African Journal of Biotechnology Vol. 9(24), pp. 3563-3568, 14 June, 2010
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2010 Academic Journals

Full Length Research Paper

Evaluation of phosphorus fertilizer rates for maize and sources for cowpea on different soil types in southwestern Nigeria

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Accepted 26 April, 2010

Flexible phosphorus (P) fertilizer rate recommendation could be based on variations in soil characteristics that affect yield responses. Experiments were conducted in the Department of Agronomy, LAUTECH, on the effects of P rates on maize and P sources on cowpea in four soil types. On average, soil types and P rates influenced maize height and grain yield. Iwo and Egbeda soils supported taller plants than Itagunmodi soil. Phosphorus fertilization enhanced height and grain yield compared with no P. To optimize maize grain yield for Itagunmodi and Egbeda soils, application of 15 kg P_2O_5 ha^{-1} was sufficient while for Majeroku and Iwo, it was 30 and 75 kg P_2O_5 ha^{-1}, respectively. Cowpea grain yield and P uptake were significantly affected by soil types and P sources. Iwo and Egbeda soils supported higher grain weights and P uptake than Itagunmodi and Majeroku soils. Triple super phosphate (TSP) and no P supported higher grain weights and P uptake than rock phosphate (RP) and single super phosphate (SSP).

Key words: Cowpea, maize, phosphorus fertilization, phosphorus uptake, soil types, southwestern Nigeria.

INTRODUCTION

The subject of soil parameter variation within fields is becoming an important topic in the agronomic community. Beckett and Webster (1971) presented a review of lateral variability of soil properties. They found that up to one-half of the variance within a field might be present in as little as one square meter of land. Recognition of this variability has prompted many researchers to consider managing this variability. Carr et al. (1991) suggested, “Farming soils, not fields”. Their study was initiated to measure crop yield differences between contrasting soils within a field and to compare the economics of varying nutrient application by contrasting soils with the traditional practice of field-average application. Returns to farming soils were generally greater than when farming fields. However, the researchers noted that it was essential to establish appropriate crop yield goals, conduct accurate soil tests and utilize reliable fertilizer recommendations to generate greater returns when managing nutrients.

Smallholder farmers effectively deal with soil variation by location-specific field management based on crop performance and crop responses they observed in their fields over past years. Research that aims to improve soil fertility management and productivity of small-scale farmers has to reckon with soil variation and has to come up with flexible recommendations rather than blanket recommendations. Blanket recommendations may raise the ‘average’ productivity in an area, but yield negative responses on parts of the fields and farms and therefore, discredit extension messages. Flexible recommendation could be based on variations in soil characteristics that affect productivity and yield responses.

Phosphorus is a major limiting factor for crop production on many tropical and sub-tropical soils (Norman et al., 1995) as a result of high P fixation and/or nutrient mining in traditional land-use systems, due to poor accessibility and high cost of soluble P fertilizers for a large population of disadvantaged farmers. Phosphorus deficiency is so

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Abbreviations: SSP, Single super phosphate; **TSP,** triple super phosphate; **RP,** rock phosphate; **WAP,** weeks after planting.

Table 1. Physico-chemical properties of four soil types in southwestern Nigeria.

Properties	Itagunmodi	Egbeda	Majeroku	Iwo
Sand (g kg^{-1})	590	690	810	690
Silt (g kg^{-1})	150	190	90	130
Clay (g kg^{-1})	260	120	100	180
Soil pH-H_2O	4.5	5.3	4.9	5.3
Ex.Ca (cmol kg^{-1})	2.05	2.12	0.96	5.33
Ex. Mg (cmol kg^{-1})	0.66	0.49	0.36	0.53
Ex. K (cmol kg^{-1})	0.14	0.12	0.16	0.29
Ex. Na (cmol kg^{-1})	0.31	0.31	0.37	0.36
Ex. Fe (ppm)	149.78	156.46	138.67	184.89
Available P (µg g^{-1})	6.84	41.88	9.64	32.18
Total N (g kg^{-1})	1.11	0.52	0.37	1.16
Organic C (g kg^{-1})	10.84	5.39	3.41	12.46

acute that plant growth ceases as soon as the phosphorus stored in the seed is exhausted in some soils of the savanna zone of Western Africa (Mokwunye et al., 1986). Consequently, they require the addition of P fertilizers for producing even moderate yields. Numerous studies have shown that P fertilizers can significantly increase crop yields (Batiano et al., 1995; Kolawole et al., 2000). Crop response to P fertilizer application however depend on many factors, such as, soil characteristics, crop grown, climate, tillage systems, interactions with other nutrients, crop management and fertilizer management. It is therefore necessary to take these factors into consideration before embarking on P fertilization programme to improve fertilizer use efficiency and economic returns. In many parts of the tropics, large spatial variability in soil characteristics occurs within short distances. Under such situation, it becomes inevitable that fertilizer recommendations should be site specific.

