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Full Length Research Paper

Effects of rock phosphate amended with poultry manure on soil available p and yield of maize and cowpea

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The effect of rock phosphate (Sokoto and Ogun rock phosphates) amended with poultry manure on soil available phosphate (P) and yield of maize and cowpea grown sequentially was evaluated for four cropping seasons. The results obtained showed superiority of single super phosphate (SSP) application over either Sokoto or Ogun rock phosphates. However, complementary application of the Sokoto and Ogun rock phosphates with poultry manure increased maize plant height by 12 and 6, and 19 and 8%, respectively. Also, percent phosphorus contents in maize and cowpea leaf tissues increased respectively by 33 and 22, and 22 and 25% in 2000, and by 25 and 6, and 16 and 18%, respectively in 2001. Maize grain yield was increased by 33 and 26, and 18 and 25%, respectively, while that of cowpea was increased by 25 and 32, and 49 and 38% in 2000 and 2001, respectively when compared with application of rock phosphate alone. Single super phosphate treated soil had the highest residual P values in all the three sampling periods. The effectiveness of rock phosphate as a P sources for crop production was remarkably enhanced by solubilizing effect of poultry manure. Its low rate (2 t ha^{-1}) in combination with rock phosphate gave almost similar effects like higher rates (3 and 4 t ha^{-1}) of applications.

Key words: Rock phosphates, poultry manure, available phosphorus, maize, cowpea.

INTRODUCTION

Application of phosphorus fertilizer is often necessary for crop production in sub-Saharan African soils. The high cost of soluble phosphate fertilizer such as single or triple super phosphate has generated considerable interest in the utilization of rock phosphate (Nnadi and Haque, 1988; Chien and Hammond 1989; Akande et al., 1998). However, concerns are often expressed on the effectiveness of rock phosphate for direct application to soil. Direct application of ground rock phosphate had been proved to be beneficial to crops on acids soils (Nnadi and Haque, 1988). There are only a limited number of climatic and soil situation in which rock phosphate will be sufficiently reactive for use as direct application fertilizer, especially for fast growing annual crops. Numerous studies have been conducted amending rock phosphates to increase their immediate phosphorus availability and also to enhance their rate of dissolution after application to soil (Adediran and Sobulo, 1998).

Compositing of rock phosphates with agricultural wastes is known to increase solubility of rock phosphates (Bangar et al., 1985; Mey et al., 1986; Mishra et al., 1984; Mishra and Bangar, 1986; Kothandaraman, 1987; Singh and Amberger, 1990; Akande et al., 1998). The content of P solubility of a given rock phosphate varies with the kind of organic material and the rate of decomposition (Banger et al., 1985). Akande et al. (2003) reported that okra growth and yield were significantly increased by the combined used of rock

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phosphate with either poultry manure and to a lesser degree urea compared to sole used of the materials. They also reported an increase in soil available P of between 112 and 115%, and 144 and 153%, respectively for a two year field trials.

The immediate or short term effects of applied fertilizers are often emphasized to the neglect of residual effects. Yet when farming is continued on the same site for several years, residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently crop yield (Enwezor et al., 1989). Reviewing residual effect of rock phosphates, Khasawneh and Doll (1978) did not confirm the common assumption that rock phosphates have greater residual effect than soluble phosphorus fertilizer. On the contrary, it appeared that the residual effects of soluble phosphorus fertilizer were greater than those of rock phosphate in the first 3 or 4 years after application.

In comparing the residual effects, it must be remembered that with soluble phosphorus fertilizer, the residual effect derives from the soil–phosphate reaction products and the reaction of prime importance is conversion of phosphorus from labile to non-labile forms. But the phosphorus from rock phosphate needs to be released into the solution before any residual phosphorus can manifest itself. Therefore in the short term, one is likely to find a lower residual effect from rock phosphate application. The situation is different in coarse textured acid soil where large and rapid leaching of soluble phosphorus from rock phosphate gives a greater residual effect in short term (Yeates and Clarke, 1993).

