Effect of Phosphorus Fertilizer Application on the Yield of Component Crops in Cassava/Maize/Egusi Mixture on Alfisols in Nigeria.

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Abstract

The scarcity and high costs of fertilizers which characterize the deregulating fertilizer market in Nigeria have engendered the search for alternative nutrient sources. Phosphate rock-fortified organo-mineral fertilizer (OMF), ground rock phosphate (GRP) and single superphosphate (SSP) were evaluated as P sources for cassava/maize/egusi mixtures at Ikere-Ekiti and Omuo-Ekiti, Ekiti State, Nigeria. P was applied at 0, 26 and 52 kg P ha^{-1} in 2001-2002 to cassava, maize and egusi mixed at 10,000, 20,000 and 20,000 plants ha^{-1} respectively. In 2002-2003, maize was in the mixture at 20,000, 25,000 and 35,555 ha^{-1} while P was applied at 0, 26 kg ha^{-1}. The residual effects of applied P were measured in 2003-2004. P application significantly ($P<0.05$) increased the yields of component crops and 26 kg P ha^{-1} was the optimum for the P sources at the two locations. The increase in maize population significantly decreased maize and egusi yields but did not affect cassava tuber yield. GRP application gave highest maize yield at all maize populations and the highest or similar egusi and cassava yields compared to SSP and OMF in 2002-2003. The P sources showed significant residual effects on the mixture crops but the yields decreased as maize population increased. GRP had the highest residual effects in the two locations. Cropping decreased soil pH, available P and exchangeable Ca and Mg but the P sources increased soil pH and available P. The direct application and residual effects on crop yields and soil nutrients show the potentials of GRP and OMF as substitutes for SSP in cassava/maize/egusi mixtures.

Keywords: Organo-mineral fertilizer, ground phosphate rock, crop yields, residual effects

Introduction

Intercropping in which a long-season crop is planted (mixed) with short-season crops that mature earlier and are harvested first characterizes the traditional food crop production systems and, so relevant to the food security equation in south-western Nigeria (Adetiloye *et al*., 2006). According to Okigbo and Greenland (1976), the advantages of intercropping are erosion control, insurance against crop failure, even spread of labour over the cropping season, minimum storage problems and production of many commodities in a limited land area and the efficient utilization of resources by plants of different heights, rooting systems and nutrient requirements. Despite these, it has the disadvantage of difficulties in the mechanization of field operations and application of improved inputs.

Cassava-based intercropping involving cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.) and egusi (*Citrullus lanatus* Thunberg; Mansf., Matsum & Nakai) grown in various combinations is common with the three crops grown at random without regard for spacing and plant population. The intercropping systems often involve low plant populations of the component crops which cause poor yields such that the adoption of the sole crop plant densities had produced the most favourable yields and intercrop advantages (Agboola, 2000). The development of early-maturing maize with low leaf densities which showed better compatibility with cassava than medium and late maturing varieties ensured the attainment of the optimum maize population needed for the agronomic interaction of the crops and increased the yields of the component crops whose combined output showed distinct advantage over the pure stands (IITA, 1979). Thus, intercropping was superior to monocropping with the land equivalent ratio showing higher efficiency (Ossom, 1986).

The use of chemical fertilizers to correct nutrient deficiencies that characterize the inherently poor fertility status of the soils is more of the exception in the traditional food crop production systems in Nigeria. Apart from the technical difficulties encountered in fertilizer application to crops grown in the predominant intercropping systems, the fertilizers are costly and beyond the reach of most smallholder farmers (Banful *et al*., 2010). Organic manures are promoted as alternative sources of nutrients for maintaining soil fertility in low-input crop production systems. Farmers routinely apply animal dungs (wastes) to replace the soil nutrients depleted by continuous cropping in the sub-humid and semi-arid savannah zones northern Nigeria where large ruminant livestock population exists. However, the low and variable nutrient contents, slow nutrient release and the high water contents mean that large amounts of manures must be applied to meet the optimum nutrient requirements of crops. The ensuing problems of non-availability and waiting time for manures to decompose and release nutrients make the integrated use of chemical fertilizer a sound soil fertility management option. Kondapa *et al*. (2009) had noted that the separate application of chemical fertilizer and manure would not sustain productivity whereas the efficiency of manures is enhanced when applied with chemical fertilizers. The agro-economic benefits catalyzed the development, production and promotion of organo-mineral fertilizers (Adeoye, 2005).

