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Oil Palm (*Elaeis guineensis*) Seedling Performance in Response to Phosphorus Fertilization in Two Benchmark Soils of Nigeria

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Abstract: The response of polybag oil palm (*Elaeis guineensis*) seedlings to different sources of phosphorus, P (applied at 0, 7.56 and 15.12 g P_2O_5/palm) was monitored in two Nigerian benchmark soils (a strongly acidic Rhodic Paleudalf and a weakly acidic Plinthic Tropudalf from Epe and Ibadan, respectively). Rock phosphates, RP (Ogun rock phosphate, ORP and Crystalliser, CRYS - a blend of ground Sokoto rock phosphate with talc) were the P- fertilizer sources tested while the popular commercial fertilizer - Single Super Phosphate (SSP) was used as a standard reference. The 3×3×2 (= 18) treatment combinations were replicated three times in Randomised Complete Block Design (RCBD), giving a total of 54 experimental units (polybags). Growth parameters measured include plant height, number of leaves/palm, stem girth, leaf area and number of split-leaves/palm. Nutrient content of the Index leaves was also determined. In consonance with earlier reports, oil palm seedlings grown in the two soils responded positively to P application, 7.56 g P_2O_5/palm level being the optimum while ORP and CRYS performed equally or better than SSP in respect of stem thickness, number of leaves produced/palm and nutrient contents of the index leaves of the seedlings. Evidently, Ogun rock phosphate and Crystalliser would be more appropriately used to advantage in acid soils than single super phosphate for raising oil palm seedlings.

Key words: Polybag oil palm, *Elaeis guineensis*, strongly acidic rhodic paleudalf, weakly acidic plinthic tropudalf, rock phosphate, super phosphate fertilizer

INTRODUCTION

Oil-palm (*Elaeis guineensis*) is one of the most important economic crops in several countries of the world, including Nigeria. Significant responses of this crop to phosphorus (P) fertilization have been obtained in soils of Nigeria (Ataga, 1978), Malaysia (Zaharah *et al*., 1997) and Northern Brazil (IRHO, 1974). In these areas, it is a common practice to supply P in the form of super phosphate and Di-ammonium phosphate, the use of which has been limited by high cost and unavailability at the period of peak demand (Menon and Chien, 1990; Komolafe, 1997). The alternative to depending on these imported P-fertilizers is to exploit indigenous sources such as phosphate rocks (PRs). According to Nehikhare (1987) as well as Obigbesan and Udozen (1995) deposits of rock phosphates are found in four sedimentary basins in Ogun State, Sokoto state, Edo state and Imo State of Nigeria. The Sokoto source has particularly been noted to occur in commercial quantities, with geologic estimates of between 5 to over 10 million tons (Obigbesan and Udozen, 1995; Fayiga, 1998).

However, it is not all soils and cropping situations that are suitable for the use of PRs (Le Mare, 1991) besides the fact that they are low in available P content compared with the high-analysis fertilizers such as Single Super Phosphate (SSP) and Triple Super Phosphate (TSP) (Yeates and Allen, 1987). In the acid soils of the humid tropics, reactive PR can be substituted profitably for soluble fertilizers (Hammond *et al*., 1986; Udosen, 1995; Fayiga, 1998). Several researchers (Casanova and Solórzano, 1994; Rooge *et al*., 1998; Obigbesan and Akinrinde, 2000) have reported on the agronomic efficiencies of PR in arable crop production. Despite the abundant deposits of PR in different parts of Nigeria, there has been no report on the use of these local PRs for growing oil palm. Hence, the hypothesis that PRs could be used to advantage in oil palm production needs to be specifically tested.

Finely ground PR directly applied to the soil in Malaysia (Zaharah *et al*., 1997) and Brazil (IRHO, 1974) for raising oil palm (*Elaeis guineensis*) at both nursery and field conditions improved growth and yield. The objective of this study was to determine the response of oil palm

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seedlings' growth in polybags to Ogun Rock Phosphate (ORP) and Crystallizer, (CRYS)-a blend of ground Sokoto rock phosphate and talc. In line with the work of Akinrinde *et al.* (2005), the conventional phosphate source (Single Super Phosphate, SSP) would be used as reference.

