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Full Length Research Paper

Effects of phosphate rock application on dry matter yield and phosphorus recovery of maize and cowpea grown in sequence

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The study was conducted in a greenhouse at the Institute of Agricultural Research and Training (IAR&T) Ibadan, Nigeria to evaluate the influence of P source, rate and frequency on dry matter yield of maize and cowpea grown sequentially in three soil types. Three sources of P: Ogun phosphate rock (OPR: 20.2% P_2O_5); Crystallizer super (CS: 31.4% P_2O_5) and Single super phosphate (SSP: 18.0% P_2O_5); Four rates (0, 20, 40 and 60 kg/ha P_2O_5) and Two frequencies (regular and alternate application) were studied on three soil types (Ilora-Udipsamment; Ibadan- Arenic Haplustalf and Epe - Aquic Arenic Haplustalf soils). The experiment was laid out in a split-split plot arrangement, using completely randomized design. Phosphate application significantly enhanced dry matter yields of maize and cowpea. Single super phosphate (SSP) gave a higher total biomass than the phosphate rocks (PR). On Ilora soil with the regular application frequency in the first cropping, maize total biomass was increased by SSP from 4.23 g/plant to 8.20, 9.25 and 9.72 with 20, 40 and 60 kgP/ha while it was increased to 6.78, 6.26 and 6.34 g with OPR but to 6.88, 7.60 and 7.15 g with CS. Cowpea yields were increased from 2.12 g/plant to 3.28, 4.04 and 3.36 g with SSP; to 3.34, 3.27 and 2.61 with CS and to 2.59, 2.78 and 2.39 g with OPR. On Ibadan soil, maize biomass yield ranged between 6.13 and 6.37 g with OPR; between 7.22 and 7.56 with CS and between 6.80 and 10.45 g with SSP. Cowpea yields were between 6.54 and 7.81 with OPR; between 5.70 and 6.80 with CS and were between 6.59 and 8.94 with SSP. Both Ogun and crystallizer super PRs gave comparable dry matter yields of maize and cowpea as single super phosphate. Best growth performance was observed with application of 60 kg/ha in all the soils. Significant treatment effects in shoot, root and total dry matter yields of maize and cowpea were obtained with 60 kg P/ha. Alternating maize with cowpea gave a higher total plant biomass than continuous maize. Regular frequency of application was superior to alternate frequency of application. Cumulative apparent P recovery of maize and cowpea at the end of final cropping was maximal with 20 kgP/ ha SSP in the three soils. It had 75, 80 and 70% recoveries for Ilora, Ibadan and Epe soils respectively.

Key words: Phosphorus sources, recovery, corn, dry matter yield.

INTRODUCTION

Phosphorus is one of the most limiting plant nutrients in crop production. Its deficiency sharply decreases crop yield. This is particularly true in tropical and subtropical regions. These soils are low in apatite - bearing rock, thus giving rise to soils low in native P (Enwezor et al., 1989). In Nigeria, low P availability is well established (Adepetu, 1983). Significant responses to P application through water -soluble sources have been observed for some arable crops (Adetunji, 1994, 1997). Super

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phosphate is the most prominent phosphorus fertilizer source used on agricultural soils in Nigeria. Most commonly used are single super phosphate (SSP) and triple super phosphate (TSP).

A high cost of the soluble phosphate fertilizers has resulted in considerable interest in the utilization of the phosphate rocks (Akande et al., 1998; Akintokun et al., 2003, Akande et al., 2008b). However, concerns are often expressed on the effective-ness of PRs for direct application to soil. Phosphate rock deposits exist in many parts of Nigeria and attempts are being made to utilize the indigenous phosphate rocks as an alternative source of phosphorus for direct application. Earlier efforts (Sale and Mokwunye, 1993, Akande et al., 2000, Alloush and Clark, 2001) have indicated that phosphate rocks in many African countries are poor in P content and are of low chemical reactivity. Direct application of phosphate rock to soil as a possible alternative to the more expensive soluble phosphate fertilizers in tropical cropping system has received considerable attention in recent years (Rajan et al., 1994; McLay et al., 2000; Sekhar and Aery, 2001; Adetunji et al., 2005; Odiete et al., 2005; Taalab and Badr, 2007). Interest in the use of phosphate rocks as alternative P sources has been increasing due to their relative lower costs, coupled with their utilization potentials, with or without amendments, when not really suitable for manufacturing phosphoric acid and other soluble fertilizers such as triple (TSP) or single super phosphate (SSP). The PRs are natural minerals requiring minimum processing and are environmentally - friendly (Schultz, 1992). It has been reported that they could be more efficient than the soluble fertilizers in terms of recovery of phosphate by plants, even for short duration crops, especially in soils where soluble P is readily leached (Yeates and Clarke, 1993) and possibly for long-term crops in other soils (Rajan et al., 1994). Maize is a popular cereal in the tropics. It is consumed to supply energy. It is also utilized industrially to extract starch. It is more commonly used as an energy supplier in the livestock feed factories.

