de	8.53c	6.20
15.0	4.80gh	5.60efg	6.90d	10.67b	6.99
30.0	5.40fg	6.80od	8.16c	13.0a	8.32
Marginal means	4.55	5.67	6.81	10.26	6.82

CV 6.51

Means within the same column followed by the same letter are not significantly different at P<0.05 according to the New Duncan's New Range Test.

Table 5: Effect Minjingu phosphate rock - farmyard manure on soil Bray -1-Pat maize plant's harvesting time (11 weeks of contact)

FYM-rates	Minjingu Phosphate rock rates (mg P kg^{-1})				
gkg^{-1} soil	0.0	50	100.0	150.0	Marginal means
	Bray -I-P-(mgPkg^{-1} soil)				
0.0	4.33i	4.78i	8.45f	10.45cd	7.00
7.5	4.53i	6.50gh	9.52e	11.20bc	7.94
15	4.54i	6.00h	9.60e	12.00b	8.04
30.0	4.65i	7.21g	10.23de	15.00a	9.27
Marginal means	4.51i	6.12	9.45	12.16	8.06

Means within the same column followed by the same letter are not significantly different at $P<0.05$ according to the New Duncan's New Multiple Range Test.

Maize dry matter yields

The maize dry matter yields at the various rates of MPR. FYM and MPR x FYM are presented in Table 6. The treatments significantly increased the dry matter yields of the maize. The positive response by the maize plants to the MPR. FYM and MPR x FYM treatments could be attributed to the elevated availability of phosphorus accruing from the P contained in the MPR and FYM. The P contained in the FYM and MPR was released during the dissolution of the MPR and decomposition of the FYM (Table 4 and Table 5).

Table 6: Effet of MPR and FYM combinations on the dry matter yields of maize

FYM rate (gkg-^{1}soil)	Phosphate rates (mg Pkg-1 soil) as MPR 0.0	50.0	100.0	150.0	Marginal means
		yields g/pot			
0.0	22.59i	33.30k	35.15h	37.041	32.02
7.5	24.39i	37.431	39.25ih	42.92fg	36.00
15.0	28.9j	39.64ih	43.41fg	46.60nl	39.64
30	33.12k	42.19fg	47.21nl	50.50nh	43.0
Marginal Means	27.26	38.14	41.20	44.29	

Means within the same column follwed by same letter are not significantly different at $P<0.05$according to the New Duncans's New Multiple Range Test.

Maize phosphorus contents

The response of the maize plants to the MPR and MPR x FYM in terms of phosphorous accumulation in the maize plants (% P content) are presented in Table 7. The MPR and FYM when applied alone and when the two were combined did not significantly influence the % P contents in the maize plants. The data in Table 7 conform with the data in Table 4 and Table 5 where the Bray – I – P in the potted soils were deficient to marginal according to the categorization of plant available phosphorus by Landon (1991). The maize plants were, therefore. not sufficiently supplied with phosphorus. hence the sub-optimal P contents in the maize plants.

Table 7: Effect of MPR and FYM combinations on the % P contents in the maize plants

FYM rate (gFYM kg soil)	Phosphorous rate as MPR (mgPkg-1soil) Marginal Means				
		%P Contents			
0	0.17	0.21	0.22	0.23	0.20
7.5	0.18	0.20	0.23	0.24	0.21
15.0	0.20	0.24	0.27	0.28	0.24
30.0	0.21	0.25	0.28	0.29	0.25
Marginal means	0.19	0.23	0.25	0.26	

Conclusions

It could, therefore. be concluded that the rates of P applied as MPR were low. based on the observations that the Bray-I-P and % P contents in the maize plants were below the critical levels. The high amount of Bray-I-P. at 11 weeks of MPR-FYM-soil contact compared to 4 weeks of the same confirms the gradual dissolution of MPR. Combined application of MPR and FYM enhanced MRP dissolution and decomposition of FYM. hence P release. The significant increase in the maize dry matter yields were attributed to increased availability P among other factors.

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