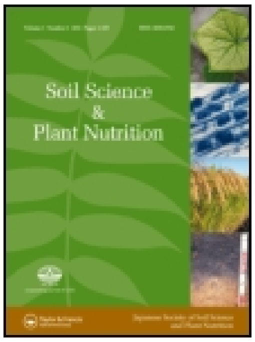

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Management of Phosphate Rock in Maize-Cowpea Cropping System

Roland Nuhu Issaka, Edward Albert Dennis, and Mohammed Moro Buri

Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana

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In the forest zone P is one of the major yield-limiting nutrients in most of the well drained soils. In this study, attempts were made to improve the phosphorus and calcium status of the soil for maize production through the use of ground Togo phosphate rock (TPR). Since TPR is unreactive, it is therefore necessary to allow for a time lag between time of application and nutrient availability. The possibility that legumes may enhance the dissolution of TPR was also considered. The experiment was started in the minor season of 1998. Initial soil properties showed that the soil was acidic with a very low content of available phosphorus. The experimental design was a split plot. Surface broadcast and broadcast incorporation were the main plot treatments. Four rates of TPR viz. 400, 600, 800, and 1,200 kg ha^{-1} and two checks (Control and 200 kg ha^{-1} SSP) constituted the subplot treatments. All the treatments (only in the major season) received 30 kg N ha^{-1} and 30 kg K_2O ha^{-1} at planting and a second dose of 20 kg N ha^{-1} six weeks after planting. SSP was applied directly to maize in the major season, while TPR was applied only to cowpea in the minor season. For the three year running, cowpea grain yield was similar for all the subplot treatments. Incorporation gave a significantly higher cowpea grain yield only in the first year. While maize grain yield was similar for all the treatments in the first year, SSP (4.47 t ha^{-1}), 800 kg TPR ha^{-1} (4.59 t ha^{-1}), and 1,200 kg (4.35 t ha^{-1}) gave a significantly higher yield than the control (3.19 t ha^{-1}) in the second year. Significant improvement of soil properties such as available P and exchangeable calcium by the TPR 800 and 1,200 kg ha^{-1} treatments suggests that these treatments can support a higher maize yield if rates of N and K are increased.

Key Words: **dissolution, farming system, maize-cowpea, phosphate rock, soil fertility.**

Increasing population and the need for land for other uses than agricultural use have gradually reduced the extent and duration of fallow periods. Continuous cultivation with minimal or no input has resulted in serious nutrient mining. Coupled with the inherent low fertility status of most of these soils, soil fertility has become the major limiting factor to crop production.

High prices of high analysis fertilizers have necessitated the need to rely on low grade but cheaper sources of mineral fertilizer. Even though phosphate rock (PR) is relatively cheap, it cannot be used for all soils and cropping conditions. The effectiveness of PR is influenced by several factors, mainly soil characteristics, plant and fertilizer management (Rajan et al. 1996). Soil pH exerts a strong influence on PR dissolution. Using highly reactive, moderately reactive and unreactive PR, Bolan and Hedley (1990) observed a 30% increase of available P over the control (at pH 5.5) for the unreactive PR source after 84 d. Robinson and Syers (1991) also mentioned the importance of calcium when they observed a linear relationship between the log of Ca activity and the log of P in solution. According to Flach et al. (1987), there are considerable differences in the ability of plant species to extract P from PR. Legumes generally enhance PR dissolution through the creation of excess cations over anions.

Togo phosphate rock (TPR) is available and cheaper. Unfortunately, the fertilizer shows a low solubility and no immediate response when applied. In this study, an attempt was made to improve the solubility of the product in order for the nutrients to become available. Legumes have been observed to be able to solubilize PR. In addition, to ensure adequate availability of nutrients, a time lag between PR application and maize cultivation was allowed.

Maize-cowpea cropping system is a common practice in the forest zone of Ghana. The inclusion of cowpea and the application of TPR in the minor season was aimed at improving its solubility and to allow for enough time for solubilization for maize crop in the major season.

MATERIALS AND METHODS

Experimental area and design. The experiment was conducted at Kwadaso Experimental Station located in the forest agro-ecological zone. Rainfall is bimodal with two cropping seasons (major and minor) Fig. 1. The trial was located on a sandy loam soil which was allowed to fallow for one year after more than 10 years of continuous cultivation.

