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Evaluation of some locally sourced phosphate rocks for oil palm production

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The effectiveness of some locally sourced phosphorus rocks (Sokoto Rock Phosphate (SRP), Crystallizer Super (CRY)) as P_2O_5 fertilizers for manuring oil palm applied on a long term basis (2000-2008) were evaluated along with conventional imported single superphosphate fertilizer at Okomu Oil Palm Plc., Ovia North East Local Government Area of Edo State, Nigeria. The rocks were tested at the rates of 1.5, 2.5 and 3.5 kg/palm/year respectively (214.5, 357.5 and 500.5 kg/ha), and the single superphosphate at 1.0, 2.0 and 3.0 kg/palm/year (143, 286 and 426 kg/ha). Urea (N), murate of potash (K), and kieserite (Mg) were applied as basal application at the rates of 0.5 kg N, 2.0 kg K and 0.2 kg mg/palm/year (71.5, 286 and 28.6 kg/ha) to all treatment plots except the control (treatment without fertilizer application). Treatments were laid out as Randomized Complete Block Design, replicated three times. The phosphorus sources enhanced soil pH and soil nutrient availability and thereby enhanced palm development and yield. Applied phosphorus fertilizers had significant ($P \leq 0.05$) effect on mean bunch number per palm, mean single bunch weight and fresh fruit bunch (FFB) production. Palms treated with these fertilizers performed better than the control where no fertilizer was applied. Yield increases as rates of application increases and the optimum rates appeared to be 2.0 kg SSP, 2.5 kg SRP and 2.5 kg CRY beyond which there was no corresponding yield increase. Locally sourced P_2O_5 competed favourably with the conventional inorganic single superphosphate as fertilizer for manuring oil palm. However, these fertilizers are better used in combined form with single superphosphate due to their slow nutrients release and singly when Single superphosphate is not readily available. This along with basal application of N, K and Mg at the rates of 0.5, 2.0 and 0.2 kg /palm/year (71.5, 286 and 28.6 kg/ha) is very necessary for optimum yield.

Key words: Fresh fruit bunch (FFB), oil palm, phosphorus treatment, rock phosphate, yield.

INTRODUCTION

Tropical soils, are especially often low in available phosphorus and require addition of P fertilizer for optimum yield (Omoti, 1989). The parent materials of these soils are low in appetite bearing rocks and thus result in low P. Also the soils contain substantial amounts of free iron and aluminium oxide which are the main agents of P fixation. Thus low recovery of P by crops is usually observed due to their substantial P sorption capabilities with high residual effects. Maintenance of soil fertility and assured nutrient availability to oil palm on a long term basis in such soils demand for good soil management practices involving fertilizer use. The need for fertilizer to give optimum returns from oil palm production is well established. Large yield responses have been demonstrated in many fertilizer experiments.

Improving the fertility of the soil has consistently been pin pointed as one of the most critical factors in the bid to promote agricultural sustainability in Nigeria. A very crucial aspect of improving and maintaining soil fertility is the application of deficient nutrients of which phosphorus is one of the most important. This is due to the vital roles this element plays in crop production. Over the past four decades, evidence has been obtained on the significant

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responses of oil palm to phosphorus fertilizer on many soils in Nigeria (NIFOR, 1965; Zaharah et al., 1997).

The common practice is to supply P in the form of superphosphate, triphosphate and diammonium phosphate. However, their uses have been limited by high cost and unavailability at the period of peak demand (Menon and Chien, 1990; Komolafe, 1997). With scarcity and rising cost of these inorganic fertilizers, fertilization of oil palm plantation has become very expensive. These have necessitated the need to look inward for viable alternative sources as fertilizer for oil palm manuring. The alternative to dependence on imported P fertilizers is to exploit indigenous sources such as phosphate rocks (PR). Fortunately, geological surveys have shown that there are extensive deposits of local rock minerals in Nigeria.

In the acid soils of the humid tropics, reactive phosphate rock can be substituted profitably for soluble fertilizers. Finely ground PR directly applied to soil in Malaysia for oil palm production was reported to have improved growth and yield (Zaharah et al., 1997). Application of PR increased fresh fruit bunch (ffb) yield with the highest increase in plots that received 2.73 kg/palm (NIFOR, 1966). On acid sands, ground rock phosphate was found to be superior to single super phosphate.