Some naturally-occurring minerals are often proposed as alternative sources of nutrients. One of these is rock phosphate (RP) mineral which occurs in extensive geologic formations in Nigeria and some West African countries and whose effectiveness as P source from direct application and residual effects compare to conventional water-soluble P fertilizers sources in terms of crop yield and uptake (Adediran and Sobulo, 1998; Adediran *et al*., 1998). Thus, the use of RP as a P source for crop production has been advocated (Mcllellan and Van Kauwenbergh, 1990) because it is indigenous, requires minimum energy to process to utilizable forms and represents a cheap P fertilizer compared to single superphosphate (SSP) and NPK compound fertilizers whose optimal use is hampered by high costs and inadequate supply due to inefficient distribution systems as products of unstable government policy on fertilizer marketing (Chien and Menon, 1995; Banful *et al*., 2010).

There is the need to identify materials with potential as alternatives to expensive manufactured water-soluble P fertilizers. The prospects of organo-mineral fertilizers and RP as sources of P have been shown in several trials involving sole crops. This study was carried out to evaluate the effectiveness of ground RP and RP-fortified organo-mineral fertilizer (OMF) on the yield of component crops in cassava/maize/egusi mixture in two agro-ecological zones of Ekiti State, Nigeria.

Materials and Methods

Surface soil samples (0-20 cm) were collected randomly from two farmer's plots at Ikere-Ekiti (7º 27′ 38.6″ N, 5º 18′ 44.2″ E; 338.3 m) in the dry upland forest zone and Omuo-Ekiti (5º 44′ 52.1″ E, 7º 44′ 51.0″ N; 533.5 m) in the derived savannah zone. The soil samples were bulked to make a composite for each location, air dried, crushed and sieved (< 2 mm). The soils were analyzed for pH (in 1:1 soil/water suspension ratio), the particle size distribution, total N, organic carbon, available P and exchangeable cations (K, Ca, Mg and Na) and exchangeable acidity using methods described in Udo *et al*. (2009).

In 2001-2004, cassava (TMS 30572), maize SUWAN 2 SR and egusi (Bara) were intercropped in the two locations on heaps made at 1×1 m spacing. In the first year (2001/2002), each sub-plot was 10×5 m to accommodate 50 heaps. The cassava stems were planted at the crest to attain 10,000 plants ha^{-1} while egusi and maize seeds were sown at 1×1 m alternately half-way on the side of the heap and seedlings thinned to 2 to attain 20,000 plants ha^{-1} population. In 2002/2003 and 2003/2004, each plot was 8×5 m (40 heaps) and the maize was varied at 1×1, 0.90×0.9 and 0.75×0.75 m spacing to attain 20,000, 25,000 and 35,555 plants ha^{-1} population. The treatments were P sources: SSP (18% P_2O_5), GRP (21% P_2O_5) and phosphate rock-fortified organo-mineral fertilizer (OMF, 26% P_2O_5) applied at 0, 26 and 52 kg P ha^{-1} in 2001/2002 and at 0 and 26 kg P ha^{-1} in 2002/2003 and none in 2003/2004 to measure the residual effects. The treatments were laid out in a randomized complete block design with four replications. The P fertilizers were broadcast and slightly worked into the surface soil one week before planting while 100 kg N ha^{-1} (as urea) and 60 kg K_2O ha^{-1} as muriate of potash (KCl) were mixed and applied at 2-3 WAP. The plots were weeded manually by hoeing at 3-4 WAP and subsequently as necessary. The maize cobs were harvested dry at 12 WAP, dehusked and shelled. The grains were weighed and adjusted for moisture content. Egusi fruits were harvested at 12 WAP when the vines had dried, collected in heaps, broken with heavy sticks and allowed to rot for 3-4 days. The seeds were extracted, washed, air-dried and weighed. Cassava tubers were uprooted at 48 WAP and weighed. Top soil (0-15 cm) samples were taken randomly from each plot after harvesting the crops, bulked and taken to the laboratory for analysis.