Fertilizer recommendations in Nigeria have generally been based on research results from a limited number of sites (Orkwor and Asadu, 1998). Hence, such 'blanket recommendations' can be misleading when transferred to another ecology.

Variable P fertilizer rates and sources management can improve both fertilizer use efficiency and economic returns. The objective of the present study is to provide an insight into the appropriate P fertilizer rates for maize and the appropriate P fertilizer sources for cowpea in the dominant soil types of the moist savanna of southwestern Nigeria.

MATERIALS AND METHODS

The experiments were conducted in the Department of Agronomy, Ladoke Akintola University of Technology (LAUTECH) in Ogbomoso (Longitude 4° 10' E, Latitude 8° 10' N and altitude 213 m asl), Oyo State, Nigeria, during May - August 2006 and February - April 2007, respectively.

Experiment 1: Effects of soil types and P fertilizer rates on the performance of maize

Surface soil (0 – 15 cm depth) of four soil types (Itagunmodi (Rhodic Paleutult), Iwo (Oxic Haplustalf), Egbeda (Oxic Paleustult) and Majeroku (Abruptic Tropaqualf) series were collected from four study sites in Oyo and Osun States, Nigeria. The soils were air-dried, sieved through a 2 mm sieve and subsamples were taken for laboratory analysis. The physico-chemical characteristics of the soils are presented in Table 1. Smyth and Montgomery (1962) described in details the characteristics of these soils.

The four soil types formed the main plot treatments and six P rates: 0 (control), 15, 30, 60, 75 and 90 kg P_2O_5 ha^{-1} applied as single super phosphate (SSP) were the sub treatments. The treatments were replicated four times and arranged in completely randomised design. Fifteen kilogram soil each was weighed into 24 pots for each of the four soil types. This makes a total of 96 pots. The soil was watered to field capacity and left to equilibrate for 48 h before planting. Three seeds each of maize variety DMR-L-SR were sown in the middle of the pots and the seedlings were later thinned to one per pot at two weeks after emergence. Nitrogen fertilizer in form of urea and potassium fertilizer in the form of muriate of potash were applied to all the pots in equal amounts (120 kg N ha^{-1} that is, 2 g Urea 15 kg $soil^{-1}$) and (60 kg K_2O ha^{-1} that is, 0.8 g MOP 15 kg $soil^{-1}$) as basal dressing. The plants were watered regularly as necessary. Weeds were hand pulled as they emerged and left in the pots to decompose. Maize height was measured fortnightly starting from 2 weeks after planting (WAP) up to 10 WAP. At physiological maturity, dry grain yield was determined at 15% moisture content using moisture tester.

Experiment 2: Effects of soil types and P fertilizer sources on performance of cowpea

The four soil types used in experiment 1 above formed the main plot treatments and four P sources: no P (control), phosphate rock (RP) (90 kg P_2O_5 ha^{-1}), triple super phosphate (TSP) (30 kg P_2O_5 ha^{-1}) and single super phosphate (SSP) (30 kg P_2O_5 ha^{-1}) were the sub treatments. The treatments were replicated three times and arranged in completely randomised design. Higher rates of RP compared to SSP and TSP was used because Zapata (1986) reported that the relative P effectiveness of rock P is about 3 - 5 times less than that of artificial P-fertilizers on annual crops. Four kilogram soil each was weighed into 12 pots for each of the four soil types. This makes a total of 48 pots used for the experiment. The soil was watered to field capacity and left to equilibrate for 48 h before planting. Five seeds each of cowpea var. IT 90K – 277 – 2 were sown in each pot and the seedlings thinned to one per pot at two weeks after emergence. The fertilizers were applied in a ring form about 5 cm away from the cowpea plant at the time of thinning. The plants were watered regularly as necessary. Weeds were hand pulled as they emerged and left in the pots to decompose. Insect attack was controlled by mixing one ml of karate® 2.5 E.C. (a.i. 25 g lambda-cyhalothrin per liter) insecticide into 500 ml of water to spray the plants. This was done four times before harvesting of cowpea. At physiological maturity, the number of pods was counted, the pods were harvested and the grains removed. The shoot was cut at ground level with a sharp knife. Litter was collected as part of the shoot biomass. The leaves and petioles were separated from the stem. All plant parts were placed in separate paper bags and oven dried at 65°C for 72 h to determine their dry weights. The grains were ground to pass through a 2 mm mesh sized sieve and analysed for P concentrations. For determination of P, samples were wet–digested with a mixture of $HClO_4$- HNO_3. Phosphorus was measured calorimetrically by auto-analyzer (IITA, 1982).