MATERIALS AND METHODS

Materials: The top 15 cm of two soil types (one Rhodic Palaudalf and the other Plinthic Tropudalf) (Soil Survey Staff, 1975) from two locations in Nigeria (Epe in Lagos State and Ibadan in Oyo State) were collected, air-dried, passed through 2 mm sieve and prepared for nursery planting of oil palm seedlings. The physico-chemical properties of these soils are provided in Table 1. The phosphate fertilizers tested were Single Super Phosphate (SSP), Ogun Rock Phosphate (OSP) and Crystalliser, (CRYS) - a blend of ground Sokoto rock phosphate with talc. The chemical properties of the phosphate fertilizers are also given in Table 1.

Methods

Soil analysis: Particle size analysis of the soil was determined by the Bouyoucos (1951) hydrometer method, using sodium glass electrode pH meter. Organic carbon was estimated on 2 g soil samples (passed through 0.5 mm sieve) by the dichromate wet oxidation method of Walkey and Black (1934) as outlined by Jackson (1968). Total nitrogen (N) was determined by the macro-Kjeldhal method (Jackson, 1968). Available phosphorus (P) was extracted with Bray-1 (Bray and Kurtz, 1945) solution and determined by the molybdate blue technique of Murphy and Riley (1962). Exchangeable cations (Ca, Mg, Na and K) were determined in extracts obtained after leaching the soils with neutral normal ammonium acetate (IN NH_4OAC, pH 7.0) solution. Potassium (K) and Na were estimated by flame photometry while Ca and Mg were estimated by the versenate (0.01M EDTA) titration solution.

Greenhouse study: Ten kilograms of soil were weighed per polythene bag (40×35 cm) and replicated three times. A total of 54 bags were prepared and placed 46×46 cm on metal benches in an open space near the Agronomy Departmental greenhouses at the Ibadan University, Nigeria. Three-month old seedlings were grown in the polythene bags between August 1998 and June 1999. The P-treatment was applied 1-month after planting at a depth of 2.5 cm by ringing. It was applied at the rate of 0, 7.56 and 15.12 g P_2O_5/palm (based on NIFOR , 1965, 1982 recommended rates) using the reference fertilizer (SSP) as well as the ones being tested (ORP and CRYS). In addition to the P-treatments, a basal dressing including nitrogen, N and potassium, K (8.85g N/palm and 25.2 g K_2O/palm using urea, 45% N and muriate of potash, 60% K, respectively) was applied. For comparison, control (Zero P) pots were added to elicit the effect of P derived from the soil. The moisture level of the soils in the polythene bags was maintained at 60% field capacity by regular watering. The index leaves (Heartley, 1988) of the oil palm seedlings were harvested after 10 months of growth, dried in an oven at 70°C, weighed and ground. The samples were then digested and nutrient (P, K, Ca, Mg and Zn) contents determined.

Table 1: Physico-chemical properties of the soils and chemical analysis of phosphorus fertilizer sources used

Soil properties	Soil A (Epe location) Rhodic Paleudalf	Soil B (Ibadan location) Plinthic Tropudalf
pH (H_2O)	5.10	5.80
pH (KCl)	4.80	5.40
Exchangeable bases (cmol kg^{-1})		
Mg	0.90	0.14
Ca	2.35	0.80
K	0.26	0.28
Na	2.44	1.56
Org. C (g kg^{-1})	8.30	11.80
Total N (g kg^{-1})	0.80	1.20
Available-P (Bray –1) (mg kg^{-1})	8.77	8.50
Mechanical Analysis (g kg^{-1})		
Sand	933.30	846.00
Silt	13.30	80.00
Clay	53.40	74.00
Textural class	Sand	Sand

Chemical analysis of the phosphorus fertilizer sources

P-Sources	P_2O_5	CaO (%)	MgO	SiO_2	Source
Single Super-phosphate	18.00	1.85	0.35	5.400	(Chime, 1998)
Ogun rock Phosphate	30.00	19.23	1.35	26.95	(Fayiga, 1998)
Crystalliser	21.00	30.00	8.00	10.00	(Booth, 1998)

Data collection: Growth data were collected at 3, 6, 9 and 12 months after transplanting. The parameters measured were: Number of leaves/plant, plant height, stem-girth, number of split-leaves/palm and leaf area - measured non-destructively (Harden *et al*., 1969; Lucas *et al*., 1979).

