AFRIKA FOCUS Vol. 2, Nr. 2, 1986, pp. 127-138

THE USE OF ROCK PHOSPHATE AS A SOURCE OF PHOSPHORUS ON A SLIGHTLY ACID CLAYEY SOIL IN TANZANIA

MSAKY, J.J.T. (1), B.M. MSANYA (2) & A.P. URIYO (3)
Sokoine University of Agriculture, Department of Soil Science, P.O. Box 3008, Morogoro, TANZANIA.

SUMMARY

The effectiveness of rock phosphate as a phosphorus nutrient source was studied as compared to triple superphosphate (TSP), a common fertilizer used in Tanzania. Initial results showed that rock phosphate can be used as a P source for growing maize. Its application increased both grain yields and soluble floride extractable P in the soil. TSP still proved to be superior to rock phosphate for the direct effect experiments in terms of both grain yield and soluble fluoride extractable P. However, for the residual effects experiment, rock phosphate was equally effective as TSP. Grinding rock phosphate beyond -40+60 mesh did not result in an increase in soluble P. However, increase in levels of application resulted into increased soluble P in soil. A combination of fineness and level of application resulted into an increased amount of soluble P. This combination should thus be used as a criterion in the use of rock phosphate as a P nutrient source for plant growth.

KEYWORDS : Rock Phosphate, phosphorus source, soils, Tanzania

INTRODUCTION

With the possible exception of nitrogen, no other element has been as critical in the growth of plants in the field as has phosphorus (Brady, 1974). A lack of this element is extremely serious as it may even prevent the uptake of other nutrients by plants. The importance of phosphorus for plant growth has received special consideration in the formulation of commercial fertilizers.

In Tanzania, superphoshate accounts for about 90 per cent of the fertilizer phosphorus used. Triple superphosphate (TSP) is being manufactured from rock phosphate imported from overseas. The local material occurring in abundance at Minjingu, Northern Tanzania, could be advantageous over the imported rock phosphate. Its exploitation will not require much foreign exchange investment especially in the long run.

One of the disadvantages of the local material is the low phosphate (24.5 % total P_2O_5) and high silica (29.9 % as SiO_2) content which implies that it may become rather expensive to concentrate the ore as feed material towards the industrial manufacture of triple superphosphate fertilizer. However, considering the available phosphate status and the fairly high calcium and magnesium content, it may be used as a raw phosphatic material in well powdered form in place of triple superphosphate to some extent. It should also be stressed that the use of the local material in the industrial manufacture of TSP cannot be ruled out at this moment.

Experiments conducted in Tanzania between 1959 and 1970 with rock phosphate along with superphosphate on groundnuts as a test crop showed that the water soluble source of phosphatic fertilizers are generally a more efficient source of phosphate than the ground rock phosphate, though the latter has much the same residual effect (Le Mare, 1959 and Anderson, 1970).

The growing energy problem and soaring prices of imported rock phosphate coupled with Tanzania's inadequate foreign exchange calls for a need for better evaluation and utilization of local resources. The current study comprising of a series of experiments was carried out with the following objectives :

i - to investigate on the use of the rock phosphate deposit as a source of phosphorus to crops
ii - to monitor residual effects of applied rock phosphate on crop yields
iii - to investigate on the relative efficiency of the ore as compared with the commonly used triple superphosphate fertilizer.

MATERIALS AND METHODS

The soil on which the experiments were conducted was characterized and classified as Typic Rhodustult according to Soil Taxonomy (U.S.D.A.-S.C.S., 1975), based on its morphological characteristics and the physico-chemical data presented in table 1.

Powdered Minjingu rock phosphate of the meshes given in table 2 was provided by the State Mining Corporation (STAMICO) and was analysed for total and available phosphorus by standard methods. TSP was used to monitor the performance of the rock phosphate in increasing crop yields.

A simple completely randomized block design with three replications was used and included four rates of fertilizer application : 0, 20, 40 and 60 kg P/ha for each mesh size. The trials were carried out on the University Farm (Morogoro, during 1976, 1977 and 1978 cropping seasons (March-August) using maize as a test crop. The yearly weather conditions on the area remained quite stable during the period of experimentation.

The performance of the rock phosphate was monitored through (a) direct effects experiment to check the immediate effect of the rock phosphate application on crop yields and (b) residual effects experiment to see the effect of time on the release of phosphorus from rock phosphate.