All the yield data were subjected to analysis of variance (ANOVA) using Statistical Analysis System Version 6.0 for PC (SAS, 1992). The treatments means were separated using least significant difference (LSD) at 5% probability level.

Results and Discussion

Table 1 shows the characteristics of the soils from the farmers' plots used for the study. At Ikere-Ekiti in the upland forest agro-ecological zone, the soil was a slightly acid sandy loam. The organic matter and total N contents are low but high in available P and exchangeable K based on critical levels established for maize in Nigeria at 25.0, 2.5 g kg^{-1}, 10 mg kg^{-1} and 0.20 cmol kg^{-1} respectively (Adepetu *et al*., 2014). The soil from the derived savannah at Omuo-Ekiti was slightly acid loamy sand with low organic matter, total N, available P and exchangeable K. The coarse texture of the soils is typical of Alfisols developed on parent materials from acid crystalline granitic rocks of the pre-Cambrian basement complex (Ogunkunle, 2009). The higher fertility at Ikere-Ekiti is expected because the forest vegetation produces greater amount of biomass and litter whose decomposition in the soil leads to larger amounts of soil organic matter which has profound influences on nutrient contents and other soil characteristics (Esu, 2010).

The effects of P sources and rates on maize grain yield, egusi seed yield and cassava fresh tuber yield at Ikere-Ekiti and Omuo-Ekiti in 2001/2002 are shown in Table 2. The application of P increased the grain yield of maize significantly ($P<0.05$) in the two locations. The mean yields at 26 and 52 kg P ha^{-1} differed significantly from the control but were similar being 95 and 108% and 197 and 220% yield increases at Ikere-Ekiti and Omuo-Ekiti respectively. The response at Ikere-Ekiti is not expected since the available P is high while the response at Omuo-Ekiti reflected the low available P status. The response of maize to applied P in some soils which test high in available P has been of major concern in raising maize productivity in soils formed on parent materials developed from granitic basement complex rocks in the derived savannah of south-west Nigeria (Ayodele and Agboola, 1985). The optimum rate at 26 kg P ha^{-1} agrees with Akinrinde *et al*. (2002) and the recommendations for sole maize and in mixtures under medium P fertility class in the south-west agro-ecological zone of Nigeria (FFD, 2002). The order of performance was SSP>OMF>GRP in the two locations but the P sources were not significantly different.

Table 1: Characteristics of the two selected soils used for the studies

Properties	Location	
	Ikere-Ekiti	Omuo-Ekiti
pH H_2O (1:1)	5.60	5.90
Organic matter (g kg^{-1})	17.36	21.05
Total N (g kg^{-1})	0.83	0.64
Available P (mg kg^{-1})	23.16	7.53
Exchangeable cations (c mol. kg^{-1})		
Ca	3.97	2.36
Mg	1.79	1.64
K	0.40	0.17
Na	0.11	0.09
Exch. Acidity	0.21	0.12
ECEC	6.48	4.38
Particle size (g kg^{-1})		
Sand	784.0	804.0
Silt	140.0	120.0
Clay	76.0	76.0
Textural class	Sandy loam	Loamy sand

The P sources gave the highest yields at 52 kg P ha^{-1} which did not differ from 26 kg P ha^{-1}. The highest mean egusi seed yield was obtained at 52 kg P ha^{-1} which did not differ from 26 kg P ha^{-1}. The yields increased over the control by 266 and 292% at Ikere-Ekiti and 304 and 353% at Omuo-Ekiti from 26 and 52 kg P ha^{-1} application respectively. The optimum rate is slightly higher than 20 kg P ha^{-1} suggested as the recommendation for sole egusi production in south-west Nigeria (Ayodele *et al*., 2006). The performance of the P sources was in the order SSP>GRP>OMF and OMF>GRP>SSP at Ikere-Ekiti and Omuo-Ekiti respectively but the yields did not differ significantly. The highest yields were obtained at 52 kg P ha^{-1} except SSP at 26 kg P ha^{-1} in Ikere-Ekiti but the rates were not significantly different. Cassava fresh tuber yield increased significantly with P application and 26 kg P ha^{-1} gave highest value at Ikere-Ekiti while at Omuo-Ekiti, the yields at 26 and 52 kg P ha^{-1} were the same. This optimum rate is equivalent to the 60 kg P_2O_5 ha^{-1} recommended for cultivation of cassava mixture in soils which contain medium available P (FFD, 2002). The order of performance was SSP>GRP>OMF at Ikere-Ekiti and GRP>SSP>OMF at Omuo-Ekiti but the sources were not significantly different.