The data collected were analysed for statistical significance by analysis of variance (ANOVA) based on factorial arrangement in a Randomised Complete Block Design (RCBD). Standard Error (SE) was used to compare treatment means when an ANOVA showed significant differences among means.

RESULTS

Plant height: Throughout the sampling period, the oil palm seedlings growing on Soil B (Plinthic Tropudalf) were taller than those of Soil A (Rhodic Paleudalf) (Table 2). However, a significant difference in response among the P-sources and different rates of P-applied was not observed until 6 months after planting in both soils. In Soil A (Rhodic Paleudalf) SSP, ORP and CRYS treated oil palm seedlings were significantly taller ($p<0.05$) than the control. In Soil B (Plinthle Tropudalf) ORP and CRYS treated oil pain seedlings were significantly taller ($p<0.05$) than SSP and control treatment plants.

Number of leaves/palm: At all stages of growth, growth pattern in both soil types were similar in that the number of leaves/palm were relatively the same irrespective of the P-source. As from 6 months of growth, SSP, ORP and CRYS treated oil palm seedlings produced more leaves than the untreated seedlings (control) (Table 3). Although there were visible differences among the P-sources, the differences were not statistically significant until 9 months of growth. It was observed from 6 months of growth that doubling the recommended application rate (i.e. use of 15.12 g P_2O/palm) significantly ($p<0.05$) reduced the number of leaves/palm, probably as an evidence of over dosage.

Leaf area: The result presented in Table 4 shows the effect of P-sources on the leaf area of oil palm seedlings. Throughout the sampling period, oil palm seedlings grown on Soil A, (Rhodic Paleudalf) significantly ($p<0.05$) produced broader and larger leaves than those of Soil B (Plinthic Tropudalf). However, the responses among the crops treated to the P-sources (SSP, ORP and CRYS) were not significant in either of the soil types until 6 months of growth. It was observed that as from 3 months of growth, the largest leaves were recorded with the recommended application rate of 7.56 g P_2O_5/palm while the plants receiving double the rate (15.12 g P_2O_5/palm) produced leaves as narrow as the control.

Table 2: Effect of different treatments on height (cm) of oil palm seedlings at successive months of growth

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	3 months				6 months			
Soil A (Rhodic Paleudalf)								
SSP	46.4	50.3	49.3	48.7±1.17	55.0	59.0	57.3	57.1±1.16
ORP	46.4	45.9	48.5	46.9±0.80	55.0	55.3	50.7	53.7±1.49
CRY	46.4	46.4	52.5	48.4±2.04	55.0	52.3	56.7	54.7±1.28
($\bar{X}$ ±SE)	46.4	47.5±0	50.1±1.39	48.0±1.22	55.0	54.9±0	54.9±1.94	55.1±2.11
Soil B (Plinthic Tropudalf)								
SSP	60.8	60.1	59.9	62.3±0.27	67.0	69.5	66.0	67.5±1.04
ORP	60.8	65.7	59.4	62.0±1.91	67.0	72.7	67.8	69.2±1.78
CRY	60.8	63.2	62.3	62.1±0.70	67.0	72.0	70.8	69.9±1.51
($\bar{X}$ ±SE)	60.8	63.0±0	60.5±1.62	62.1±0.90	67.0	71.4±0	68.2±0.97	68.9±1.40

Table 2: Continued

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	9 months				12 months			
Soil A (Rhodic Paleudalf)								
SSP	64.3	75.4	68.5	69.4±3.24	108.3	113.7	111.2	111.1±1.56
ORP	64.3	68.8	67.7	66.9±1.36	108.3	128.7	112.7	116.5±6.21
CRY	64.3	68.6	65.2	66.0±1.31	108.3	109.7	107.3	108.4±0.70
($\bar{X}$ ±SE)	64.3	70.9±0	68.2±2.24	67.4±0.99	108.3	117.4±0	110.4±5.79	112.0±1.61
Soil B (Plinthic Tropudalf)								
SSP	78.7	81.3	76.5	78.8±1.39	95.3	94.0	89.3	92.9±1.82
ORP	78.7	80.3	86.7	81.9±2.45	95.3	103.0	118.9	105.7±6.96
CRY	78.7	86.2	76.8	80.6±2.87	95.3	113.0	106.7	105.0±5.19
($\bar{X}$ ±SE)	78.7	86.6±0	80.0±1.83	80.4±3.36	95.3	103.3±0	104.91±5.49	101.9±8.60