Cowpea is a cheap source of protein in the diet of many people in the tropics. It is usually consumed to balance the meal when a cereal or a root and tuber crop is consumed. The purpose of the study was to evaluate the influence of P source, rate and frequency of application on dry matter yields and P recovery of maize and cowpea grown sequentially.

MATERIALS and METHODS

The study was conducted in the greenhouse at the Institute of Agricultural Research and Training (I.A.R and T), Moor Plantation, Ibadan (lat.7° 22½'N and long.3° 50½'E). Surface (0 - 15 cm depth) soils were collected from three locations and used for the study. The three locations are: Epe, Ilora and Ibadan in South western Nigeria. They are classified as Udipsamment, Arenic Haplustalf and Aquic Arenic Haplustalf respectively. Three kilogrammes (3 kg) of air-dried, sieved soil was weighed into black polyethylene bags. Each bag was supplied with drainage holes and saucer for watering. Treatments consisted of three sources of P: Ogun phosphate rock (OPR), Crystallizer super (CS) and Single super phosphate (SSP); Ogun phosphate rock contained 20.2% P_2O_5, Crystallizer super was a homogenous blend of Sokoto rock phosphate and magnesite that contained 31.4% P_2O_5 and 0.1% MgO while the SSP contained 18% P_2O_5. The two sources of phosphate rock are low in re-activities. Four rates (0, 20, 40 and 60 kg P/ha) and two fertilizer application frequencies (Alternate and Regular) were studied. With the alternate frequency, only the 1st and the 3rd croppings were fertilized while all the four croppings were fertilized with the regular frequency. Three soil types were used for the study.

The experimental set-up was a split-split plot design replicated three times and arranged in a completely randomized design. Soil type was the main plot factor. Frequency of fertilizer application was the subplot factor while rate of application was the sub-subplot factor. The fertilizers were thoroughly mixed with soil and water was supplied to field capacity. It was applied at 7 days after planting. The bags were allowed to stabilize for seven days before planting. Each bag received a basal dressing of Urea and Muriate of potash at the rate 100 kg N and 50kg K ha $^{-1}$ respectively to the following cropping sequences:

1. Continuous maize for 4 cycles.
2. Maize and Cowpea in alternate croppings.

Four seeds of maize (*Zea mays* L: variety, DMR – ESR – Y) and cowpea (*Vigna unguiculata* (L) Walp: variety, Ife brown) were sown sequentially in each bag and thinned to two plants, at one week after planting. The soils were regularly moistened with water. Each cropping cycle lasted for four weeks. Total plants were uprooted and the shoots separated from the roots from the soil mark level. Each portion was dried in the oven at 65°C to a constant weight and cooled and the dry weights determined. Soil samples were taken per pot for post -cropping chemical analysis.

Laboratory analysis

Soil analysis: Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962) using sodium hexametaphosphate as the dispersing agent. Soil pH was determined in distilled water at soil to water ratio 1:1 using glass electrode on an EIL 7020 pH meter. Exchangeable bases (K, Na, Ca and Mg) were determined by extraction with neutral normal NH_4OAc at soil: solution ratio 1: 10.

Potassium, calcium, and sodium in the extract were read by flame photometry while magnesium was determined by atomic absorption spectrophotometer. Soil exchangeable acidity was determined by titration of normal KCl extracted acidity against 0.05 N sodium hydroxide to a pink end point using phenolphthalein as indicator (Mclean, 1982). Cation exchange capacity was obtained by summation of exchangeable cations (K, Na, Ca, and Mg) and exchange acidity. Available P was determined using 0.03 N NH_4F in 0.025 N HCl as extractant (Bray and Kurtz, 1945). Organic carbon was determined by wet oxidation (Walkley and Black, 1934).

Plant analysis: Chemical analysis of tissue samples from green house experiment was carried out in the laboratory. The tissue samples were dried in an oven at 65°C until a constant weight was obtained. The samples were ground in a Wiley mill of Arthur Thomas of USA equipped with stainless steel grinding chamber and passed through a 0.5 mm sieve. The tissue sample was ashed in a muffle furnace at a temperature of 450°C. The nutrients in the ash were extracted by washing with 0.1 N HCl. Phosphorus was determined colorimetrically by the vanadomolybdate (yellow) method (Kitson and Mellon, 1994). Potassium, Ca and Na were determined by flame photometry while Mg was determined by atomic absorption spectrophotometer.

Table 1. Pre-cropping soil properties.