Unlike single application, when rock phosphate application had continued over a period of several years a large pool of undissolved rock phosphate can accumulate. The substantial release from this pool can result in a high residual value of rock phosphate/phosphorus in subsequent years. Residual effects of rock phosphate relative to those from super-phosphate therefore depend on, in addition to the rate of loss of phosphorus from available soil phosphorus pool, the previous pattern of application, and the rate of dissolution of rock phosphate (Enwezor et al 1989). The objective of this study was to determine the effects of application of rock phosphates amended with poultry manure on the performance and yields of maize and cowpea grown sequentially.

MATERIALS AND METHODS

The experiment was carried out in the Institute of Agricultural Research and Training, Ibadan, Nigeria on latitude 7° 30'N and longitude 3°54'E southwestern Nigeria. The trials were established on the Aquic Arenic Haplustalf (USDA) for four cropping seasons (early and late seasons of 2000 and 2001).

Available climatic data indicate that the total annual rainfall were 1493 mm and 1256 mm for 2000 and 2001, respectively. There was a definite cycle of rain and dry seasons with bimodal rainfall pattern that divides the wet season into two.

The site was ploughed and harrowed after which the experimental layout was established. Prior to experimentation in 2000, bulk soil samples were randomly taken from topsoil (0-15 cm depth) for physical and chemical analysis. The soil had 6.1 pH with 1.85, 1.96, 0.33, 0.28 cmol kg^{-1} for Ca, Mg, Na and K, respectively. The available P was 3.24 mg kg^{-1}. The organic carbon was 0.50%. The design of the experiment was randomized complete block with three replicates. The blocks were 1 m apart. Each plot measured 5 m x 6 m. In the early season of 2000, only maize was planted. The inter row and intra-row spacing were 75x25 cm. Two maize seeds were planted per hole and two weeks latter thinned to one per stand in the early season. The fertilizer treatments consisted of control (without P fertilizer), Sokoto rock phosphate (35.5% P_2O_5) alone and Ogun rock phosphates (31.4% P_2O_5) alone, and single super phosphate alone. Also, each of the rock phosphate was combined with four rates of poultry manure (PM) equivalent to 1, 2, 3 and 4 t ha^{-1} respectively. Single super phosphate was applied at the rate of 60 kg P_2O_5 ha^{-1}. Each of the phosphate rocks was applied at the rate of 100 kg P_20_5 ha^{-1} and mixed with the PM treatments. The fertilizers were applied by drilling into the soil 3 cm away from the plant at three weeks after planting and this was done once for the four cropping. The control only received the basal nutrients of N and K. Weeding was done twice before crop maturity. Leaf just below and opposite the ear was sampled randomly per plot at 8 weeks after planting. The average heights of ten randomly selected maize plants were taken per plot prior to ear harvesting. Maize ears at maturity were harvested and grain yield per hectare was computed at 12% moisture content.

Soil samples were taken per plot for chemical analysis before cropping in the late season. There was neither ploughing nor harrowing of the site but it was weeded with hoe to avoid mixing up of treatments. Cowpea *(Vigna unguiculata*, Ife brown) was planted at 60 cm and 30 cm inter and intra row spacing, respectively. Gramozone and galex were sprayed on the site at the rate 50 and 100 ml/20 L of water as herbicides. Hoeing was done twice before crop maturity. The cowpea was sprayed repeatedly thrice before crop maturity with karate at the rate of 50 ml/15 L of water. Leaf sample was taken at flowering stage for P analysis. At maturity, the cowpea was harvested and yield was computed. In year 2001 the residual effect of P fertilizer was further assessed. Planting of maize and cowpea was repeated like in the previous year trial. Neither ploughing nor harrowing but hoe weeding of the site was done. All the necessary cultural operations were carried out like in the previous year.

Soil and plant analysis

Soil particles size distribution was determined by hydrometer method (Bouyoucos, 1962) with sodium hexametaphosphate (calgone) as dispersing agent. The soil pH was determined in distilled water (1.1 soil/water) with a glass electrode pH meter. Soil organic carbon was determined by wet oxidation with sulphuric acid (Walkley and Black, 1934). Available P was extracted by Bray 1 method (Bray and Kurt, 1945) and was determined colorimetrically at 660 mm after development of molybdenum blue colour. Exchangeable cations were determined by extraction with neutral normal NH_4OAc at soil:solution ratio of 1:10 and measured using flame photometer. Magnesium was determined by atomic absorption spectrophotometer after extraction with NH_4OA_C-EDTA (pH 4.65).