SSP = Single Super-phosphate, ORP = Ogun Rock Phosphate, CRY = Crystalliser

Table 3: Effect of different treatments on number of leaves per plant of oil palm seedlings at successive months of growth

P-Sources	Rates of P-added (g P_2O_5/palm)							
	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	3 months				6 months			
Soil A (Rhodic Paleudalf)								
SSP	15.7	15.0	15.3	15.3±0.20	17.7	17.7	18.0	17.8±0.10
ORP	15.7	15.3	15.7	15.6±0.13	17.7	18.7	18.3	18.2±0.29
CRY	15.7	16.7	14.7	15.7±0.58	17.7	18.3	17.0	17.7±0.38
($\bar{X}$ ±SE)	15.7	15.7±0	15.2±0.52	15.5±0.29	17.7	18.2±0	17.8±0.29	17.9±0.39
Soil B (Plinthic Tropudalf)								
SSP	14.7	15.0	15.7	15.1±0.30	17.0	18.0	17.7	17.6±0.30
ORP	14.7	16.3	15.8	15.6±0.47	17.0	18.3	18.0	17.8±0.39
CRY	14.7	14.7	15.0	14.8±0.10	17.0	17.0	17.0	17.7±0.00
($\bar{X}$ ±SE)	14.7	15.3±0	15.5±0.49	15.2±0.25	17.0	17.8±0	17.6±0.39	17.5±0.29

Table 3: Continued

P-Sources	Rates of P-added (g P_2O_5/palm)							
	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	9 months				12 months			
Soil A (Rhodic Paleudalf)								
SSP	19.3	17.7	19.3	19.4±0.53	20.7	21.0	21.3	21.0±0.17
ORP	19.3	21.0	19.3	19.9±0.57	20.7	22.0	21.7	21.5±0.39
CRY	19.3	19.7	19.7	19.6±0.13	20.7	23.3	21.0	21.7±0.82
($\bar{X}$ ±SE)	19.3	20.1±0	19.4±0.96	19.6±0.13	20.7	22.1±0	21.3±0.67	21.4±0.20
Soil B (Plinthic Tropudalf)								
SSP	18.7	19.3	19.0	19.0±0.17	20.0	21.3	20.7	20.7±0.38
ORP	18.7	20.3	19.7	19.6±0.47	20.0	21.7	21.3	21.0±0.57
CRY	18.7	19.0	18.7	18.8±0.10	20.0	21.3	20.0	20.4±0.43
($\bar{X}$ ±SE)	18.7	19.5±0	19.1±0.39	19.1±0.30	20.0	21.4±0	20.7±0.13	20.7±0.38

SSP = Single Super-phosphate, ORP = Ogun Rock Phosphate, CRY = Crystalliser

Table 4: Effect of different treatments on leaf area (cm^2) of oil palm seedlings at successive months of growth

P-Sources	Rates of P-added (g P_2O_5/palm)							
	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	3 months				6 months			
Soil A (Rhodic Paleudalf)								
SSP	192.4	216.7	186.4	198.5±9.27	454.5	554.0	547.0	518.5±32.1
ORP	192.4	181.3	163.3	179.0±8.49	454.5	489.0	390.0	444.5±29.1
CRY	192.4	178.9	186.6	186.0±3.91	454.5	628.0	412.6	498.4±66.0
($\bar{X}$ ±SE)	192.4	192.3±0	178.8±12.23	187.8±7.74	454.5	557.0±0	449.8±40.20	487.1±49.06
Soil B (Plinthic Tropudalf)								
SSP	237.9	290.2	254.5	260.7±15.45	547.5	594.5	507.5	549.8±25.2
ORP	237.9	302.3	263.0	267.7±18.76	547.5	760.0	703.0	736.8±63.6
CRY	237.9	275.9	298.3	270.7±17.65	547.5	842.0	626.0	671.8±88.2
($\bar{X}$ ±SE)	237.9	289.5±0	271.9±7.64	266.4±13.43	547.5	732.2±0	678.8±72.88	652.8±56.93