All data were subjected to analysis of variance (ANOVA). Where F-values were significant, the treatment means were separated with least significant difference (LSD) test at the 5% probability level. Response curves for maize grain weight to P rates for the soil types was developed using regression analysis.

RESULTS

Experiment 1

Maize plant height

At the early stage (2 weeks after planting) (WAP) of growth, the soil types had no significant effects on height of maize plants. However, at 4 and 8 WAP, Iwo and Egbeda soils supported taller plants than Itagunmodi soil and also at 6 and 10 WAP, maize plants grown on Itagunmodi soil were significantly shorter than those grown on the other three soil types (Table 2). Throughout the sampling period, application of P resulted in taller plants than the no P situation. For most of the periods, the highest P rate (90 kg P_2O_5 ha^{-1}) supported the tallest maize plants. Interaction effect between soil types and P rates on plant height was not significant.

Maize dry grain yield

Soil types did not significantly affect maize dry grain yields, but application of P fertilizer resulted in higher grain yield than the no P situation. Apart from the control, the other P rates had similar effects on grain yield. However, interaction effects between soil types and P rates were significant (Figure 1). For example, for Itagunmodi and Egbeda soil types, application of 15 kg P_2O_5 ha^{-1} appeared sufficient in optimising grain yield while application of 30 kg P_2O_5 ha^{-1} seemed sufficient for Majeroku soil type. Whereas, for Iwo soil type, application of 75 kg P_2O_5 ha^{-1} appeared adequate in influencing optimum maize grain yield under the condition of this trial.

Experiment 2

Cowpea dry grain weight

On the average, soil types and P fertilizer sources had significant effects on dry grain weight of cowpea (Table 3). Iwo (26.4 g $plant^{-1}$) and Egbeda (22.3 g $plant^{-1}$) soil types supported significantly higher grain weights than Itagunmodi (13.6 g $plant^{-1}$) and Majeroku (12.3 g $plant^{-1}$) soil types. TSP (24.4 g $plant^{-1}$) and no P treatment (21.2 g $plant^{-1}$) supported significantly higher grain weights than RP (15.6 g $plant^{-1}$) and SSP (13.3 g $plant^{-1}$). Soil types and P sources interaction effects on grain weight was significant. For example, P application had negative effects on grain weights under Iwo and Majeroku soil types whereas, under Itagunmodi and Egbeda soil types, grain weights were higher with application of RP compared with the no P situation and application of TSP profoundly improved grain weights compared with other P sources on these soils. Application of SSP under Iwo soil type resulted in higher grain weight than those of RP and TSP. For Itagunmodi and Egbeda soil types, application of SSP influenced lower grain weights than those of RP and TSP.

Shoot dry weight

Similar to the results obtained for grain weights and soil types, P sources on the average, significantly affected shoot dry weight of cowpea. Iwo soil type supported significantly higher shoot biomass than the other soil types and TSP was superior to the other P sources in their effects on shoot dry weights (Table 3). Soil types and P sources interaction effects was significant. Application of TSP influenced higher shoot biomass production in the soils except for Egbeda soil type where RP and TSP had similar effects on shoot weights.

Phosphorus concentration and uptake in cowpea grain

On the average, soil types and P fertilizer sources had significant effects on cowpea grain P concentrations and uptake. Iwo soil type influenced significantly higher P concentration than Egbeda and Itagunmodi soil types. Egbeda soil type influenced significantly higher P concentration than Majeroku soil type. Application of TSP supported significantly the highest P concentration compared with the other P sources while the no P situation and RP treatments had similar P concentrations.