Plant analysis

The leaf samples were oven dried at 65°C and ground in Wiley steel mill. The samples were then ashed at a temperature of 450°C. Phosphorus was extracted with 0.1M HCl and was determined using vanado molybdate method (Jackson, 1958).

Table 1. Effect of some P fertilizers and combination with PM on maize height (cm).

Treatment	2000	2001
Control	142f	120e
SSP	218a	193a
SRP	162d	169c
ORP	155e	153d
SRP +1PM	184c	182b
SRP + 2PM	180c	186ab
SRP + 3PM	204ab	182b
SRP + 4PM	199b	171c
ORP + 1PM	169cd	158d
ORP + 2PM	159d	160d
ORP + 3PM	173cd	170c
ORP + 4PM	194cd	174c

Means values followed by the same letter within a column are not significantly different at P = 0.05.
SSP = Single Super Phosphate, SRP = Sokoto Rock Phosphate, ORP = Ogun Rock Phosphate, 1, 2, 3 and 4 PM are tonnes/ha of poultry manure.

RESULTS AND DISCUSSION

The plant height

The effect of single super phosphate and rock phosphates applied either solely or in complementary with different rates of poultry manure significantly improved maize plant height in both years of cropping (Table 1). Maize heights averaged 178 and 169 cm in 2000 and 2001, respectively. The tallest plants were 218 and 193 in 2000 and 2001, respectively, which were obtained from single super phosphate application. The complementary use of Sokoto/Ogun rock phosphate with different rates of poultry manure produced taller plants compared to when the materials were used alone.

Soil available P

The results showed that the phosphorus fertilizer had positive residual effect on phosphorus release in the soil (Table 2). After two croppings, single super phosphate gave the highest value of soil available P. This further supports the findings of Khasawneh and Doll (1978) that the residual effects of soluble P fertilizers were greater than those of rock phosphate in the first 3 or 4 years after application.

Table 2. Effect of P fertilizers on residual soil available P ($mg.kg^{-1}$) content.

Treatment	Prior to 2nd cropping (2000)	Prior to 3rd cropping (2001)	Prior to 4th cropping (2002)
Control	3.1	2.5e	2.2d
SSP	10.4a	12.9a	9.8a
SRP	5.5d	6.2d	4.7e
ORP	5.0e	6.1d	4.2c
SRP +1PM	8.6ab	9.0ab	6.0b
SRP + 2PM	7.1bc	7.7bc	5.9bc
SRP + 3PM	8.0b	8.2b	6.1b
SRP + 4PM	8.1b	8.5b	7.0ab
ORP + 1PM	6.3c	7.0c	5.8c
ORP + 2PM	7.9b	8.4b	6.0b
ORP + 3PM	8.7b	8.0ab	6.7b
ORP + 4PM	8.0b	8.7b	7.2ab

Means having the same letter in a column are not significantly different at 5%.

The efficacy of poultry manure in facilitating the release of P from applied rock phosphate is very clearly shown after 3 or 4 croppings as this material when co-applied with Sokoto/Ogun rock phosphate resulted in significantly higher available P than using rock phosphate alone. This must have been responsible for the remarkable yield increase observed from the co-application of Sokoto/Ogun rock phosphate and poultry manure. Similar yield increases of *Cajanus cajan* has been reported by Mishra et al. (1984) through the combined use of rock phosphate composted farm wastes. The increase in P availability observed through amendment of rock phosphate with organic materials was also explained by Khanna et al. (1983) as resulting from the conversion of rock phosphate P to water-soluble form and greater efficiency of the dissolved P in terms of its availability to plant.

Phosphorus concentration in plants tissues

The percentage concentrations of P in maize and cowpea leaves sampled after treatment application are shown in Table 3. Significant differences were observed in P content in the leaves for both crops. In the case of maize, the percent P content ranged from 0.18–0.36% and 0.15–0.28% in 2000 and 2001, respectively. The single super phosphate treated maize plants recorded the highest value while the least value was from the control in 2000. However in 2001, the combined used of Sokoto rock phosphate plus 4 tonnes of poultry manure

Table 3. Phosphorus content (%) of leaves of maize and cowpea as affected by application of some P fertilizer and combined use with PM.