Table 4: Continued

P-Sources	Rates of P-added (g P_2O_5/palm)							
	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	9 months				12 months			
Soil A (Rhodic Paleudalf)								
SSP	722.6	787.7	776.1	762.1±20.07	1036.7	1198.5	1329.8	1188.3±84.86
ORP	722.6	809.0	713.2	748.3±30.52	1036.7	1256.7	1242.3	1178.6±71.14
CRY	722.6	774.0	698.0	731.5±22.42	1036.7	1342.3	1139.2	1172.7±89.91
($\bar{X}$ ±SE)	722.6	789.2±0	729.1±10.19	746.9±23.93	1036.7	1265.8±0	1237.1±41.81	1179.9±55.14
Soil B (Plinthic Tropudalf)								
SSP	600.0	699.2	572.7	623.9±38.48	701.3	891.4	624.2	738.9±79.49
ORP	600.0	811.3	990.0	800.4±112.85	701.3	833.6	1067.7	867.5±107.25
CRY	600.0	930.0	758.0	762.7±95.40	701.3	1028.2	1035.2	921.6±110.28
($\bar{X}$ ±SE)	600.0	813.5±0	773.5±66.71	729.0±120.86	701.3	917.7±0	909±57.77	832.7±142.89

SSP = Single Super-phosphate, ORP = Ogun rock phosphate, CRY = Crystalliser

Stem girth: The oil palm seedlings showed large responses to applied P as can be seen in significant ($p<0.05$) increases in stem girth (Table 5). As from 6 months of growth, there were significant ($p<0.05$) differences among the P-sources in both soils. In Soil A, (Rhodic Paleudalf) ORP and CRYS treated oil palm seedlings were about the same in stem girth but significantly bigger than SSP treated and control plants. In Soil B (Plinthic Tropudalf) ORP treated oil palm seedlings produced the biggest stems, followed by CRYS and SSP treated ones in decreasing order while the control produced the smallest sized stems. Similarly, there were significant differences ($p<0.05$) among the different rates of P applied in both soils. The response to application rate of 7.56 g P_2O_5/palm and 15.12 g P_2O_5/palm was initially about the same. However as from 4 months of growth, 7.56 g P_2O_5/palm application *rate* produced the biggest sized stems in both soils. Doubling the application rate (15.12 g P_2O_5/palm) and control (0 g P_2O_5/palm) produced plants that were statistically the same in size.

Number of split-leaves/palm: Throughout the sampling period, the number of split-leaves/palm was relatively uniform in the two soil types irrespective of P-source or rate of P applied (Table 6) except at 9 and 12 months of growth.

Nutrients content in palm leaf: The nutrient content in palm leaf was different in the soils (Table 7). In Soil A (Rhodic Paleudalf) treated oil palm seedlings were statistically the same in terms of their contents of K, Mg, Ca and Zn. However, there were significant ($p<0.05$) differences among plants treated to the P-sources with respect to their P contents. SSP (0.81%) and CRYS (0.91%) were statistically the same but significantly higher than ORP (0.74%) and control (0.60%). In Soil B (Plinthic Tropudalf) the % K content of the leaf was virtually the same in both treated and untreated (control) oil palm seedlings, but there were significant ($p<0.05$) differences among the P-sources in percent P, Mg, Ca and Zn. For % P, SSP (0.76%) treated oil palm seedlings were significantly higher than ORP (0.59%) and CRYS (0.58%) treated ones which were similar but significantly different from the control (0.54%). For % Mg, oil palm seedlings treated with CRYS (0.63%) contained the highest; ORP treated plants (0.41%) high, while SSP (0.29%) and control plants (0.30%) were smallest in Mg contents o f the leaf. For % Ca, SSP and CRYS treated oil palm seedlings were the same (0.68%) in Ca contents of the leaf but significantly higher than ORP (0.59%) and control (0.60%). For Zn (ppm), ORP (300 ppm) and CRYS (416.7 ppm) treated oil palm seedlings were statistically the same but significantly different from SSP (224 ppm) in their Zn contents

Table 5: Effect of different treatments on stem girth (cm) of oil palm seedlings at successive months of growth