The no P situation however supported significantly higher

Table 2. Effects of soil types and P fertilizer application rates on maize plant height (cm) at Ogbomoso, southwestern Nigeria.

Soil types	Plant height (cm)						
	0	15 kg P ha^{-1}	30 kg P ha^{-1}	60 kg P ha^{-1}	75 kg P ha^{-1}	90 kg P ha^{-1}	Soil type means
2 Weeks after planting (WAP)							
Itagunmodi	6.8	7.1	9.1	9.9	9.0	10.1	8.7
Egbeda	6.5	8.5	8.1	8.4	8.4	9.8	8.3
Majeroku	6.6	6.4	8.5	8.0	7.5	9.5	7.8
Iwo	6.1	7.6	10.5	8.3	9.6	9.1	8.5
P rate means	6.5	7.4	9.1	8.6	8.6	9.6	
4 WAP							
Itagunmodi	7.9	15.9	19.6	21.8	16.9	24.3	17.7
Egbeda	14.4	19.9	21.5	24.1	23.6	30.5	22.3
Majeroku	14.3	19.1	23.5	18.4	21.9	25.3	20.4
Iwo	18.6	22.5	23.9	25.6	25.3	26.4	23.7
P rate means	13.8	19.3	22.1	22.5	21.9	26.6	
6 WAP							
Itagunmodi	17.3	31.4	41.5	46.8	35.0	57.8	38.3
Egbeda	28.6	37.5	46.8	48.6	52.3	62.9	46.1
Majeroku	29.6	40.1	56.5	47.5	47.5	64.5	47.6
Iwo	36.0	42.3	50.5	58.5	59.8	66.5	52.3
P rate means	27.9	37.8	48.8	50.3	48.6	62.9	
8 WAP							
Itagunmodi	33.0	83.5	105.8	154.5	94.8	141.5	102.2
Egbeda	59.5	91.5	119.3	123.8	153.5	147.0	115.8
Majeroku	70.5	93.3	125.8	115.0	120.3	146.0	111.8
Iwo	97.0	102.3	133.8	147.3	146.8	162.8	131.6
P rate means	65.0	92.6	121.1	135.1	128.8	149.3	
10 WAP							
Itagunmodi	75.8	132.8	154.0	173.3	118.5	161.3	135.9
Egbeda	127.0	143.8	183.8	160.3	184.5	184.0	163.9
Majeroku	164.0	166.3	183.8	168.8	170.5	169.3	168.8
Iwo	151.8	169.8	173.0	169.3	178.8	189.5	167.0
P rate means	129.6	143.1	173.6	167.9	163.1	176.0	

$LSD_{(0.05)}$: Soil types: 1.06; 2.86; 6.71; 17.57; 14.86 for 2, 4, 6, 8 and 10 WAP. $LSD+_{(0.05)}$: P rates: 1.29; 3.50; 8.22; 21.52; 18.20 for 2, 4, 6, 8 and 10 WAP.

Table 3. Effects of soil types and P fertilizer sources on cowpea dry grain and shoot weights at Ogbomoso, southwestern Nigeria 2007.

Soil types	Dry grain weights (g plant^{-1})					Dry shoot weights (g plant^{-1})				
	0P	RP	SSP	TSP	Soil type means	0P	RP	SSP	TSP	Soil type means
Iwo	46.0	18.7	24.3	16.3	26.4	53.7	58.8	21.5	145.0	69.7
Itagunmodi	9.1	14.7	7.0	23.5	13.6	11.8	5.4	43.1	58.9	29.8
Egbeda	11.6	20.7	11.4	45.6	22.3	17.5	48.0	7.2	46.2	29.7
Majeroku	17.9	8.5	10.6	12.3	12.3	30.5	16.7	9.4	33.8	22.6
P source means	21.2	15.7	13.3	24.4		28.4	32.2	20.3	71.0	

Grain weight: $LSD_{(0.05)}$ soil types (S): 8.7; $LSD_{(0.05)}$ P sources (P): 5.2; $LSD_{(0.05)}$ SxP: 10.4. Shoot weight: 19.0, 20.0 and 40.0.

P concentration than application of SSP (Table 4). Soil types and P sources interaction effects on P concentrations of cowpea grain was not significant.