Property	Location		
	Epe	Ilora	Ibadan
pH (H_2O)	5.00	6.00	6.10
OM (%)	1.00	2.02	1.82
Total N (%)	0.08	0.14	0.10
Avail. P (mg kg^{-1})	1.92	4.71	5.89
K (cmol kg^{-1})	0.15	0.25	0.34
Ca “	0.50	2.30	3.20
Mg “	0.30	0.84	0.88
Na “	0.20	0.10	0.14
H^+ “	1.40	0.10	0.19
CEC “	2.55	3.59	4.82
Sand (%)	93.20	76.40	87.00
Silt (%)	1.60	18.80	8.80
Clay (%)	5.20	4.80	4.20
Textural class	Sandy loam	Loamy sand	Loamy sand

Apparent P recovery: The apparent P recovery was calculated as follows: Apparent

$$\text{P Recovery} = \frac{P_R - P_O}{P_A} \times 100$$

Where, P_R = P uptake from the P treated pot
P_O = P uptake from the control pot
P_A = Amount of P applied.

Statistics

Data collected were subjected to analysis of variance, using Mixed Model procedure of statistical analysis system (SAS, 1994). Means were separated by Duncan Multiple Range Test.

RESULTS and DISCUSSION

Characteristics of experimental soils

The Ilora and Ibadan soils, classified as Arenic Haplustalf and Aquic Arenic Haplustalf respectively were loamy sand in texture while the Epe soil, classified as Udipsamment was sandy loam. The pH was slightly acidic in Ilora and Ibadan soils while Epe soil was moderately acidic (Table 1). Exchangeable bases, total N and available P were low, implying that the soils were low in fertility.

Effects of phosphorus on root biomass

Fertilizer application frequency significantly influenced root biomass (DM basis) of maize in all soils throughout the four croppings except in the first cropping in all soils and in the third cropping in Epe soil (Table 2). Sources of P were also significantly different in all the three soils in the first cropping. In the second cropping, they were significantly different only on Ibadan soil. They were all significantly different in the third and the fourth croppings except on Ilora soil in the fourth cropping. SSP fertilizer application gave significantly higher root DM than either OPR or CS applications or the control treatment. P application rate had significant effects on Ilora and Ibadan soils only in third and first croppings, respectively (Table 2).

Cowpea root biomass obtained in alternate and regular frequencies of application were similar. The trend in Ibadan and Epe soils were almost similar to that of Ilora soil except that the reverse was the trend observed in cowpea yield (Table 2).In the fourth cropping, maize and cowpea yields were generally low in Epe soil, compared to Ilora and Ibadan soils.

Effects of phosphorus on shoot biomass

Shoot dry matter of maize and cowpea grown in no P treatments were significantly lower than shoot dry matter recorded in P-treated plants in the three soils. SSP application gave significantly higher shoot DM than both phosphate rock treatments in all the soils. In Ilora soil, with alternate fertilizer application, the highest shoot DM for maize was 6.34 g during the 1^{st} cropping at application rate of 60 kg P/ha (Table 3). During the second cropping, the highest value obtained for maize was 3.65 g with 20 kg P/ha SSP and 3.02 g with 60 kg P/ha SSP for cowpea. Maize yield decreased across the treatments. In the third cropping, when P was re-applied in the alternate frequency, pots where maize had been planted three times in a sequence had the highest DM

Table 2. Effect of frequency, sources and rates of application on root biomass (g DM) of maize and cowpea.

Soil	Treatment Frequency	1st cropping	2nd cropping		3rd cropping		4th cropping	
		Maize (m)	Maize (m^2)	Cowpea (mc)	Maize (m^3)	Maize (mcm)	Maize (m^4)	Cowpea (mcmc)
Ilora	2	1.8a	0.7a	0.5a	1.0a	1.2a	1.1a	0.6a
	4	2.3a	0.5b	0.5a	0.8b	0.9b	0.8b	0.7a
Ibadan	2	2.1a	0.5b	0.4a	0.7b	0.8b	0.9b	0.8a
	4	2.6a	1.0a	0.5a	1.5a	1.7a	1.2a	0.7a
Epe	2	0.4a	0.3b	0.3a	0.9a	0.6a	1.0b	0.5a
	4	0.6a	0.7a	0.4a	0.9a	0.5a	1.5a	0.6a
			P Source					
Ilora	Control	1.4b	0.5a	0.4a	0.7b	0.8b	1.0a	0.4b
	SSP	2.5a	0.7a	0.5a	1.0a	1.3a	1.0a	0.8a
	OPR	1.9ab	0.5a	0.6a	0.9b	1.0ab	0.9a	0.6ab
	CS	2.0ab	0.6a	0.5a	0.8b	1.0ab	1.0a	0.6ab
Ibadan	Control	1.4c	0.5b	0.4a	1.0ab	1.1ab	0.9b	0.5ab
	SSP	2.7a	0.9a	0.6a	1.2a	1.4a	1.1a	0.8a
	OPR	2.2b	0.8a	0.5a	1.2a	1.2a	1.2a	0.7a
	CS	2.3ab	0.7ab	0.6a	1.1a	1.2a	1.0ab	0.7a
Epe	Control	0.3b	0.4a	0.3a	0.6b	0.7b	1.2ab	0.4a
	SSP	0.7a	0.6a	0.4a	0.9ab	1.1a	1.4a	0.5a
	OPR	0.4ab	0.5a	0.3a	1.0a	1.3a	1.1ab	0.5a
	CS	0.4ab	0.5a	0.3a	0.9ab	1.2a	1.1ab	0.5a
			Rate					
Ilora	0	1.4a	0.5a	0.4a	0.7bc	0.7b	1.0a	0.4ab
	20	1.9a	0.6a	0.5a	0.9ab	1.1a	1.0a	0.6a
	40	2.2a	0.6a	0.5a	0.8b	1.2a	1.0a	0.6a
	60	2.2a	0.6a	0.5a	1.0a	1.1a	1.0a	0.7a
Ibadan	0	1.4c	0.5a	0.4a	1.0a	1.0ab	0.9a	0.5a
	20	2.1b	0.7a	0.6a	1.1a	1.3a	1.0a	0.7a
	40	2.4ab	0.8a	0.4a	1.1a	1.2a	1.0a	0.6a
	60	2.5a	0.8a	0.5a	1.2a	1.2a	1.1a	0.7a
Epe	0	0.3b	0.4a	0.2a	0.6b	0.7b	1.1ab	0.3ab
	20	0.4a	0.4a	0.3a	0.9a	1.0a	1.2a	0.4a
	40	0.5a	0.6a	0.3a	0.9a	1.0a	1.2a	0.5a
	60	0.6a	0.6a	0.3a	0.9a	1.0a	1.3a	0.6a