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	3 months				6 months			
Soil A (Rhodic Paleudalf)								
SSP	5.9	6.1	6.5	6.2±0.18	9.3	10.6	9.6	9.8±0.39
ORP	5.9	6.8	6.5	6.4±0.26	9.3	10.8	10.5	10.2±0.46
CRY	5.9	7.3	6.4	6.5±0.41	9.3	11.1	9.9	10.1±0.53
($\bar{X}$ ±SE)	5.9	6.7±0	6.5±0.35	6.4±0.03	9.3	10.8±0	10.0±0.15	10.0±0.26
Soil B (Plinthic Tropudalf)								
SSP	6.6	7.4	6.7	6.9±0.25	9.5	10.7	9.9	10.0±0.35
ORP	6.6	8.6	7.7	7.6±0.58	9.5	13.1	12.5	11.7±1.11
CRY	6.6	8.0	7.9	7.5±0.45	9.5	11.4	11.1	10.7±0.59
($\bar{X}$ ±SE)	6.6	8.0±0	7.4±0.35	7.3±0.37	9.5	11.7±0	11.2±0.71	10.8±0.75

Table 5: Continued

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	9 months			12 months				
Soil A (Rhodic Paleudalf)								
SSP	11.0	12.1	11.4	11.5±0.32	13.2	13.5	12.1	12.9±0.43
ORP	11.0	12.5	11.6	11.7±0.44	13.2	14.8	13.8	13.9±0.47
CRY	11.0	12.1	11.2	11.4±0.34	13.2	13.5	13.3	13.3±0.09
($\bar{X}$ ±SE)	11.0	12.2±0	1.4±0.13	11.5±0.12	13.2	13.9±0	13.1±0.43	13.4±0.51
Soil B (Plinthic Tropudalf)								
SSP	10.5	12.7	10.8	11.3±0.69	10.9	13.0	11.0	11.6±0.68
ORP	10.5	13.3	12.8	12.1±0.86	10.9	13.3	14.9	13.0±1.16
CRY	10.5	12.9	12.2	11.9±0.71	10.9	12.3	12.9	12.0±0.59
($\bar{X}$ ±SE)	10.5	18.0±0	11.9±0.18	11.8±0.59	10.9	13.2±0	12.9±0.30	12.3±1.13

SSP = Single Super-phosphate, ORP = Ogun Rock Phosphate, CRY = Crystalliser

Table 6: Effect of different treatments on number of split -leaves/palm at successive months of growth

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	3 months				6 months			
Soil A (Rhodic Paleudalf)								
SSP	3.7	3.3	3.0	3.3±0.20	6.0	5.7	5.3	5.7±0.20
ORP	3.7	3.7	2.3	3.2±0.47	6.0	6.0	5.0	5.7±0.33
CRY	3.7	3.0	2.0	2.9±0.49	6.0	5.7	5.3	5.9±0.20
($\bar{X}$ ±SE)	3.7	3.3±0	2.4±0.20	3.0±0.30	6.0	5.8±0	5.2±0.10	5.7±0.10
Soil B (Plinthic Tropudalf)								
SSP	2.7	3.3	3.0	3.0±0.17	5.3	6.0	5.3	5.5±0.23
ORP	2.7	4.3	3.3	3.4±0.47	5.3	7.0	5.7	6.0±0.51
CRY	2.7	3.0	3.7	3.1±0.30	5.3	5.3	5.7	5.4±0.13
($\bar{X}$ ±SE)	2.7	3.5±0	3.3±0.39	3.2±0.20	5.3	6.1±0	5.6±0.49	5.6±0.13

Table 6: Continued

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	9 months			12 months				
Soil A (Rhodic Paleudalf)								
SSP	8.7	8.7	8.0	8.5±0.23	13.0	12.3	11.3	12.2±0.49
ORP	8.7	8.7	8.3	8.6±0.13	13.0	13.0	12.7	12.9±0.10
CRY	8.7	8.0	8.7	8.5±0.23	13.0	11.3	12.0	12.1±0.49
($\bar{X}$ ±SE)	8.7	8.5±0	8.3±0.23	8.5±0.20	13.0	13.0±0	12.2±0.49	12.4±0.40
Soil B (Plinthic Tropudalf)								
SSP	7.7	8.0	7.3	7.7±0.20	10.3	10.3	9.3	10.0±0.33
ORP	7.7	10.0	7.3	7.7±0.84	10.3	12.0	10.3	10.9±0.57
CRY	7.7	7.7	7.7	7.7±0.00	10.3	10.7	11.3	10.8±0.29
($\bar{X}$ ±SE)	7.7	8.6±0	7.4±0.72	7.9±0.13±0	10.3	11.0±0	10.3±0.51	10.5±0.58