Iwo and Egbeda soil types influenced higher cowpea grain P uptake than Itagunmodi and Majeroku soil types. Application of TSP and the no P situation had higher P

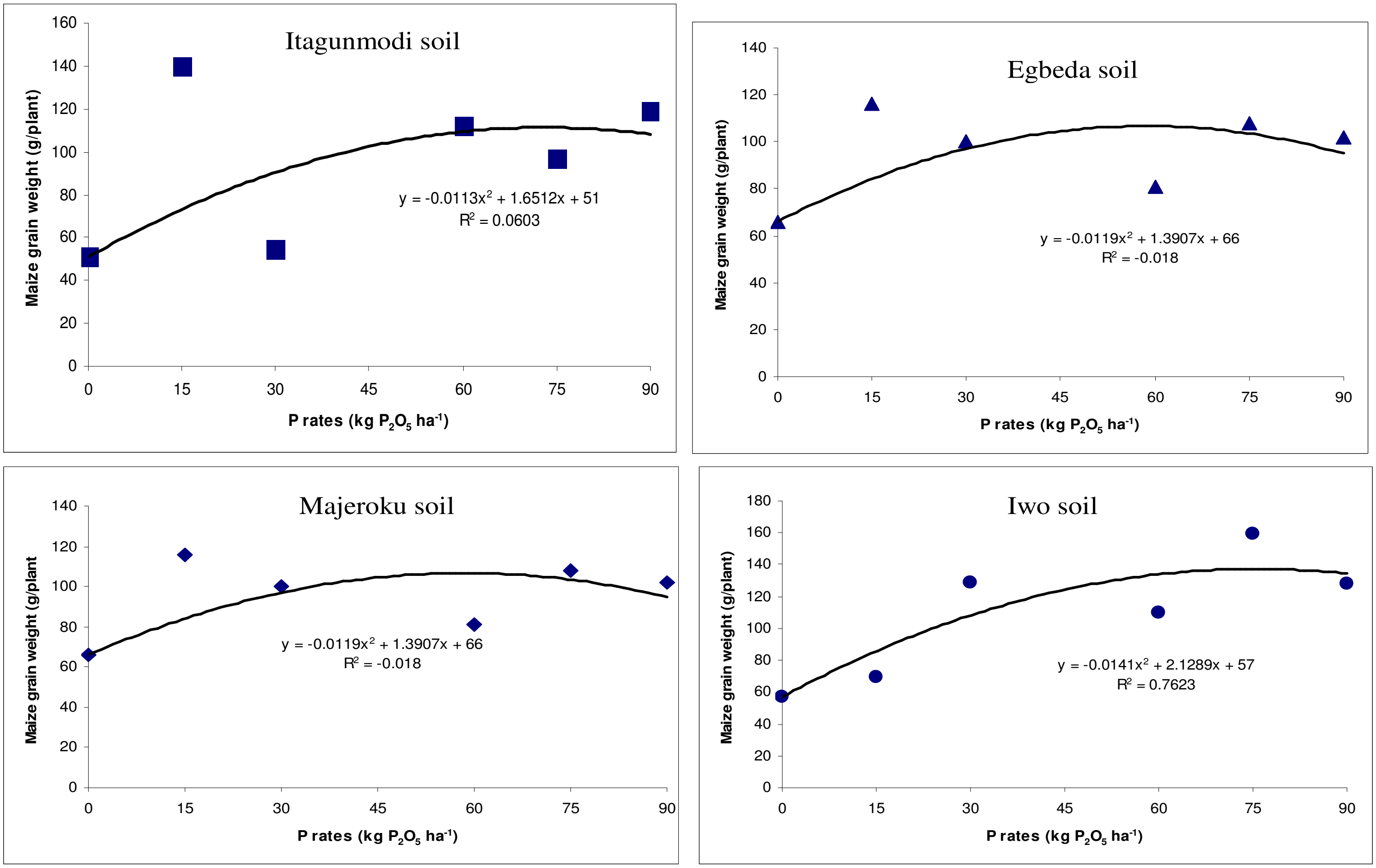

Figure 1. Response curves of maize grain yields to P rates on different soil types in southwestern Nigeria.

Table 4. Effects of soil types and P fertilizer sources on cowpea grain P concentrations and uptake at Ogbomoso, southwestern Nigeria 2007.