Figures with the same letter(s) in a column are not significantly (P=0.05) different according to Duncan Multiple Range Test m, m^2, m^3, and m^4: Maize in 1, 2, 3, and 4 consecutive croppings. mc: Maize followed by cowpea cropping; mcm/ mcmc: Maize and Cowpea in alternate croppings. 2 = Alternate Frequency (Applied to every other crop) 4 = Regular Frequency (Applied to every crop)

Table 3. Effect of phosphorus source and rate on shoot biomass (g) of maize and cowpea.

Soil type	Application frequency	Phosphorus		Planting sequence						
		Source	Rate	1st cropping	2nd cropping		3rd cropping		4th cropping	
			kg/ha	Maize (m)	Maize (m^2)	Cowpea (mc)	Maize (m^3)	Maize (mcm)	Maize (m^4)	Cowpea (mcmc)
Ilora	Alternate	Control SSP	0	3.38bc	2.47ab	2.34ab	2.16b	2.25b	1.77c	2.39a
			20	4.72ab	3.65a	2.81ab	2.39b	3.67a	2.84bc	2.66a
			40	6.20a	2.75ab	2.88ab	2.45b	2.96ab	2.63bc	2.72a
			60	6.34a	2.92ab	3.02a	3.35a	3.53a	2.88bc	2.49a
		OPR	20	3.88b	2.67ab	2.52ab	2.29b	2.51ab	2.55bc	2.36a
			40	3.71b	3.20a	2.69ab	2.37b	2.53ab	2.57bc	2.54a
			60	4.30ab	2.49ab	2.31ab	2.49b	2.41ab	2.58bc	2.54a
		CS	20	4.16ab	2.62ab	2.64ab	2.26b	2.30ab	2.53bc	2.67a
			40	4.09ab	2.62ab	2.81ab	2.71b	2.75a	2.54bc	2.48a
			60	3.62b	2.46ab	2.52ab	2.57b	2.62a	2.46bbc	2.50a
	Regular	Control SSP	0	3.02bc	1.63b	1.76b	2.38b	2.05b	2.30bc	1.53b
			20	4.75ab	2.58ab	2.33ab	3.60a	2.98a	5.82ab	1.61b
			40	4.99ab	3.06a	2.32ab	3.60a	3.56a	6.52ab	1.89b
			60	5.92a	2.68ab	2.22ab	3.38a	3.30a	8.94a	1.98b
		OPR	20	3.86b	1.81b	1.58b	2.34b	2.27ab	4.31b	1.66b
			40	4.21ab	2.07ab	1.67b	2.40b	2.56ab	3.57b	1.71b
			60	4.39ab	1.78b	1.68b	2.56b	268ab	4.22b	1.43b
		CS	20	4.35ab	2.55ab	1.73b	2.67b	2.38ab	4.55b	1.93b
			40	4.77ab	1.76b	1.87b	2.46b	2.67ab	8.12a	2.36b
			60	4.06ab	2.06ab	1.86b	2.88b	2.41ab	3.59b	1.75b
Ibadan	Alternate	Control SSP	0	3.26b	2.15c	1.24b	1.70cd	1.55c	3.12c	1.29c
			20	4.81ab	2.84c	1.91b	2.59c	2.60c	3.93c	1.51c
			40	5.60a	2.97c	2.47a	3.12b	3.12b	6.77b	1.48c
			60	6.61a	3.16bc	2.62a	2.79c	3.59b	6.76b	2.19b
		OPR	20	4.89ab	2.74c	2.19a	2.52c	1.60c	4.20bc	1.33c
			40	4.68ab	2.77c	1.77b	2.50c	2.09c	3.78c	1.45c
			60	5.10a	2.58c	1.76b	2.71c	1.91c	3.73c	1.69c
		CS	20	4.91ab	2.24c	1.80b	2.24c	1.64c	3.62c	1.44c
			40	4.08ab	2.42c	1.81b	2.26c	1.65c	3.48c	2.25b
			60	4.36ab	2.43c	1.63b	2.48c	1.77c	3.35c	1.83c
	Regular	Control SSP	0	3.27b	3.48b	1.16b	3.63b	2.23c	4.09bc	2.20b
			20	4.43ab	5.18ab	1.70b	5.53ab	4.13b	6.00b	4.28a
			40	6.27a	6.41a	1.48b	7.82a	3.75b	6.42b	3.59ab
			60	6.24a	5.13ab	2.71a	6.96a	6.47a	8.77a	4.95a
		OPR	20	8.86b	5.30ab	1.44b	5.09ab	2.71c	4.78bc	2.65b
			40	3.79b	4.76b	1.77b	5.71ab	3.31b	4.36bc	2.44b
			60	3.64b	4.96b	1.67b	5.59ab	3.54b	4.98bc	2.71b