Despite the positive response obtained from such early trials, further evaluations were not pursued. Several scientists have advocated the direct application of phosphate rocks to the soil to recapitalize it (Obigbesan and Udosen, 1995; Akande et al., 1998). The advantages of this lie in their being relatively cheap, affordable, readily available and also, environmental friendly (Amapu et al., 1990). Their use has also been shown to have great potentials for liming due to their high content of calcium (Isenmila et al., 2006). In Nigeria, with abundant deposits of PR in different parts of the country, there is little or no report of the use of these local phosphate rocks for manuring oil palm. Hence, the objective of this study was to evaluate the effectiveness of the local rock phosphates as an alternative source of P for manuring oil palm in oil palm fresh fruit production.

MATERIALS AND METHODS

The trial was conducted at Okomu Oil Palm Plantation Plc; located at Ovia North East Local Government area of Edo State. The oil palm plantation established in 1993 with NIFOR EWS Seedlings G99 at Okomu was used for the trial. The trial commenced in 1998 when the palms were about 5 years old. The trial consists of 10 treatments and these were laid out on the field as Randomized Complete Block Design replicated three times. Each treatment plot consists of 8 palms and guard row palms separating each plot and block from each other. Two palm rows make one block with 4 palms per row in a plot and each separated by a guard row palm before the next plot and also palm row separating block. The blocks were parallel to each other. Treatments were applied at a radius of 1 m away from the palm base. The fertilizers were evenly spread round the palm base within the ring weeded circle of 2.0 m diameter.

Two sources of locally sourced phosphorus were evaluated along with imported conventional single super phosphate (SSP) fertilizer at three different rates. The locally sourced P fertilizers evaluated are Sokoto rock phosphate (SRP) and crystallizer super (CRY). Single superphosphate (SSP) was evaluated at the rates of 1.0, 2.0, and 3.0 kg/palm/year while Sokoto Rock Phosphate (SRP), and Crystallizer Super (CRY), were evaluated at the rates of 1.5, 2.5, and 3.5 kg/palm/year respectively. The control treatment was zero (no fertilizer) application. All treatment palms received basal dressing (BD) of 0.5 kg Urea (N), 2.0 kg murate of potash (K) and 0.5 kg dolomite (Mg)/palm/year.

Soil samples were collected at two depths 0 to15 cm and 15 to 30 cm prior to treatment applications. Composite soil samples collected were bulked, air dried, sieved, ground and then sieved again with a 2 mm sieve. The sieved samples were then analysed for soil physico-chemical properties. The soil pH was determined in 1:1 soil water suspension ratio and read in a glass electrode pH metre. Organic carbon was determined by the dichromate wet oxidation method of Walkey and Black (1934) as modified by Allison (1965). The particles size distribution was determine by a consideration of wet sieving and hydrometer technique (Bouyocous, 1951). Total N was determined by macro Kejeldah method, available P was extracted by using Bray 1 method and P in the extract determined calorimetrically by the blue colour method (Bray and Kurtz, 1945). Exchangeable cations were extracted using NH_4OAc. Potassium and sodium were determined on flame photometer, while Calcium and Magnesium were by EDTA titration. The effective cation exchange capacity (ECEC) was a summation of exchangeable bases and exchange acidity.

Locally sourced P_2O_5 were analysed. The rocks were crushed, milled and the samples collected were extracted with perchloric acid (wet digestion) and analysed for percentage content of Ca, P_2O_5, Mg, Al, Fe and NaO_3, K_2O and N. Al and Si were determined by the $NaCO_3$ fusion, carbon (organic matter) by the locally and black method, C by $AgNO_3$ (Argentriometric) method, CO_3 by phenolphthalein acidity using HCl, and NO_3 by sodium phosphate/salicylic acid method (Allison, 1965). Data were collected on fresh fruit bunches on forth night bases. Fresh fruit bunches (ffb) harvested with bunch number and bunch weight recorded per treatment palm. Data collected were subjected to analysis of variance and their means separated using the New Duncan's Multiple Range (DMRT) at 5% levels of probability (Steel and Torrie, 1984)

RESULTS AND DISCUSSION

Chemical composition of locally source P fertilizers

The chemical composition of Sokoto rock phosphate and crystallizer is presented in Table 1. Sokoto rock phosphate contains 25.2% P_2O_5. It has a high content of Ca (44.2% CaO) and therefore has a great potential for liming. Its nutrient composition and solubility are comparable to most rock phosphates used in oil palm estates in South East Asia (Goh et al., 2000; Zaharah et al., 1997). Crystallizer has about 22.2% total P_2O_5. It contains 12.6% CaO and can be used for liming, but it is not as effective as Sokoto rock phosphate.

Soil physical properties

Physio-chemical properties of the experimental site prior

Table 1. Chemical composition of Sokoto rock phosphate and crystallizer super.