The P sources produced significantly ($P<0.05$) higher yields of the component crops than the control treatments and the lack of significant differences among them indicates similar agronomic efficiencies as observed by Akinrinde *et al.* (2002) and Oluleye *et al*. (2008).

Table 2: Effects of P sources and rates on grain yield of maize, egusi and cassava in cassava/maize/egusi mixture in 2001/2002 season

	Ikere-Ekiti				Omuo-Ekiti			
	P sources				P sources			
P (kg ha^{-1})	SSP	OMF	GRP	Mean	SSP	OMF	GRP	Mean
a) Maize grain yield (t ha^{-1})								
0	1.82	1.82	1.82	1.82	1.09	1.09	1.09	1.09
26	3.82	3.46	3.36	3.55	3.27	3.18	3.27	3.24
52	4.03	3.91	3.46	3.79	3.55	3.46	3.46	3.49
SE	0.58	0.52	0.53		0.78	0.75	0.76	
b) Egusi seed yield (t ha^{-1})								
0	0.075	0.075	0.075	0.075	0.069	0.069	0.069	0.069
26	0.288	0.275	0.263	0.275	0.250	0.325	0.263	0.279
52	0.281	0.313	0.288	0.294	0.300	0.350	0.288	0.313
SE	0.07	0.07	0.07		0.07	0.09	0.07	
c) Cassava fresh tuber yield (t ha^{-1})								
0	11.29	11.29	11.29	11.29	11.57	11.57	11.57	11.57
26	15.72	13.14	13.86	14.24	13.43	12.29	13.29	13.00
52	14.57	12.86	13.29	13.57	13.57	11.72	13.86	13.05
SE	1.33	0.58	0.78		0.64	0.22	0.69	

The effects of increasing maize population and P sources applied at 26 kg P ha^{-1} and compared to the control on the yield of component crops in cassava/maize/egusi mixture are shown in Table 3. The mean maize grain yield decreased by 15.1 and 26.1% at Ikere-Ekiti and 35.1 and 48.9% at Omuo-Ekiti as maize population in the mixture increased to 25,000 and 35,555 plants ha^{-1} respectively. Akintoye *et al*. (1997) had observed that maize yield was optimum at the lower population in different ecological zones of West Africa because the higher plant density increased competition for nutrients which decreased yields. Maize yields of the P sources were significantly higher than the control. GRP was better than SSP and OMF which were similar at 20,000 maize plant population but the sources did not differ with the higher maize populations at Ikere-Ekiti. At Omuo Ekiti, the performance was in the order GRP>OMF>SSP for the maize populations but GRP and OMF gave the same yield which differed significantly from SSP at 35,555 maize population. Egusi seed yield decreased by 25.0 and 47.1% at Ikere-Ekiti and 26.1 and 52.7% at Omuo-Ekiti as the maize population increased to 25,000 and 35,555 plants ha^{-1} respectively. The P sources gave significantly higher seed yields compared to the control and the order of performance was GRP>SSP>OMF for all plant populations at Ikere-Ekiti. The sources gave similar yields for 20,000 population but the order of performance was OMF>GRP>SSP and GRP>SSP>OMF for 25,000 and 35,000 maize population respectively at Omuo-Ekiti. The effect of maize population was not significant on cassava tuber yield but the increase in maize population to 35,555 plants ha^{-1} enhanced yield by 3.0 and 7.8% at Ikere-Ekiti and Omuo-Ekiti respectively. The P sources increased tuber yield but SSP and GRP gave highest yields for all the maize populations at

Ikere-Ekiti whereas GRP was the best and followed by OMF at Omuo-Ekiti.