Table 3. Cont'd.

		CS	20	4.97ab	4.42b	1.61b	4.72b	3.56b	4.71bc	2.70b
			40	4.51ab	4.88b	1.56b	4.56b	3.36b	4.44bc	2.33b
			60	5.21a	5.27ab	2.52a	4.63b	3.56b	4.40bc	2.30b
Epe	Alternate	Control	0	0.74c	0.52c	1.12b	0.88b	1.85b	0.45d	2.36b
		SSP	20	2.52ab	0.62c	1.42b	0.53b	1.96b	1.46c	2.65b
			40	3.11a	1.03c	1.75b	0.73b	3.00a	1.79c	4.07a
			60	3.67a	0.76c	1.89b	0.75b	2.85a	1.97c	4.73a
		OPR	20	1.64b	0.53c	1.77b	0.59b	1.51b	0.83d	2.38b
			40	1.56b	0.65c	1.74b	0.81b	1.60b	0.65d	2.13b
			60	1.94b	0.65c	1.86b	0.68b	1.75b	0.68d	2.57b
		CS	20	1.67b	1.06b	1.55b	0.70b	1.62b	1.39c	2.39b
			40	1.60b	0.95c	1.68b	0.61b	1.15bc	1.32c	3.75ab
			60	1.71b	0.84c	1.43b	0.66b	1.62b	1.05c	2.88b
	Regular	Control	0	0.89c	1.03b	1.24b	1.44a	0.84c	2.51b	1.41c
		SSP	20	2.40ab	2.65a	1.70b	1.40a	1.23bc	6.17a	1.76c
			40	3.14a	2.77a	2.40a	1.39a	1.57b	4.49ab	1.68c
			60	3.23a	2.16a	2.55a	1.96a	2.34a	6.36a	1.74
		OPR	20	1.63b	1.71b	1.38b	1.32a	0.62c]	3.52b	1.51c
			40	1.71b	1.59b	1.69b	1.50a	0.61c	4.32ab	1.59c
			60	1.76b	1.06b	1.45b	1.45a	0.72	3.67b	1.53c
		CS	20	1.92b	1.19b	1.80b	1.22a	0.83c	3.11b	1.61c
			40	1.65b	1.51b	1.44b	1.92a	1.03bc	3.77	1.43c
			60	1.90b	1.37b	1.29b	1.56a	0.71c	5.80a	1.57c

Figures with the same letter(s) in a column are not significantly (P=0.05) different according to Duncan Multiple Range m, m^2, m^3, and m^4: Maize in 1, 2, 3, and 4 consecutive croppings; mc: maize followed by cowpea; mcm / mcmc: maize and cowpea in alternate croppings. 2 = Alternate Frequency (Applied to every other crop) 4 = Regular Frequency (Applied to every crop)