Element	SRP	CRY	SSP
P (%)	25.2	22.2	18.6
K (%)	0.23	0.18	-
Na (%)	1.23	1.01	-
Mg (%)	0.32	0.29	0.35
Ca (%)	14.25	13.24	1.85
Al (%)	2.0	2.14	-
Fe (%)	6.75	6.0	-
C (%)	0.90	-	-
Zr (%)	0.013	0.012	-
Si (%)	3.04	2.74	5.40
Specific gravity	1.72	-	-
Water absorption capacity	11.1	-	26.5
Solubility in 2% citric acid	38.42	-	-

Table 2. Soil physio-chemical properties before and 18 months after treatment applications.

Property	Prior to treatment application	18 MAP
pH	4.8	5.5
OM (g/kg)	2.12	2.31
Total N (g/kg)	0.09	0.14
Available P (g/kg)	14.9	26.9
Exchangeable cations (cmol/kg):		
K	0.25	0.30
Ca	0.96	1.60
Mg	0.24	0.32
Sand (%)	69.5	67.5
Clay (%)	19.8	18.5
Silt (%)	10.7	14.0

to and after (18 months) treatments application are presented in Table 2. Application of locally sourced P_2O_5 slightly increased soil pH, the exchangeable cations and available P. The pH increased from 4.8 to 5.5 and also the soil available P increased by 44.6%. Generally applied locally sourced P_2O_5 improved the soil structure. There was a decrease in the percentage of sand and clay particles and an increase in the percentage of silt particle.

Effect of locally sourced P fertilizers on fresh fruit bunch production (ffb)

Application of P fertilizers to oil palm significantly ($p \leq 0.05$) affected oil palm fresh bunch (ffb) production. Yield components (bunch number per palm, mean single bunch weight in kg/bunch and fresh fruit bunch in yield/ha), were markedly affected by applied P sources (Tables 3, 4 and 5).Oil palm responded positively to applied phosphorus. Generally, bunch number and single bunch weight increased significantly with increased rates of application over the control.

Effect of P source on yield components (bunch number and weight) and ffb production tons per ha for the years 2000 to 2008 are presented in Tables 3, 4 and 5. Application of P fertilizers had significant ($p \leq 0.05$) effects on bunch number, single bunch weight and fresh fruit bunch (ffb) production. Significant difference in responses among the P sources at different rates of P applied was low in the first 2 years of application (that is 2000 and 2001). However from the 4th year, there were marked significant differences in yield components especially on bunch weight and ffb production.

Application of P fertilizers increased soil pH from highly acidic (4.8) to moderately acidic (5.5) and thus improved soil fertility which indirectly enhanced nutrient availability and utilization of soil nutrients by the palms, This in turn enhanced palm growth and yield components. The significant effects of applied P sources on yield components especially bunch weight and fresh fruit bunch

Table 3. Effect of phosphorus fertilizers on oil palm mean bunch number from 2000 to 2008.

Fertilizer	Rate (kg/palm)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cont	0	5.9^{a}	6.0^{b}	7.0^{c}	8.2^{e}	8.5^{e}	7.0^{f}	9.2^{d}	6.0^{e}	7.5^{e}
SSP	1.0	6.0^{a}	6.5^{a}	8.0^{c}	9.0^{cd}	8.7^{e}	8.0^{e}	9.5^{c}	10.0^{b}	9.5^{bc}
SSP	2.0	5.9^{a}	6.7^{a}	11.5^{a}	13.0^{a}	11.5^{b}	11.0^{b}	12.0^{a}	12.5^{a}	11.0^{ab}
SSP	3.0	5.5^{a}	6.3^{a}	10.0^{b}	11.5^{b}	9.5^{d}	9.0^{d}	11.0^{b}	10.0^{b}	8.5^{c}
SRP	1.5	5.5^{a}	6.1^{ab}	6.8^{d}	8.5^{d}	9.5^{d}	9.5^{cd}	9.7^{c}	10.0^{b}	8.0^{d}
SRP	2.5	5.4^{a}	6.3^{a}	7.1^{c}	11.0^{b}	12.5^{a}	12.0^{a}	12.5^{a}	12.0^{a}	11.5^{a}
SRP	3.5	5.6^{a}	6.2^{ab}	7.0^{c}	9.5^{c}	10.0^{c}	9.5^{cd}	10.8^{b}	10.5^{b}	8.0^{d}
CRY	1.5	5.0^{b}	5.8^{b}	6.8^{d}	8.5^{c}	8.5^{e}	9.0^{d}	8.8^{de}	7.5^{d}	9.8^{b}
CRY	2.5	5.8^{a}	5.9^{b}	9.5^{b}	10.5^{b}	12.0^{a}	11.5^{ab}	10.5^{b}	9.5^{bc}	9.0^{bc}
CRY	3.5	5.7^{a}	5.7^{b}	9.0^{b}	8.8^{d}	10.5^{bc}	10.0^{c}	10.0^{c}	8.0^{c}	9.7^{b}