A split plot design with four replications was used. Surface broadcast and broadcast incorporation were the main plot treatments. Four rates of TPR; 400, 600, 800, and 1,200 kg ha^{-1} and two checks, control and 200 kg SSP ha^{-1}, constituted the subplot treatments. In the major season, all the treatments received 30 kg N ha^{-1} and 30 kg K_2O ha^{-1} at planting and a second dose of 20 kg N ha^{-1} six weeks after planting.

Agronomic practices. Maize (*Zea mays* L.) variety Obatanpa (local name), was planted at 90 × 40 cm with 2 plants per hill resulting in 55,555 plts ha^{-1}. Plant population for cowpea (*Vigna unguiculata*) was 167,000 plts ha^{-1} (2 plants / hill at row spacing of 60 × 20 cm).

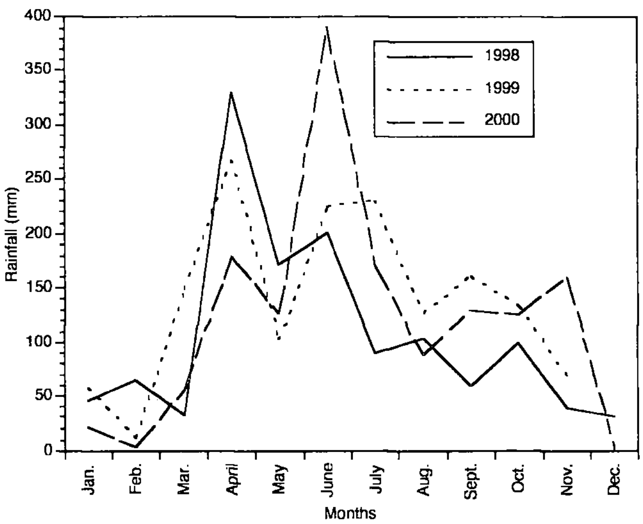

Fig. 1. Monthly rainfall (mm) at Central Agricultural Station, Kumasi, during the experimental period.

Table 1. Crop sequences and time of phosphorus application.

Year	Season	
	Major (April–July)	Minor (August–November)
1998	—	Cowpea (TPR applied)
1999	Maize (SSP applied)	Cowpea (TPR applied)
2000	Maize (SSP applied)	Cowpea

Phosphorus source in parenthesis.

Except in 1998, two crops were grown each year in the sequences shown in Table 1. In 1998, cowpea variety, Asuntem (local name), was grown while cowpea variety Black Eye (local name), was grown in 1999 and 2000. The maize variety Obatanpa used for the experiment and was grown only in the major season. The sequence in Table 1 also shows the time of application of phosphorus. TPR was applied at least one week before planting.

Soil samples (0–20cm) were initially taken in 1998 before the treatments were imposed. In 1999, soil samples were taken and the treatments were repeated. In 2000, PR was not applied and soil samples were taken after cowpea was harvested. Crop residues were allowed to remain on the plots.

Soil analysis. Air-dried soil samples were ground and passed through a 2 mm sieve. Soil pH was measured using a glass electrode (pH meter) in a soil : water ratio of 1 : 2.5, according to the method recommended by IITA (1979) and Mclean (1982). Organic matter content was determined by wet combustion (Walkley and Black 1934). Exchangeable bases (Ca, Mg, and K) were first extracted by neutral ammonium acetate (1 M NH_4OAc) and the contents determined using an Atomic Absorption Spectrophotometer (AAS) as described by Thomas (1982). Available phosphorus content was determined by the method of Bray and Kurtz (Bray P 2) (1945).

RESULTS AND DISCUSSION

Effect of treatments on soil properties

Phosphorus and calcium contents of the rock phosphate, and the initial soil properties are presented in Tables 2 and 3. The soil was acidic with a very low content of available phosphorus.