For the direct effects experiment, both rock phosphate and triple superphosphate were broadcasted and incorporated into the soil two weeks before planting. No phosphate

Table 1 : Physico-chemical properties of the soil

Horizon	Depth (cm.)	Texture^{I} % Sand	% Silt	% Clay	B.D.^{II} g/cc	pH^{III} 1:2.5 soil-liquid H_2O	1M KCl	% O.C^{IV}	% total N^{V}	Avail. P^{VI} ppm.	Exch. cations^{VII} meq./100g Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	H^{+}	CEC^{VIII} meq./100 g soil	% B.S.
Ap	0- 20	42.6	8.4	49.0	1.21	6.5	6.1	1.63	0.15	14.9	8.23	4.81	0.58	1.38	9.14	25.2	59.5
B_{1t}	20- 45	33.9	8.1	58.0	1.34	6.3	4.3	0.72	0.13	n.d.	4.00	2.84	0.08	0.18	n.d.	30.0	23.5
B_{21t}	45- 75	31.6	8.1	60.3	1.18	6.1	4.4	0.58	0.11	n.d.	3.20	2.84	0.16	0.07	n.d.	25.2	24.9
B_{22t}	75-110	29.3	10.4	60.3	1.18	6.0	4.4	0.55	0.09	n.d.	2.00	3.24	0.23	0.07	n.d.	28.0	19.8
B_{23t}	110-200+	27.1	12.6	60.3	1.16	6.1	4.2	0.39	0.08	n.d.	3.60	2.43	0.47	0.09	n.d.	30.6	21.6

I. Hydrometer method (Day, 1965x)
II. Core method (Blake, 1965x)
III. Modified glass electrode method (Peech, 1965x)
IV. Wet combustion method - Walkley and Black (Allison, 1965x)
V. Macro-Kjeldahl method (Bremner, 1965x)
VI. Bray and Kurtz method (1945)
VII. Ca^{2+} and Mg^{2+} EDTA titration (Head, 1965x)
Na^{+} and K^{+}-Flame photometry
H^{+}-Mehlich's method (1953)
VIII. NH_4^{+}-saturation method (Chapman, 1965x)

x : In Black, C.A. et al. (1965).
n.d. : not determined.

carrying material was applied in the residual experimental field and the plot boundaries from the 1977 direct effects experiment were maintained during the tillage operations.

Table 2. Minjingu rock phosphate mesh sizes and their phosphate forms

Mesh size (*)	% total P in rock phosphate	% P citric acid soluble
- 11 + 22	10.50	9.75
- 22 + 40	11.00	10.50
- 40 + 60	11.40	10.10
- 80 + 100	11.70	10.50
- 100	11.70	9.62

(*) Fineness of rock phosphate increases downwards

Maize variety Ilonga composite was sown at 75 cm between the rows and 30 cm within the row spacing. For the residual effect, the same variety of maize was grown during 1978 cropping season on the respective treatment plots used in 1977. Nitrogen at 40 N kg/ha was topdressed at knee height for both direct and residual experiments. For plant analysis, a composite sample consisting of ear leaves (the uppermost leaf opposite the topmost cob) from ten randomly selected plants was collected from the plots at cob formation. The samples were dried in an oven at 105° C to constant moisture and ground in a Willy mill. The ground material was ashed and analysed for P by the vanadate-molybdate yellow colour method (Chapman and Pratt, 1961).

RESULTS AND DISCUSSION

(a) Direct and residual effects

Table 3 shows the effect of applying P carrying materials on the availability of soil P at cob formation stage for 1976 and 1977 (average for two years).

Table 3. Mean available phosphorus levels (ppm) in the soil at cob formation

Sources	Meshes	Levels of application (kg P/ha)				
		0	20	40	60	Means
Rock phosphate	-11 +22	10.7	12.5	12.9	12.8	12.2
	-22 +40	13.7	14.8	15.7	17.5	15.4
	-40 +60	12.8	14.0	14.9	19.8	15.4
	-80 +100	11.1	14.3	19.7	18.1	15.8
	-100	14.2	16.9	15.6	15.0	15.4
Triple super-phosphate		15.8	17.4	18.6	22.4	18.6
	Means	13.1	15.0	16.2	17.6	15.5

Increasing rate of P application resulted in increased levels of soluble fluoride extractable phosphorus in the soil sampled at cob formation. There was a slight increase in soluble fluoride extractable phosphorus from -11 +22 to -40 +60 mesh rock phosphate. However, it appears that grinding the material into finer particles does not necessarily result in an increase in fluoride extractable phosphorus. Statistical analysis on the extractable phosphorus data revealed that the increase in soluble fluoride extractable phosphorus from the plot where triple superphosphate had been applied, when compared to the treatments that had received -11 + 22 mesh rock phosphate were highly significant.