SSP = Single Super-phosphate, ORP = Ogun Rock Phosphate, CRY = Crystalliser

Table 7: Effect of different treatments on nutrient content of index leaf of polybag oil palm seedlings grown in different soils at 10 months of growth

	Rates of P-added (g P_2O_5/palm)											
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	P (%)				K (%)				Mg (%)			
Soil A (Rhodic Paleudalf)												
SSP	0.68	0.80	0.96	0.81±0.08	2.6	2.6	2.8	2.7±0.07	0.18	0.25	0.24	0.22±0.02
ORP	0.68	0.80	0.74	0.74±0.03	2.6	3.0	2.6	2.7±0.13	0.18	0.17	0.60	0.32±0.14
CRY	0.68	0.80	1.25	0.91±0.17	2.6	2.4	3.2	2.7±0.24	0.18	0.15	0.34	0.22±0.06
($\bar{X}$ ±SE)	0.68	0.80±0	0.98±0	0.82±0.15	2.6	2.6±0	2.9±0.18	2.7±0.18	0.18	0.19±0	0.39±0.03	0.25±0.11
Soil B (Plinthic Tropudalf)												
SSP	0.55	0.74	0.99	0.76±0.13	2.4	3.2	2.4	2.7±0.27	0.50	0.19	0.18	0.29+0.11
ORP	0.55	0.68	0.54	0.59±0.05	2.4	3.4	2.6	2.8±0.31	0.50	0.54	0.19	0.41±0.11
CRY	0.55	0.63	0.55	0.58±0.03	2.4	3.0	2.4	2.6±0.20	0.50	1.00	0.40	0.63±0.19
($\bar{X}$ ±SE)	0.55	0.68±0	0.69±0.03	0.64±0.15	2.4	3.2±0	2.5±0.12	2.7±0.07	0.50	0.58±0	0.26±0.23	0.44±0.07

Table 7: Continued

	Rates of P-added (g P_2O_5/palm)							
P-Sources	0	7.56	15.12	($\bar{X}$ ±SE)	0	7.56	15.12	($\bar{X}$ ±SE)
	Ca (%)				Zn (ppm)			
Soil A (Rhodic Paleudalf)								
SSP	0.68	0.40	0.46	0.51±0.09	102	150	82	111.3±20.20
ORP	0.68	0.64	0.76	0.69±0.04	102	64	68	78±12.07
CRY	0.68	0.60	0.64	0.64±0.02	102	94	92	96±3.06
($\bar{X}$ ±SE)	0.68	0.55±0	0.62±0.07	0.62±0.09	102	102.7±0	80.7±25.23	95.1±6.97
Soil B (Plinthic Tropudalf)								
SSP	0.72	0.72	0.60	0.68±0.04	400	192	80	224±93.86
ORP	0.72	0.44	0.60	0.59±0.08	400	250	250	300±50.06
CRY	0.72	0.68	0.64	0.68±0.02	400	500	350	416.7±44.15
($\bar{X}$ ±SE)	0.72	0.61±0	0.61±0.09	0.65±0.01	400	314±0	226±94.6	313.6±78.9

SSP = Single Super-phosphate, ORP = Ogun Rock Phosphate, CRY = Crystalliser

in the leaf tissue. The Zinc (Zn) contents of leaves of plants grown with these three P-sources were significantly higher than the control (100 ppm). Significant ($p<0.01$) interactions of P-source/P-rate/soil-type and P-rate/soil-type were obtained in respect of palm leaf Mg and P contents, respectively.