Table 4A and B shows the soil properties after 2 and 4 seasons of continuous cultivation. After 2 seasons (August 1999 samples) of cultivation, no differences were observed in each of the selected soil parameters (soil pH, organic matter content, available P status, and exchangeable cations). It's likely that TPR was not dissolved or that the amount that dissolved was utilized by the crop. After 4 seasons (November 2000 samples) of cultivation, significant differences were observed in the contents of available P and exchangeable calcium. TPR applied at 800 and 1,200 kg ha^{-1} gave significant higher values for both available P and exchangeable calcium contents than the other treatments, followed by TPR application at 600 kg ha^{-1} which showed similar values to those of TPR applied at 400 kg ha^{-1} but higher than those of SSP and Control. Significant increases in the contents of available P and exchangeable calcium for most of the TPR treatments indicate that the TPR had been solubilized to some extent, releasing calcium together with phosphorus. However, it remains to be determined whether the dissolution was due to the legume, time lag, soil properties, or a combination of any of these factors.

Changes in selected soil properties after 4 seasons of continuous cropping are shown in Fig. 2. After 4 seasons, the content of soil organic matter increased for all the treatments. Crop residues were allowed to remain on the plots, which is probably the main reason for the observed increases in the content of soil organic matter. Larger returns of maize stover for TPR 1,200, SSP, and TPR 800 also explain why these treatments gave relatively higher values for soil organic matter content. Control and SSP showed a decreasing trend for the values of soil pH, available P, and exchangeable calcium contents. Addition of phosphorus and calcium from the phosphate rock resulted in the improvement of all the four parameters for the TPR 800 and 1,200 treatments. Increases in the values of these parameters were not appreciably high for the TPR 400 and 600 treatments, especially soil pH and exchangeable calcium.

Table 2. Phosphorus and calcium contents of phosphate rock.

Total CaO	50.0%
Total P_2O_5	28.6%
Bray P 2	526.3 mg kg^{-1}

Table 3. Initial soil properties.*

pH (H_2O)	5.6
Organic matter (g kg^{-1})	18.5
Available P (mg kg^{-1}) Bray P2	3.5
Exchangeable Ca [cmol(+) kg^{-1}]	2.25
Exchangeable Mg [cmol(+) kg^{-1}]	0.80
Exchangeable K [cmol(+) kg^{-1}]	0.25
CEC [cmol(+) kg^{-1}]	4.42
Soil texture	Sand loam

*Soil sampled in August 1998.

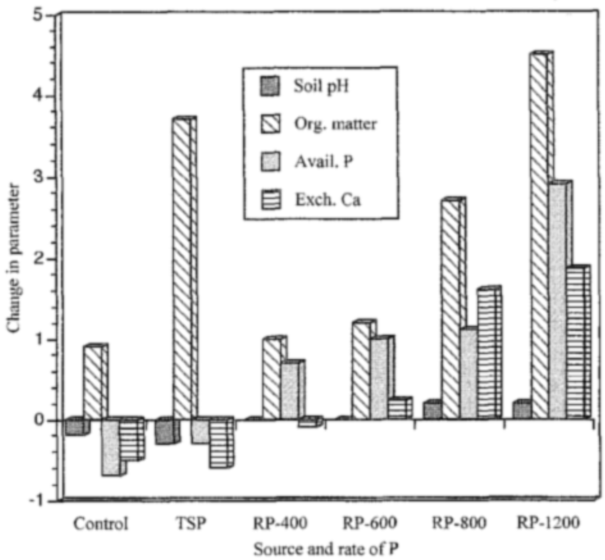

Fig. 2. Changes in soil properties between August 1998 and November 2000.

Table 4. Soil properties after one and two years of cultivation.

A: Soil properties after one year of cultivation. (Soil sampled in Aug. 1999)

Treatment	Soil pH (H_2O)	Org. matter (g kg^{-1})	Available P Bray No. 2 (mg kg^{-1})	Exchangeable cations (cmol(+) kg^{-1})		
				Ca	Mg	K
Control	5.5 a	19.2 a	3.0 a	1.85 a	0.75 a	0.21 a
SSP	5.4 a	19.4 a	3.4 a	1.92 a	0.79 a	0.20 a
TPR 400	5.6 a	19.1 a	3.2 a	2.15 a	0.71 a	0.22 a
TPR 600	5.5 a	19.0 a	3.2 a	2.18 a	0.83 a	0.21 a
TPR 800	5.7 a	19.5 a	3.4 a	2.18 a	0.74 a	0.19 a
TPR 1,200	5.7 a	19.4 a	3.6 a	2.20 a	0.82 a	0.18 a