The concentration of P in the leaves increased significantly with increasing P rates in the case of triple superphosphate treatment. A similar but slightly less consistent trend was observed for the rock phosphate treatments (table 4).

Table 4. Mean phosphorus concentration (%) in maize leaves at cob formation

P Sources	Meshes	Levels of application (kg P/ha) 0	20	40	60	Means
Rock phosphate	-11 +22	0.19	0.22	0.21	0.20	0.21
	-22 +40	0.21	0.21	0.20	0.25	0.22
	-40 +60	0.19	0.22	0.21	0.25	0.22
	-80 +100	0.19	0.21	0.20	0.20	0.20
	-100	0.12	0.21	0.19	0.25	0.19
Triple superphosphate		0.17	0.20	0.22	0.25	0.21
	Means	0.18	0.21	0.21	0.25	0.21

	Levels	Meshes
Significant effects :	Levels	Meshes
LSD P = 0.01	0.011	0.015

With regard to mesh sizes of applied rock phosphate, there was only a slight increase in leaf P concentration from -11 +22 to -40 +60 mesh, and this was only in the case of the highest level of rock phosphate application (60 kg P/ha).

Table 5 shows grain yield data for 1976 and 1977 as affected by fertilization with different sources of phosphorus. In both years increasing levels of P application resulted in increased yields of maize. The yields obtained from the application of triple superphosphate were superior to those obtained at similar rates of Minjingu rock phosphate application. Mesh sizes also affected the yield of maize in both years although the increases in yield with increase in mesh size were not consistent.
For the direct effect it would appear that under the present circumstances grinding the ore beyong -40 +60 mesh may not necessarily give superior performance. Furthermore, grinding the material into the finer meshes beyong -40 +60 mesh may increase the rate of P fixation because of the

Table 5 : Grain yield (Kg./ha) of maize as affected by fertilization with different sources of phosphorus

P Sources	Meshes	1976 Levels of application (Kg P/ha)				Meshes	1977 Levels of application (Kg P/ha)				
		0	20	40	60		0	20	40	60	Means
Rock phosphate	-11+22	3051	3050	2750	3463	3076	2337	2592	2939	2346	2553
	-22+40	2987	3750	3951	3580	3592	2538	3209	3365	3121	3058
	-40+60	3919	3805	3743	3838	3830	3045	3150	3224	3270	3172
	-80+100	3950	3532	3171	3884	3629	2760	3000	3334	3301	3098
	-100	3403	3958	4028	4215	2896	3350	3350	3438	3587	3317
Triple Superphosphate		3534	4181	4468	4874	4264	2978	3542	3790	4166	3619
	Means	3474	3713	3685	3991		2759	3140	3348	3298	

	1976 Levels	1976 Meshes	1977 Levels	1977 Meshes
Significant effects :	Levels	Meshes	Levels	Meshes
LSD P = 0.01	246	720	510	622

increased total surface area of the rock phosphate. In such circumstances there will be considerable crop improvement in yield mostly in subsequent years as the P rate gets slowly released.

Table 6 shows the effect of residual P on the yield of Ilonga composite maize in 1978. Significant yield increases due to P application for all levels were obtained over the control (0 level).

Table 6. Effect of residual P on the yield of Ilonga composite maize (kg P/ha)

P Sources	Meshes	Levels of application (kg P/ha) 0	20	40	60	Means
Rock phosphate	-11 +22	1375	1563	1800	1856	1649
	-22 +40	1632	1743	2095	1904	1844
	-40 +60	1868	2007	2184	2142	2050
	-80 +100	1803	2009	1910	1931	1913
	-100	1647	1966	2075	2176	1966
Triple superphosphate		1562	2290	2241	2253	2087
	Means	1648	1930	2051	2044	

Significant effects
LSD P = 0.01

Although considerable variation in yield was obtained due to mesh sizes, the effects were not consistent. The yields from the plots where triple superphosphate had been applied were generally higher than those from the treatments that had received rock phosphate applications. Previous experiments have generally shown that the dry matter yield response to rock phosphate is less than that to superphosphate in the short term, except on acid soils (Fitzpatrick, 1961). In the later years of long term experiments, in which the fertilizers are added in a single initial application, the cumulative yield response to rock phosphate may or may not be as great as that obtained with superphosphate (McLachlan, 1960 ; Russell, 1960). Russell (1960) suggested that rock phosphate might be used to more advantage where the labile phosphorus content of the soil had been increased by previous fertilization to the extent that further supplies are needed only to maintain the labile store of phosphorus, and that they might be particularly useful where water soluble phosphate is readily leached.