Table 3: Effects of maize population and P sources on the yields of component crops in cassava/maize/egusi mixture in 2002-2003 season

Maize population ha^{-1}	P sources	Maize grain yield t ha^{-1}	Egusi seed yield t ha^{-1}	Cassava tuber yield t ha^{-1}
Ikere-Ekiti				
20,000	0	1.67	0.067	9.41
	SSP	3.33	0.717	12.47
	OMF	3.25	0.558	10.35
	GRP	3.42	0.783	12.24
25,000	0	1.67	0.058	9.41
	SSP	2.75	0.550	12.71
	OMF	2.67	0.367	10.35
	GRP	2.83	0.617	12.24
35,555	0	1.46	0.050	9.53
	SSP	2.42	0.383	12.82
	OMF	2.38	0.258	10.59
	GRP	2.39	0.433	12.94
SE		0.31	0.13	0.79
Omuo-Ekiti				
20,000	0	1.74	0.064	10.12
	SSP	3.56	0.655	10.82
	OMF	3.39	0.664	12.00
	GRP	3.65	0.658	13.18
25,000	0	1.44	0.046	10.12
	SSP	2.09	0.436	10.82
	OMF	2.04	0.536	12.00
	GRP	2.35	0.491	13.18
35,555	0	1.35	0.027	10.12
	SSP	1.65	0.327	11.18
	OMF	1.64	0.273	12.00
	GRP	1.66	0.336	13.18
SE		0.24	0.11	0.66

The residual effects of P sources on the yields of component crops in cassava/maize/egusi mixture are shown in Table 4. The P sources increased the yields of maize, egusi and cassava significantly compared to the control. The yields of maize and egusi were higher for the P sources at maize population of 20,000 plants ha^{-1} and decreased as population increased but the sources did not differ significantly. However, the cassava yield did not differ at the various maize populations and at each population the P sources were not significantly different. GRP gave the highest residual effects for maize, egusi and cassava at Ikere-Ekiti and Omuo-Ekiti

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Table 4: Residual effects of P application on the yields of component crops in cassava/maize/egusi mixture in 2003/2004

Maize population ha^{-1}	P sources	Maize grain yield t ha^{-1}	Egusi seed yield t ha^{-1}	Cassava fresh tuber yield t ha^{-1}
Ikere-Ekiti				
20,000	0	1.44	0.033	9.38
	SSP	3.74	0.683	12.25
	OMF	3.22	0.500	10.25
	GRP	3.65	0.800	12.13
25,000	0	1.30	0.025	9.25
	SSP	2.74	0.492	12.50
	OMF	2.78	0.392	10.13
	GRP	2.96	0.700	12.00
35,555	0	1.39	0.022	9.38
	SSP	2.44	0.267	12.50
	OMF	2.52	0.283	10.50
	GRP	2.61	0.517	12.75
SE		0.40	0.14	0.76
Omuo-Ekiti				
20,000	0	1.50	0.036	10.82
	SSP	3.70	0.618	11.65
	OMF	4.00	0.609	12.94
	GRP	4.20	0.782	14.12
25,000	0	1.40	0.027	10.82
	SSP	2.00	0.491	11.53
	OMF	2.40	0.527	12.82
	GRP	2.90	0.618	14.12
35,555	0	1.30	0.018	11.29
	SSP	1.75	0.391	12.00
	OMF	1.90	0.327	12.94
	GRP	2.00	0.418	14.12
SE		0.37	0.13	0.69

The effects of 3-year cropping of cassava/maize/egusi mixture and application of P sources on soil pH are shown in Table 5. The soil pH increased in all the treatments relative to the status before cropping and the control. After the 2001-2002 cropping season, SSP applied at 26 kg P ha^{-1} increased the soil pH to neutral and was significantly higher than GRP applied at 52 kg P ha^{-1} in Ikere-Ekiti while the control gave the highest value which did not differ from GRP and OMF applied at 26 and 52 kg P ha^{-1} respectively at Omuo-Ekiti. After 2002-2003 cropping, GRP gave the highest values which did not differ from the control at Ikere-Ekiti and the other treatments at Omuo-Ekiti. The pH did not differ among the treatments after the 2003/2004 cropping. The trend observed is a decrease in soil pH over the period of cropping which may be due to organic exudates from roots leading to acidification of the soil.