B: Soil properties after two years of cultivation. (Soil sampled in Nov. 2000)

Treatment	Soil pH (H_2O)	Org. matter (g kg^{-1})	Available P Bray No. 2 (mg kg^{-1})	Exchangeable cations (cmol(+) kg^{-1})		
				Ca	Mg	K
Control	5.4 a	19.4 a	2.8 a	1.75 a	0.81 a	0.22 a
SSP	5.3 a	22.2 a	3.2 a	1.64 a	0.89 a	0.21 a
TPR 400	5.6 a	19.5 a	4.2 b	2.26 ab	0.76 a	0.23 a
TPR 600	5.6 a	19.7 a	4.5 b	2.48 b	0.78 a	0.22 a
TPR 800	5.8 a	21.2 a	5.6 c	3.85 c	0.83 a	0.24 a
TPR 1,200	5.8 a	23.4 a	6.4 c	4.12 c	0.91 a	0.23 a

For each table numbers within a column followed by the same letter(s) are not significantly different at the 5% level of DMRT.

Table 5. Effect of method of application on crop yield.

A. Cowpea grain yield (kg ha^{-1}).

Method of application	1998	1999	2000
Broadcast	245.3 a	896.5 a	895.4 a
Broadcast incorporated	306.6 b	916.0 a	922.6 a

B. Maize grain and stover yield (t ha^{-1}).

Method of application	1999		2000	
	Grain	Stover	Grain	Stover
Broadcast	2.13 a	3.05 a	4.02 a	5.76 a
Broadcast incorporated	2.36 a	3.06 a	4.25 a	5.82 a

For each table numbers within a column followed by the same letter are not significantly different at the 5% level of DMRT.

Table 6. Effect of phosphorus application on crop yield.

A: Cowpea grain yield (kg ha^{-1}).

Treatment	1998	1999	2000
Control	262.4 a	931.0 a	908.1 a
SSP	247.9 a	943.8 a	926.4 a
TPR 400	260.4 a	910.7 a	932.6 a
TPR 600	274.9 a	925.2 a	941.4 a
TPR 800	297.9 a	906.0 a	935.7 a
TPR 1,200	312.0 a	919.2 a	946.2 a

B: Maize grain and stover yield (t ha^{-1}).

Treatment	1999		2000	
	Grain	Stover	Grain	Stover
Control	2.22 a	3.0 a	3.19 a	4.4 a
SSP	1.90 a	2.4 a	4.47 b	5.8 b
TPR 400	2.17 a	2.5 a	3.65 ab	5.1 ab
TPR 600	2.48 a	3.3 a	3.72 ab	5.3 ab
TPR 800	2.25 a	3.1 a	4.59 b	6.3 b
TPR 1,200	2.48 a	4.1 a	4.35 b	6.5 b

For each table numbers within a column followed by the same letter(s) are not significantly different at the 5% level of DMRT.

Effect of treatment on crop yield

Effect of method of application was significant only in the first season when broadcast incorporation gave higher grain yield than broadcast (Table 5A and B). Higher yields in the 1999 and 2000 seasons may be due to better rainfall (Fig. 1). In 1998, in addition to lower monthly rainfall, dry periods were relatively longer than in 1999 and 2000.

Table 6A and B shows the yield of cowpea and maize during the five seasons. Cowpea yield was not affected by the treatments throughout the three seasons. No interaction between method of application and phosphorus treatment was observed (data not presented). In the first season of maize cultivation, no significant differences were observed in either grain or stover yield. In the second year, grain and stover yield for the application of SSP, TPR at 800 and 1,200 kg ha^{-1} was significantly higher than that of the Control. General improvement of the soil conditions by the application of TPR 800 and 1,200 (Table 4B) may be the major reason for the better performance of these treatments. For SSP, phosphorus is readily available, which probably enhanced crop performance.

Conclusion

To improve the soil fertility status, especially the contents of available P and exchangeable calcium, at least 800 kg phosphate rock ha^{-1} should be applied over a two year period in a maize-cowpea cropping system.

If necessary, broadcast incorporation should be done only in the first year.

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