Soil types	P contents (%)					P uptake (mg plant^{-1})				
	0P	RP	SSP	TSP	Soil type means	0P	RP	SSP	TSP	Soil type means
Iwo	0.308	0.234	0.236	0.379	0.289	1.46	0.42	0.50	0.54	0.73
Itagunmodi	0.224	0.260	0.155	0.337	0.244	0.20	0.41	0.11	0.52	0.31
Egbeda	0.249	0.277	0.178	0.316	0.255	0.17	0.48	0.12	1.10	0.47
Majeroku	0.274	0.196	0.192	0.259	0.230	0.37	0.17	0.13	0.33	0.25
P source means	0.264	0.242	0.323	0.190		0.55	0.37	0.21	0.62	

P concentrations: $LSD_{(0.05)}$ soil types (S): 0.016; $LSD_{(0.05)}$ P sources (P): 0.057; $LSD_{(0.05)}$ SxP: ns. P uptake: 0.34, 0.14, 0.43.

uptake than application of RP and SSP but RP was superior to SSP in their effects on P uptake. Soil types and P sources interaction effects on P uptake of cowpea grain was significant. For example, on Iwo and Majeroku soil types, the no P situation had highest P uptake values while for Egbeda and Itagunmodi soil types, TSP treatment had the highest P uptake values. In all the soil types (except Iwo), P uptake values were the least with application of SSP (Table 4).

DISCUSSION

The available data indicated that the soil types used in this study varied in soil available P. Whereas soil available P was low in Itagunmodi and Majeroku soils, Egbeda and Iwo soils have high soil available P. This probably influenced the response of maize to varied P rates in the different soils. Although the trend fluctuations of maize grain weights with changes in P rates were inconsistent for the soil types (except for Iwo soil) (Figure 1), nonetheless, there were indications of the P rates at which highest grain weights were observed for the different soil types under the conditions of this experiment. For example, to optimize maize grain yield for Itagunmodi and Egbeda soil types' application of 15 kg P_2O_5 ha^{-1} appeared sufficient while for Majeroku and Iwo, it was 30 and 75 kg P_2O_5 ha^{-1}, respectively. This is an indication that different amounts of fertilizer inputs are needed to achieve similar yields on different soil types, indicating that response to applied inputs or their agronomic use efficiency is likely to be affected by soil characteristics that affect productivity and yield responses. McKenzie et al. (2003) reported that soil types affected P fertilizer response by different crops in Canada. Sanchez and Uehara (1980) stated that the soil solution P concentration required for maximum plant growth differs with soil properties related to the diffusion of P to plant roots. In the present study, Iwo soil which had high soil available P also require the highest P rate to obtain optimum maize grain. This may be due to its highest Ca and Fe contents which may make applied P unavailable for plant use through fixation. Availability of soil P is a complex phenomenon which is affected by both soil and plant properties (Barber, 1995). Even when P fertilizers are used, it may become adsorbed in various P compounds of low solubility, hence it is unavailable to the crop (Holford, 1997). The poor performances of both maize and cowpea crops in Itagunmodi soil could be due to its low available P content and high clay content which encourages caking, leading to poor root development. Javid (1999) reported that clay contents showed best correlation with P adsorbing capacities of soils. Conversely, Iwo and Egbeda soils which influenced good crop performance had lower clay contents and contained high available P contents.

It is quite interesting to note that for cowpea, fertilizer P sources that promote good performance differ for the different soil types. For example, P application had negative effects on grain weights under Iwo and Majeroku soil types whereas, under Itagunmodi and Egbeda soil types, grain weights were higher with application of RP compared with the no P situation and application of TSP profoundly improved grain weights compared with other P sources on these soils. Application of SSP under Iwo soil type resulted in higher grain weight than those of RP and TSP. For Itagunmodi and Egbeda soil types, application of SSP influenced lower grain weights than those of RP and TSP. It has been reported that phosphorus availability was differentially influenced by different P sources and different soils (Torres-Dorante et al., 2006). Van Ray and Van Diest (1979) also noted that for three P sources, super phosphate, calcium aluminium phosphate and hyperphosphate, a relationship between soil acidity and P uptake was found.

From the results of this study, it can be deduced that blanket P fertilizer recommendations can be misleading and that variable P fertilizer rates and sources management can improve both fertilizer use efficiency and economic returns. It is therefore suggested that soil characteristics that influence productivity and yield responses should be taken into consideration before embarking on P fertilizer management.

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