Table 5: Effects of P sources and three-year cropping of cassava/maize/egusi mixture on soil pH

P Sources	P rates kg P ha^{-1}	Years of cropping 2001/02	2002/03	2003/04
Ikere-Ekiti				
Control	0	6.56	6.72	6.42
Ground phosphate rock	26	6.71	6.80	6.34
	52	6.86	-	-
Organo-mineral fertilizer	26	6.77	6.32	6.40
	52	6.58	-	-
Single super phosphate	26	7.20	6.32	6.42
	52	6.70	-	-
LSD (0.05)		0.16	0.42	0.45
Omuo-Ekiti				
Control	0	6.83	6.24	6.40
Ground phosphate rock	26	6.70	6.54	6.32
	52	6.50	-	-
Organo - mineral fertilizer	26	6.50	6.51	6.32
	52	6.74	-	-
Single super phosphate	26	6.58	6.15	6.49
	52	6.14	-	-
LSD (0.05)		0.48	0.45	0.29

Exchangeable Ca showed substantial reduction in the soils with cropping despite the application of the P sources (Table 6). The Ca decreased from the pre-cropping value by 88.4-91.9% with the highest reduction due to the application of SSP after the 2001/2002 cropping at Ikere-Ekiti where further cropping reduced soil Ca to 0.16 cmol kg^{-1} soil from the application of 26 kg P ha^{-1} as GPR. Similar reduction was observed at Omuo-Ekiti from 2.36 to 0.33-0.42 cmol kg^{-1} soil after 2002/2003 season and 0.24-0.27 cmol kg^{-1} after 2003/2004

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Table 6: Effect of cropping and application of P sources on exchangeable Ca

P Sources	P rate (kg ha^{-1})	Exchangeable Ca (cmol kg^{-1}) Years of cropping 2001/02	2002/03	2003/04
Ikere-Ekiti				
Control	0	0.38	0.14	0.42
Ground phosphate rock	26	0.37	0.16	0.32
	52	0.39	-	-
Organo-mineral fertilizer	26	0.43	0.27	0.38
	52	0.46	-	-
Single super phosphate	26	0.32	0.24	0.28
	52	0.34	-	-
LSD (0.05)		0.02	0.02	0.43
Omuo-Ekiti				
Control	0	0.47	0.31	0.21
Ground phosphate rock	26	0.42	0.28	0.25
	52	0.36	-	-
Organo-mineral fertilizer	26	0.40	0.19	0.27
	52	0.42	-	-
Single super phosphate	26	0.33	0.22	0.24
	52	0.45	-	-
LSD (0.05)		0.03	0.04	0.08

Exchangeable Mg in the soil decreased drastically after cropping compared to the initial content (Table 7). At Ikere-Ekiti, exchangeable Mg was 0.08 cmol kg^{-1} in the control after 2001/2002 cropping season and slightly increased thereafter. The exchangeable Mg reduced in plots which received the P sources to the least (0.09 cmol kg^{-1}) from 52 kg P ha^{-1} as SSP and highest value (0.23 cmol kg^{-1}) from 26 kg P ha^{-1} as OMF after 2001/2002. The pattern was similar at Omuo-Ekiti as exchangeable Mg reduced with cropping compared to the initial value. The application of 26 kg P ha^{-1} as OMF gave the highest value (0.14 cmol kg^{-1}) after 2001/2002 cropping which increased with further application of P in 2002/2003 and the residual cropping in 2003/2004.