DISCUSSION

There were significant responses to the different P-sources applied. Without added P the number of leaves/plant and stem girth of oil palm seedlings was much less. Application of P-fertilizer irrespective of source or rate significantly increased the number of leaves/plant and stem thickness in both soils. Similar responses of oil palm to P-fertilization had been observed in Nigeria (Ataga, 1978) and in Malaysia (Zaharah *et al*., 1997). The better performance of Ogun rock phosphate (ORP) and crystalliser (CRYS) over single super phosphate (SSP) is an indication of the enormous potential of these local phosphate rocks for direct use as P-fertilizers. This confirms the results reported by IRHO (1974) that phosphate rock treated palms had superior effect compared to annual triple super phosphate. Thus, the expectation that water soluble P-fertilizer should have superior effect over phosphate rock was not supported by this finding.

The superior performance of recommended application rate (7.56 g P_2O_5/palm) over the double dose (15.12 P_2O_5/palm) in some of the growth parameters suggests that the recommended application rate of 7.56 g P_2O_5/palm by NIFOR (1982) is adequate. This was consistent with the findings of Lucas *et al.* (1979) who also confirmed the recommended fertilizer rates by NIFOR but suggested that the frequency and time of application be reviewed.

This study has also shown that without added P, nutrient content in the leaf of oil palm seedlings was very low. Application of P-fertilizers irrespective of source or rate significantly increased the P (both soils) as well as the Mg, Ca and Zn (Soil B-Plinthic Tropudalf only) content of the plants.

The better performance of CRYS and ORP treatments over the SSP fed oil palm seedlings with respect to the nutrient content of the index leaf could be due to properties of the soils and the P-sources. The findings of Lucas *et al.* (1979) and Menon and Chien (1990) also show that there was significant increase in P-leaf content of oil palm seedlings and maize treated with different P-sources. Doubling the application rate (15.12 g P_2O_5/palm) increased the nutrient content of the leaf more than the recommended application rate (7.56 g P_2O_5/palm) in Soil A (Rhodic Paleudalf). This agrees with the work of Agboola and Obigbesan (1974) that affirmed the high correlation existing between P-levels (rates) and P-uptake in plant. However, recommended application rate of 7.56 g P_2O_5/palm was better than double dose in Soil B (Plinthic Tropudalf). These contrasting results between the two soils could be due to high clay content in Soil B (Plinthic Tropudalf) that served as a binding agent between soil colloids and applied nutrients. This may prevent the nutrients from being leached easily from the soil and make the applied nutrients sufficient for the plant. However, Soil A (Rhodic Paleudalf) was low in clay content and there may be little cementing agents for the applied nutrients to adhere to. Hence they may be easily leached from the soil and higher rate of application is necessary to meet the plant nutrient requirement. This reasoning is in line with the view expressed by previous workers (Hammond *et al*., 1986; Rajan *et al*., 1986) that soil texture affects the rate and amount of dissolution of phosphate rock - which consequently affect P-uptake in soil.

The results of this investigation showed that using polybag oil palm seedlings as test crop, rock phosphates had higher availability and better crop response than super phosphate in acid soils. The behaviour of these P-sources in the two soils (Rhodic Paleudalf and Plinthic Tropudalf) is consistent with the findings of Obigbesan and Mengel (1981) and Fayiga (1998) that rock phosphates are useful fertilizers in acid soils. Obigbesan and Mengel (1981) showed that solubility of single super phosphate is much better in more neutral soils compared with acid soils. Thus, phosphate ions released from it are probably strongly adsorbed by sexquioxides and thus become less soluble than rock phosphates. This could be responsible for its low performance.

Based on the findings of this experiment, the following conclusions were drawn:

- The variations observed in the parameters taken were largely attributable to P sources, rate of P added and soil type.
- The superior response to various P-fertilizers over the control is a clear indication of the low P status of the soils and that young oil palm seedlings require P-fertilization.
- Crystalliser and Ogun rock phosphate appear to have better agronomic potential as P-source than single super phosphate in both soils when applied to oil palm seedlings.
- The earlier recommendation of 7.56 g P_2O_5 /palm for polybag oil palm seedlings in Nigeria was adequate and increasing the application rate may be wasteful.

It is therefore recommended that these rock phosphates be used in more acid soils for raising oil palm seedlings. However, the economic feasibility of the use of these local rock phosphates need to be assessed in comparison with water soluble commercial phosphate fertilizers such as single super phosphate. Finally, to validate these results, a field experiment is suggested to see the effect of these rock phosphates on the performance of oil palm.

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