(b) Interaction effect

Statistical analysis for the 1977 results showed a definite interaction pattern between mesh size and levels of application of rock phosphate. The interaction effect was very highly significant ($F = 6.142^{***}$). This means that for the effective use of rock phosphate both the fineness and the rate of application should be considered as important factors and the main factors controlling the amount of available P for plant uptake. However, the residual experiment did not show any significant interaction effect ($F = 0{,}94$).

CONCLUSIONS AND RECOMMENDATIONS

The results obtained in this study clearly indicate that the local rock phosphate can be used in powdered form to improve crop yields. It was also apparent that under the conditions of the experiments, fineness of the phosphate material is a controlling factor in P release for plants. In this respect, grinding of rock phosphate up to -40 +60 mesh size is recommended for optimum yields. Grinding the material into finer particle sizes may be unjustifiably costly and may not necessarily improve crop yields particularly in the short run.

As for the rates of phosphate application, it was also obvious that increased levels of phosphate improved crop yields.

Considering the results obtained from both the direct and residual effects of phosphate application, the rate of 40 kg P/ha can be recommended as an ideal one.

Lastly the authors would still like to urge the government of Tanzania to further a study on the possibilities of using the local rock phosphate in future as a feed material for the manufacture of superphosphate fertilizers by the Tanzania Fertilizer Company. The arguments against its use for that purpose (i.e. high costs of concentrating the ore) need to be substantiated by a multi-disciplinary study).

NOTES

MSAKY, J.J.T. (1) ; B.M. MSANYA (2) and A.P. URIYO (3)
Lecturers (1 and 2) and Professor (3) respectively.
Present addresses :

1. Science du Sol, Institut National Agronomique Paris-Grignon, 78850 Thiverval Grignon, FRANCE.
2. State University Ghent, Department of General Pedology, Krijgslaan 281, B-9000 Ghent, BELGIUM.
3. International Institute of Tropical Agriculture, P.M.B. 5320 Ibadan, NIGERIA.

BIBLIOGRAPHY

ANDERSON, G.D. (1970). Fertility studies on a sandy loam in Semi-Arid Tanzania. II. Effects of P, K and Lime on Yields of Groundnuts. Expl. Agric. Vol. 6 : 213.

BLACK, C.A., D.D. EVANS, J.L. WHITE, L.E. ENSMINGER and F.E. CLARK (eds.) (1965). Methods of Soil Analysis, Agron. 9. Amer. Soc. Agron. Madison Wisc., U.S.A.

BRADY, N.C. (1974). The nature and properties of soils, 8th edition. MacMillan Publ. Co., Inc., New York, U.S.A.

BRAY, R.H. and L.T. KURTZ (1945). Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59 : 39-45.

CHAPMAN, H.D. and P.F. PRATT (1961). Methods of Analysis for Soils and Waters. Univ. of California, Riverside, U.S.A.

FITZPATRICK, E.H. (1961). Rock phosphate as a fertilizer. J. Agric., Western Australia 2 : 459-461.

LE MARE, P.H. (1959). Soil Fertility studies in three areas of Tanganyika. Empire Journ. of Exper. Agric. Vol. 27 : 197-222.

McLACHLAN, K.D. (1960). Rock phosphate and superphosphate compared as pasture fertilizers on acid soils. Australian Journ. Agric. Research 11 : 513-517.

MECHLICH, A. (1953). Rapid determination of cation and anion exchange properties and pH of soils. Assoc. of Officials of Agric. Chem. Journ. 36 : 445-457.

RUSSELL, J.S. (1960). Soil fertility changes in the long term experimental plots Kybybolite, South Australia. II : Changes in phosphorus. Australian Journ. Agric. Research 11 : 927-934.

U.S.D.A.-S.C.S. (1975). Soil Taxonomy. U.S. Dept. Agric., Soil Cons. Service, Agric. Handbook No. 436.

ACKNOWLEDGEMENTS

The authors wish to express thanks to the State Mining Corporation (STAMICO) of Tanzania for providing the research funds.

Paysage dans l'Ouanyamouézi. — Dessin de Lavieille d'après Burton.

Landscape in Unyamwezi (Tanzania)

Gravure uit / *Engraving from* :

Capitaine BURTON. Voyage aux Grands Lacs de l'Afrique orientale. In: Le Tour du Monde. Nouveau Journal des Voyages. 1860, deuxième semestre . Paris, Hachette , 1860, p.321 .