value of 3.35 g at the application rate of 60 kg P/ha when alternating maize with cowpea had the highest DM yield of 3.67 g at the rate of 20 kg P/ha. There where slight increases in shoot biomass when maize was alternated with cowpea. There were 4, 35, 8 and 2% increments in control, SSP, OPR and CS respectively at an application rate of 20 kg P/ ha. In the fourth cropping, highest values for maize and cowpea were 2.88 and 2.72 g at application rates of 60 and 40 kg P/ha respectively in SSP-treated plants (Table 3). With the regular frequency of fertilizer application in the 1st cropping, the highest shoot DM yield value was 5.92 g in SSP-treated plant atthe rate of 60 kg P/ha. There were 54, 33 and 32% increments over control, OPR and CS treatments, respectively at the same application rate. In the second cropping, 3.06 and 2.33 g were the highest yield values obtained for maize and cowpea, respectively, at the rates of 40 and 20 kg P/ha in SSP-treated plants. In the third cropping, unlike the trend observed with alternate frequency of fertilizer application where slight increments were observed when cowpea was alternated with maize over that of maize grown in sequence three times, the reverse was observed. In the fourth cropping with regular frequency, maize shoot DM yield was significantly increased, almost doubling the yield obtained in the 3rd cropping at the same frequency. However, with alternate frequency of application, there were 23, 67, 39 and 46% increments for control, SSP, OPR and CS respectively at the rate of 60 kg P/ha (Table 3). Cowpea shoot biomass with regular application frequency declined by 50, 26, 77 and 42% in control, SSP, OPR and CS respectively, when compared to yields obtained with alternate frequency of application of the same fourth cropping. Trends in Ibadan and Epe soils (Table 3) were almost similar to that of Ilora soil except that the reverse was the trend observed in cowpea yield. In the fourth cropping, maize and cowpea shoot biomass were generally low in Epe soil (Table 5) compared to Ilora and Ibadan soils. The effects of frequency, source, and rate of P application on shoot yield were significant.

Table 4. Effect of phosphorus source and rate on total biomass (g DM) of maize and cowpea.

Soil type	Freq of application	Phosphorus		Planting sequence						
		Source	Rate	1st cropping	2nd cropping		3rd cropping		4th cropping	
			kg/ha	Maize (m)	Maize (m2)	Cowpea (mc)	Maize (m3)	Maize (mcm)	Maize (m4)	Cowpea (mcmc)
Ilora	Alternate	Control	0	4.60bc	3.19b	3.53a	2.34cd	2.24cd	3.30c	3.24a
		SSP	20	6.4	5.06a	3.31a	2.91cd	3.39bc	4.34bc	3.45a
			40	8.40a	3.95b	3.39a	3.78c	4.16b	4.34bc	3.57a
			60	8.55a	3.34b	3.14a	3.50c	4.67b	4.38bc	3.60a
		OPR	20	5.74b	3.26b	3.09a	3.48c	3.00bC	4.09bc	2.92ab
			40	5.56b	3.84b	2.93ab	3.40c	3.99bC	3.99c	3.42a
			60	6.32b	3.23b	2.85ab	3.55c	3.60bC	3.77c	3.60a
		CS	20	6.32b	3.90b	3.23a	3.22c	3.27bc	3.61c	3.13a
			40	6.20b	3.56b	3.33a	3.90c	3.12bc	3.29c	3.22a
			60	6.07b	3.45b	3.02a	3.16c	3.56bc	4.36bc	3.29a
	Regular	Control	0	4.23bc	2.12bc	1.97b	5.99b	3.05bc	3.52c	1.90b
		SSP	20	8.20a	3.28b	2.62ab	7.47ab	5.06ab	7.34ab	1.86b
			40	9.25a	4.04ab	2.56ab	10.23a	4.62b	7.44ab	2.19ab
			60	9.72a	3.36b	2.58ab	9.25a	7.64a	9.10a	2.33ab
		OPR	20	6.78b	2.59bc	1.80b	8.34b	3.83bc	5.49b	2.16ab
			40	6.26b	2.78bc	1.88b	8.22ab	4.33b	4.64bc	1.98b
			60	6.34b	2.39bc	2.11b	7.43ab	4.60b	5.73b	1.83b
		CS	20	6.88b	3.34b	1.97b	6.13b	4.30b	5.73b	2.22ab\
			40	7.60ab	2.27bc	2.23b	5.86b	3.99b	8.14a	2.62sb
			60	7.15ab	2.61c	2.11b	6.40b	4.10b	4.58bc	2.05ab
Ibadan	Alternate	Control	0	4.82c	2.80cd	1.40b	3.05b	3.28b	4.18bc	1.67c
		SSP	20	7.20ab	3.54c	2.17a	3.76ab	5.00a	5.32b	1.96c
			40	8.35ab	3.92c	2.71a	3.28b	3.97b	8.17ab	2.00bc
			60	8.93ab	3.92c	2.04a	4.11a	4.89a	8.30ab	2.63bc
		OPR	20	7.23ab	3.60c	2.45a	3.27b	3.50b	5.24b	1.64c
			40	7.07ab	3.71c	2.01a	3.03b	3.72b	6.01b	1.92c
			60	8.00ab	3.44c	2.34a	3.07b	3.92b	4.65bc	2.11bc
		CS	20	7.52ab	2.89cd	2.04a	3.20b	3.15b	5.34b	1.88c
			40	6.40b	3.12c	2.06a	3.60ab	3.60b	4.11bc	2.94bc
			60	6.80b	3.10c	1.86b	4.01a	3.28b	5.32b	2.26bc
	Regular	Control	0	4.73c	4.40bc	1.64b	3.23b	2.67b	5.89b	2.70bc
		SSP	20	6.80b	6.59b	1.94b	4.29a	4.10a	6.91b	4.88ab
			40	9.51a	8.94a	1.67b	4.43a	3.06b	7.92b	4.26ab
			60	10.45a	6.87b	3.07a	4.18a	4.10a	10.74a	5.88a
		OPR	20	6.37b	7.81ab	1.71b	3.28b	2.90c	7.67ab	2.72bc
			40	6.13b	6.54b	1.99b	3.36b	3.22b	5.94b	2.71bc
			60	6.17b	6.75b	1.94b	3.55b	3.43b	7.35ab	3.08b

Table 4. Contd.