Treatment	Maize 2000	Cowpea 2000	Maize 2001	Cowpea 2001
Control	0.20f	0.14d	0.15d	0.12d
SSP	0.36a	0.30a	0.24b	0.18b
SRP	0.24e	0.19cd	0.20d	0.18b
ORP	0.23e	0.18cd	0.19d	0.17bc
SRP +1PM	0.30c	0.20c	0.22c	0.19b
SRP + 2PM	0.32b	0.22bc	0.24b	0.20ab
SRP + 3PM	0.33b	0.24b	0.26ab	0.20ab
SRP + 4PM	0.30c	0.27ab	0.28a	0.22a
ORP + 1PM	0.26d	0.19cd	0.20d	0.18b
ORP + 2PM	0.28cd	0.20c	0.22c	0.22ab
ORP + 3PM	0.30cd	0.24b	0.22c	0.20ab
ORP + 4PM	0.29c	0.27b	0.24b	0.22a

Means having the same letter in a column are not significantly different at 5%.

Table 4. Effect of some P sources and in combination with PM on the grain yield of maize and cowpea.

Treatment	Maize (t/ha)		Cowpea (t/ha)	
	2000	2001	2000	2001
Control	3.0e	2.5a	2.2a	1.4e
SSP	5.5a	4.8a	5.0a	2.0a
SRP	3.6d	3.3c	2.7d	1.9d
ORP	3.8cd	3.4c	2.5d	1.8d
SRP +1PM	4.8ab	4.3ab	4.0b	2.3c
SRP + 2PM	4.9ab	4.3ab	3.3c	2.3c
SRP + 3PM	5.0ab	3.9b	4.3ab	2.6ab
SRP + 4PM	4.5b	4.1ab	4.0b	2.9a
ORP + 1PM	4.5b	3.9b	3.3c	2.1a
ORP + 2PM	4.6b	3.8b	4.0b	2.9a
ORP + 3PM	4.6b	3.8b	4.2ab	2.4ab
ORP + 4PM	4.2bc	3.9b	3.4c	2.5ab

Means having the same letter in a column are not significantly different at 5%.

gave the highest value, while the control recorded the least. The percentage P in the treatments that received the complementary use of rock phosphate with different rates of poultry manure was significantly different from the sole application. It could be seen that as the rates of poultry manure increased the P content increased.

In the case of cowpea, the percent P content ranged from 0.14–0.30% and 0.12–0.22% in 2000 and 2001, respectively. The Single super phosphate treated plants recorded the highest value in 2000 whereas in 2001, the highest was from complementary used of rock phosphate with 4 tonnes of poultry manure. The control had the least values in the two years. The combined use of rock phosphates plus poultry manure was significantly different from their sole use. It was observed in both years that as the rate of poultry manure increased the percent P content increased.

Grain yields of maize and cowpea

The effects of P sources on the grain yield of maize and cowpea are presented on Table 4. Grain yields in both maize and cowpea as influenced by treatments were significantly (P = 0.05) different in the two years. The superiority of single super phosphate over the rock phosphates or their combination with poultry manure was shown clearly in the grain yield of maize in both years. There were no significant differences due to various rates of poultry manure combined with the rock phosphates. This has economic implication to the farmer, because either lower or higher rate of poultry manure application gave almost the same results. Thus it pays the farmer to adopt the lowest rate. In the case of cowpea, the trend was almost the same as for maize except that in 2001, cowpea yields from rock phosphates combined with poultry manure were superior to that from single super phosphate.

The results of this study showed that the application of single super phosphate gave higher effects on growth and yield of both maize and cowpea than the use of Sokoto and Ogun rock phosphates. Crop yields however, improved remarkably through the solubilizing effects of poultry manure. Furthermore, combined use of rock phosphate with low rate (2 t ha^{-1}) of poultry manure gave almost similar effect as using higher rates (3-4 t ha^{-1}) of the later. The residual effect of one time application of the P sources was able to sustain four successive cropping of maize and cowpea in this study. (followed by Tables 1-4).

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