Cont: Control, SSP: Single Super Phosphate, SRP: Sokoto Rock Phosphate and CRY: Crystallizer Super. Means followed by the same alphabets are not significantly different from each other by the New Duncan's Multiple Range Test (p = 0.05) probability.

Table 4. Effect of phosphorus fertilizers on oil palm single bunch weight (kg/bunch) at Okomu Oil Palm Estate from 2000 to 2008.

Fertilizer	Rate (kg/palm)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cont.	0	11.37^{c}	13.67^{c}	14.67^{d}	17.0^{e}	15.0^{d}	15.0^{e}	16.5^{d}	14.5^{e}	18.5^{e}
SSP	1.0	13.07^{ab}	14.86^{b}	16.0^{c}	20.5^{b}	19.5^{b}	17.5^{d}	19.5^{b}	21.5^{b}	23.5^{b}
SSP	2.0	14.05^{a}	16.08^{a}	18.5^{a}	22.5^{a}	21.0^{a}	18.5^{c}	22.5^{a}	24.5^{a}	26.5^{a}
SSP	3.0	13.56^{a}	16.0^{a}	17.0^{b}	19.5^{b}	19.5^{b}	18.0^{d}	18.5^{c}	22.0^{b}	24.0^{b}
SRP	1.5	13.2^{ab}	14.0^{b}	16.5^{c}	19.0^{bc}	18.0^{c}	17.5^{d}	18.5^{c}	20.5^{c}	21.5^{d}
SRP	2.5	14.0^{a}	16.1^{a}	17.9^{b}	20.5^{a}	20.5^{a}	20.1^{a}	20.5^{a}	22.7^{b}	22.8^{c}
SRP	3.5	12.57^{b}	15.5^{a}	17.0^{b}	20.0^{a}	19.0^{b}	18.5^{c}	20.5^{a}	21.5^{b}	21.0^{d}
CRY	1.5	13.6^{a}	14.9^{b}	15.9^{d}	18.5^{d}	18.5^{c}	17.2	18.8^{c}	19.5^{d}	21.1^{d}
CRY	2.5	13.0^{ab}	15.9^{a}	17.5^{b}	20.3^{a}	20.5^{a}	19.5^{b}	21.1^{a}	22.5^{b}	23.0^{b}
CRY	3.5	13.4^{a}	14.5^{b}	16.5^{c}	19.5^{b}	20.0^{a}	18.3^{c}	20.2^{a}	20.2^{c}	21.5^{d}

Cont: Control, SSP: Single Super Phosphate, SRP: Sokoto Rock Phosphate and CRY: Crystallizer Super. Means followed by the same alphabets are not significantly different from each other by the New Duncan's Multiple Range Test (p = 0.05) probability.

(ffb) production over the control is a clear indication that for optimum yield of oil palm, external inputs such as fertilizer is necessary. The yield components increased as P rate increased, until what seemed to be an optimum rate of 2.0 kg SSP, and 2.5 kg each of SRP and CRP per palm per year (286 kg SSP per ha and 357.5 kg CRY and SRP per ha) was reached. Beyond these rates, there was a decline in bunch number, bunch weight and ffb production.

The conventional imported single superphosphate showed rapid increases in bunch number,

Table 5. Effect of phosphorus fertilizers on fresh fruit bunch (ffb) production (tons per ha) at Okomu Oil Palm Estate from 2000 to 2008.