Table 7: Soil Mg as affected by the application of P sources during three years of cropping

P sources	P rates ($kg\ ha^{-1}$)	Exchangeable Mg (c mol kg^{-1}) Years of cropping		
		2001/02	2002/03	2003/04
Ikere-Ekiti				
Control	0	0.08	0.12	0.12
Ground phosphate rock	26	0.12	0.13	0.10
	52	0.11	-	-
Organo-mineral fertilizer	26	0.23	0.15	0.14
	52	0.11	-	-
Single super phosphate	26	0.09	0.14	0.11
	52	0.13	-	-
LSD (0.05)		0.03	0.03	0.02
Omuo-Ekiti				
Control	0	0.07	0.10	0.06
Ground phosphate rock	26	0.12	0.10	0.16
	52	0.08	-	-
Organo-mineral fertilizer	26	0.14	0.15	0.17
	52	0.13	-	-
Single super phosphate	26	0.09	0.14	0.01
	52	0.08	-	-
LSD (0.05)		0.01	0.03	0.01

Available P decreased from the initial value of 23.18 mg kg^{-1} by 52.3% in the control and 15.5-39.9% with application of the P sources after 2001/2002 cropping at Ikere-Ekiti (Table 8). As P rate increased from 26 to 52 kg P ha^{-1} as GRP and OMF, the available P reduced. The available P increased in the GRP and OMF treatments after 2002/2003 cropping and in the residual were 25.46 and 24.21 mg kg^{-1} soil respectively. At Omuo-Ekiti, available P decreased with cropping in the control treatment but showed 74.3-203.8% accumulation from application of the P sources but which showed reduction as the rate increased for OMF and SSP after 2001/2002 cropping. The available P decreased for all P sources with cropping except GRP which showed accumulation in the residual. The slightly acid soil reaction (pH 5.60 and 5.90 at Ikere-Ekiti and Omuo-Ekiti respectively) would favour the dissolution of phosphate rock and mineralization of the organo-mineral fertilizer thereby increasing the available P in the soils. The increase observed in 2001/2002 and 2002/2003 followed by slight decrease in 2003/2004 could be due to variable effects of rainfall which was high during the first two croppings (1,513.9 and 1,421.1 mm respectively) and lower precipitation in the third cropping (1,298.0 mm). The relatively high levels of plant available phosphate in the soils treated with GPR, SSP and OMF represent 50-95% increase which is higher than 48%

increase observed under poorly-drained soil conditions (Diaz *et al.*, 1993).

Table 8: Soil available P as influenced by application of P sources in three years of studies

P Sources	P Rates (kg ha^{-1})	Available P (mg kg^{-1}) Years of cropping 2001/02	2002/03	2003/04
Ikere-Ekiti				
Control	0	11.06	16.49	10.29
Ground phosphate rock	26	19.58	22.12	25.46
	52	13.92	-	-
Organo-mineral fertilizer	26	18.62	21.04	24.21
	52	13.92	-	-
Single super phosphate	26	18.60	21.02	17.33
	52	19.31	-	-
LSD (0.05)		0.19	1.24	0.87
Omuo-Ekiti				
Control	0	6.20	5.34	4.08
Ground phosphate rock	26	13.81	5.14	15.15
	52	17.68	-	-
Organo-mineral fertilizer	26	17.47	8.17	6.69
	52	13.30	-	-
Single super phosphate	26	23.18	6.48	6.83
	52	13.30	-	-
LSD (0.05)		0.17	6.61	0.18

The highest available P observed in soils treated with GPR after 2003/2004 cropping confirms the observation that phosphate rock is effective in some soils especially when residual values are considered (Adediran and Sobulo, 1995, Adediran *et al.*, 1998 and Akinrinde *et al.*, 2003). Bationo *et al.* (1986) noted that the rate of P supply from phosphate rock is regarded as slow and released over a number of cropping seasons

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Conclusion

The results of this investigation show that component crops in cassava/maize/egusi mixture showed significant yield responses to the application of 26 kg P ha^{-1} from SSP, GRP and OMF in two locations- Ikere-Ekiti and Omuo-Ekiti in the dry upland forest and derived savannah of Ekiti State respectively. The direct application and residual effects of GRP and OMF on yields, soil pH and soil nutrients indicate the high potentials and can be used as substitutes for SSP to improve P fertilizer management by resources-poor farmers who produce arable crops in mixtures. The responses of the component crops to P application despite the high available P in the soil at Ikere-Ekiti are not expected and suggest the need to identify the factors that underlie the concerns for soil and fertilizer P management as a requirement for increased crop productivity

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