		CS	20	7.55ab	5.70b	1.82b	3.40b	2.57c	6.4b	2.28bc
			40	7.22ab	6.80b	1.86n	3.34b	3.10b	6.38b	2.70bc
			60	7.72ab	6.60b	2.73a	3.52ab	3.07b	6.20b	2.97bc
Epe	Alternate	Control	0	0.81d	0.93cd	1.32cd	1.42c	2.40b	1.10c	3.16b
		SSP	20	2.73b	0.88cd	1.70b	1.07c	3.05ab	2.69c	3.69b
			40	3.89ab	1.59bc	2.02ab	1.23c	4.57a	2.67c	6.57a
			60	4.45a	1.16c	2.23ab	1.67c	3.93ab	3.33bc	6.10a
		OPR	20	1.86c	0.82cd	2.02ab	1.24c	3.21ab	1.64d	3.67b
			40	1.86c	1.11c	2.03ab	1.34c	2.57ab	2.91c	3.08b
			60	1.99c	1.03c	1.96b	1.22c	3.36ab	1.31d	3.81b
		CS	20	1.78c	1.47bc	1.90b	1.25c	3.11ab	2.33c	3.51b
			40	1.98c	1.45bc	1.92b	1.34c	2.05b	2.06c	4.25ab
			60	2.23bc	1.30bc	1.69b	1.20c	3.10ab	2.04c	4.18ab
	Regular	Control	0	1.17cd	2.08b	1.49c	2.44b	1.40c	5.40b	1.80d
		SSP	20	2.72b	3.59ab	1.97b	2.40b	2.38b	8.93a	2.40c
			40	4.30a	4.31a	2.79a	2.06b	2.80b	7.29a	2.51c
			60	4.74a	4.72a	2.71a	3.04a	2.96b	8.47a	2.66c
		OPR	20	2.05bc	2.42b	1.81b	2.53b	1.16c	3.94b	1.90d
			40	2.19bc	3.13ab	1.96b	2.33b	1.21c	6.64ab	2.02cd
			60	1.91c	1.83bc	2.07ab	2.87b	1.36c	5.58b	1.85d
		CS	20	2.08bc	2.11b	2.03ab	2.20b	1.33c	4.96b	1.92d
			40	2.16bc	2.58b	1.76b	3.20a	1.87c	5.47b	1.86d
			60	1.85c	2.67b	1.60b	2.50b	1.13c	8.86a	1.99d

Figures with the same letter(s) in a column are not significantly (P = 0.05) different according to Duncan Multiple Range Test.
m, m^2, m^3, and m^4: Maize in 1, 2, 3, and 4 consecutive croppings; mc: maize followed by cowpea; mcm / mcmc: maize and cowpea in alternate croppings. 2 = Alternate Frequency (Applied to every other crop) 4 = Regular Frequency (Applied to every crop

Effects of phosphorus on total dry matter yield

The trend in response of total dry matter yield of P application was similar to trends observed in shoot and root DM yields. In Ilora soil, with alternate frequency of P application, the highest total biomass of maize was 8.55 g DM at the rate of 60 kg P/ha. SSP in the first cropping (Table 4). The two phosphate rock sources did not differ significantly. The control treatment had the least total biomass. In the second cropping, highest yield values obtained for maize and cowpea were 5.06 and 3.53 g DM respectively, with SSP application. Maize yields decreased when compared to the first cropping. In the 3rd cropping, when P fertilizer was re-applied, pots where maize has been planted three times in a sequence had the highest value of 3.78 g DM when SSP was applied at the rate of 40 kg P/ha. When maize was alternated with cowpea, it had 4.67 g at the rate of 60 kg P/ha of SSP. A slight increase in total biomass yield was observed when maize was alternated with cowpea. In the fourth cropping, the highest values for maize and cowpea were 4.36 and 3.60 g DM at an application rate of 60 kg P/ ha SSP. In the regular frequency of fertilizer application, the trend observed was similar to the alternate frequency. SSP application still gave the highest total DM yields. In the second cropping, there was a decline in yields of both maize and cowpea despite addition of fertilizer when compared to first cropping. In the third cropping, total dry matter yield significantly increased relative to second cropping. Unlike the trend observed with alternate frequency of application, maize grown three times in sequence had higher total biomass than maize grown alternated with cowpea. In the fourth cropping, maize yields declined compared to yields obtained in the 3rd cropping where maize grown three times in a sequence gave greater yields than where maize was grown alternated with cowpea (Table 4). Cowpea yields were lower with regular frequency compared to the alternate frequency of fertilizer application. The trend was almost similar in Ibadan soil (Table 4) and also in Epe soil (Table 4) except that total DM yields of cowpea in the fourth cropping in Ibadan soil with regular frequency of fertilizer application were greater than alternate frequency of fertilizer application. Total biomass was significantly influenced by P sources. Differences in total dry matter obtained between P treatments and control were highly significant ($P \leq 0.05$) throughout the four croppings in the 3 soils. SSP application gave significantly higher total dry matter yields than the phosphate rocks but the two PRs gave comparable biomass yields throughout the four croppings. Application rate had significant effect on total dry matter yield in all soils. Forty and 60 kg P ha^{-1} application rates gave similar maize yields which were significantly higher than yields from 20 kg P/ha in the first and second croppings in all the soils. However, in the third and fourth croppings, no significant differences were observed with the three rates.