Fertilizer	Rate (kg/palm)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cont.	0	7.6^{a}	8.3^{d}	10.5^{b}	10.4^{e}	11.5^{d}	11.3^{e}	10.3^{d}	9.5^{f}	8.8^{f}
SSP	1.0	9.0^{a}	10.7^{b}	11.5^{b}	12.7^{c}	12.0^{c}	13.0^{c}	14.5^{c}	14.5^{c}	14.0^{b}
SSP	2.0	8.7^{a}	11.5^{a}	12.5^{a}	14.0^{a}	14.5^{a}	16.0^{a}	17.0^{a}	15.0^{b}	15.5^{a}
SSP	3.0	8.9^{a}	10.9^{b}	12.0^{a}	13.4^{b}	14.0^{a}	14.5^{b}	15.0^{b}	14.5^{c}	14.5^{b}
SRP	1.5	8.7^{a}	9.5^{c}	11.0^{b}	12.0^{cd}	11.9^{d}	12.5^{d}	13.5^{c}	11.5^{e}	10.5^{e}
SRP	2.5	8.9^{a}	10.3^{b}	11.7^{b}	13.0^{b}	13.5^{b}	15.0^{b}	16.5^{a}	16.0^{a}	15.5^{a}
SRP	3.5	9.0^{a}	10.1^{b}	10.9^{bc}	12.7^{c}	12.0^{c}	14.0^{b}	15.0^{b}	14.0^{c}	13.5^{cd}
CRY	1.5	7.5^{b}	9.5^{c}	10.5^{c}	11.5^{d}	11.5^{d}	12.0^{d}	14.0^{c}	12.0^{d}	11.5^{e}
CRY	2.5	8.5^{a}	9.8^{c}	10.8^{bc}	13.5^{b}	12.0^{c}	14.5^{b}	15.0^{b}	14.0^{c}	14.0^{b}
CRY	3.5	7.0^{b}	9.7^{c}	10.4^{c}	12.0^{cd}	11.0^{d}	13.0^{c}	15.0^{b}	13.5^{cd}	13.0^{c}

Cont: Control, SSP: Single Super Phosphate, SRP: Sokoto Rock Phosphate and CRY: Crystallizer Super. Means followed by the same alphabets are not significantly different from each other by the New Duncan's Multiple Range Test (p = 0.05) probability.

bunch weight and ffb production immediately it was applied and this continued until the 7th year (2005) and thereafter, the yield components began to decline and then picked up again. However, for the local rock phosphate, the bunch number, bunch weight and ffb production increased at a slow rate which continued to increase before the termination of the experiment. This may be attributed to their slow nutrient release unlike the conventional phosphates fertilizers which show nutrient release immediately in the soils once they are applied. The highest bunch number, bunch weight and ffb production was obtained when SSP was applied at 2.0 kg/palm/year. A similar trend was observed in locally sourced P fertilizers with the highest bunch number, bunch weight and ffb production at the rate of 2.5 kg/palm/year for SRP and CRY. Palm receiving P, irrespective of source, performed better than that which received no P fertilizer. This performance could be attributed to the applied fertilizers. A similar finding was reported by Isenmila et al. (2006) where they observed that applied locally sourced magnesite significantly ($p < 0.05$) affected bunch number, bunch weight and ffb production of oil palm at Rison Palm and Okomu Oil Palm Estate. They further reported that palms receiving applied Mg irrespective of source out yielded palms that received no external input.

The highest performance of palm treated with P fertilizer over the control gives an indication of their efficacy in low P soil of Nigeria. When P sources were compared, the conventional SSP performed better than the SRP and CRY during the early years. This may be attributed to its quick mineralization, than the locally sourced SRP and CRY, which released their nutrients slowly. The palm treated with SRP and CRY exhibited steady increases in bunch number, bunch weight and ffb production until the 5th year compared to 2007 when there was a drop in yield which again picked up in 2008. This may be attributed to the gradual release of phosphorus. Further increase in rates of application resulted in yield reduction; a similar observation was made by Isenmila and Omoti (2003) and Abidemi and Obigbesan (1999) in their separate studies on rocks utilization as fertilizers. This suggested that to go beyond what seems to be optimum rates will amount to waste of resources.

Conclusion

The findings from this trial showed that the variations observed in the parameters taken were largely attributed to the applied P. The superior response of palm to various P fertilizers over the control is a clear indication of the low P status of the soils and that oil palm requires P fertilization for optimum growth. SRP and CRY as P sources appeared to have agronomic potential for oil palm manuring. The two locally sourced P_2O_5 bearing rock minerals (Sokoto rock phosphate and crystallizer) evaluated in this trial, imparted significant positive effects on lowering soil acidity and increasing oil palm yield component. For quick response to alleviate phosphorus deficiency, it was shown that single super phosphate was a suitable alternative to SRP and CRY, while for long time effects both SRP and CRY are effective substitutes to SSP. On the whole, locally sourced P such as SRP and CRY could be used for manuring oil palm at the rate of 2.5 kg P_2O_5/palm/year. This should be applied along with basal use of urea at the rate of 0.5 kg N/ palm/year, murate of potash at the rate of 2.0 kg K/palm/year and kieserite at the rate of 0.2 kg/palm/year.

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