Effects of phosphorus application on cumulative apparent P recovery in maize and cowpea

The cumulative recovery of P at the end of four croppings was maximal at 75% for Ilora soil, 80% for Ibadan soil and 70% for Epe soil (Figure 1). With alternate application frequency, values were lowest at 120 kg P/ha and highest at 40 kg P/ha. With regular frequency of application of P, the value ranged between 13 and 70% in Ilora soil; between 18 and 70% in Ibadan soil and was between 8 and 50% in Epe soil. Apparent P recovery was also lowest at 120 kg P/ha and highest at 40 kg P ha^{-1} (Figure 1). Lower percent recovery values were recorded with regular frequencies of P applications.

DISCUSSION

Soil pH was slightly acidic for Ibadan and Ilora soils but was within the range for optimum maize and cowpea production. The observed low organic matter content can be attributed to land use, vegetation and intensity of cropping of the sites where the soils were collected. Total N content appeared to be related to the organic matter content of the soils, as well as cropping history. Available phosphorus (Bray 1) with a mean value of 4.14 mg kg^{-1} was very low based on the 8-12 mg kg^{-1} critical level reported by Udo and Ogunwale (1977). Exchangeable calcium values in Ilora and Ibadan soil appeared adequate but Epe soil was critical, based on the 2.0 cmol (+) kg^{-1} as the critical Ca level. The low nutrient levels of the soils qualify them for the study.

Maximum maize and cowpea dry matter yields are usually limited by inadequate availability of nutrients. The results highlighted the superiority of fertilized plants over non-fertilized plants in terms of dry matter yield development. The consistently poor performance of the non-fertilized maize and cowpea plants indicates the potentials of the crops to give optimal yields with adequate fertilization.

In this study, dry matter yield was markedly increased by phosphorous application with the three phosphate materials. This was reflected in increased shoot and root biomass. Increase in yield has been reported as an overall benefit derived from phosphate application (Enwezor et al., 1989; Akande et al., 1998; Yusuf et al., 2003). Frequency of P application had significant effect on shoot and root dry matter in all the soils. Regular frequency of P application consistently gave significantly higher yields than alternate frequency, indicating no residual effects. Total dry matter yield was not significantly affected by frequency of P application throughout the four cropping cycles except at Ilora soil in the 4^{th} cropping. Significant effects were observed in Ibadan soil except at first cropping. Source of P had significant effects on shoot, root and total dry matter yields in all the soils and throughout the four croppings. SSP has proved to be a superior P source to the other PR sources. P application rate had significant effects on shoot and total DM yields throughout the four croppings in all the soils. In the case of root dry matter yield, application rate was only significant in Ilora and Ibadan soil in the 3^{rd} and 1^{st} cropping respectively. These findings agree with the observations of Khasawneh and Sample (1979) that the maximum yield attained with increasing rates of phosphate rocks varies among the sources. It was also observed that these maxima are less than the maximum yield attained with increasing rates of water-soluble P sources such as super phosphate (Engelstad et al., 1974; Akande et al., 1998).

The extent of recovery of added P by crop should influence P application rates. Increasing levels of P decreased the apparent P recovery. Highest apparent P recovery was obtained with the lowest rate. This might be explained in terms of the fact that a plant grown in a nutrient deficient soil, exhibits greater competition for nutrient absorption at lower doses. Results showed that irrespective of crop, percent recovery of added P varies widely among soils. Recovery values are within the ranges reported by Adepetu, 1970, Halvorson and Black, 1985; Thomas and Hanway, 1985). This observation agrees with the report of Adepetu (1983) that the recovery of added P by four successive crops in a greenhouse study ranged from 26 to 55 with a mean of 42%. The shoot and total dry matter yields of maize and cowpea was significantly influenced by phosphate addition. The frequency, the source and the rate of P application varied in their degree of significance from Ilora, Ibadan and Epe soils. SSP was consistently superior to the PRs

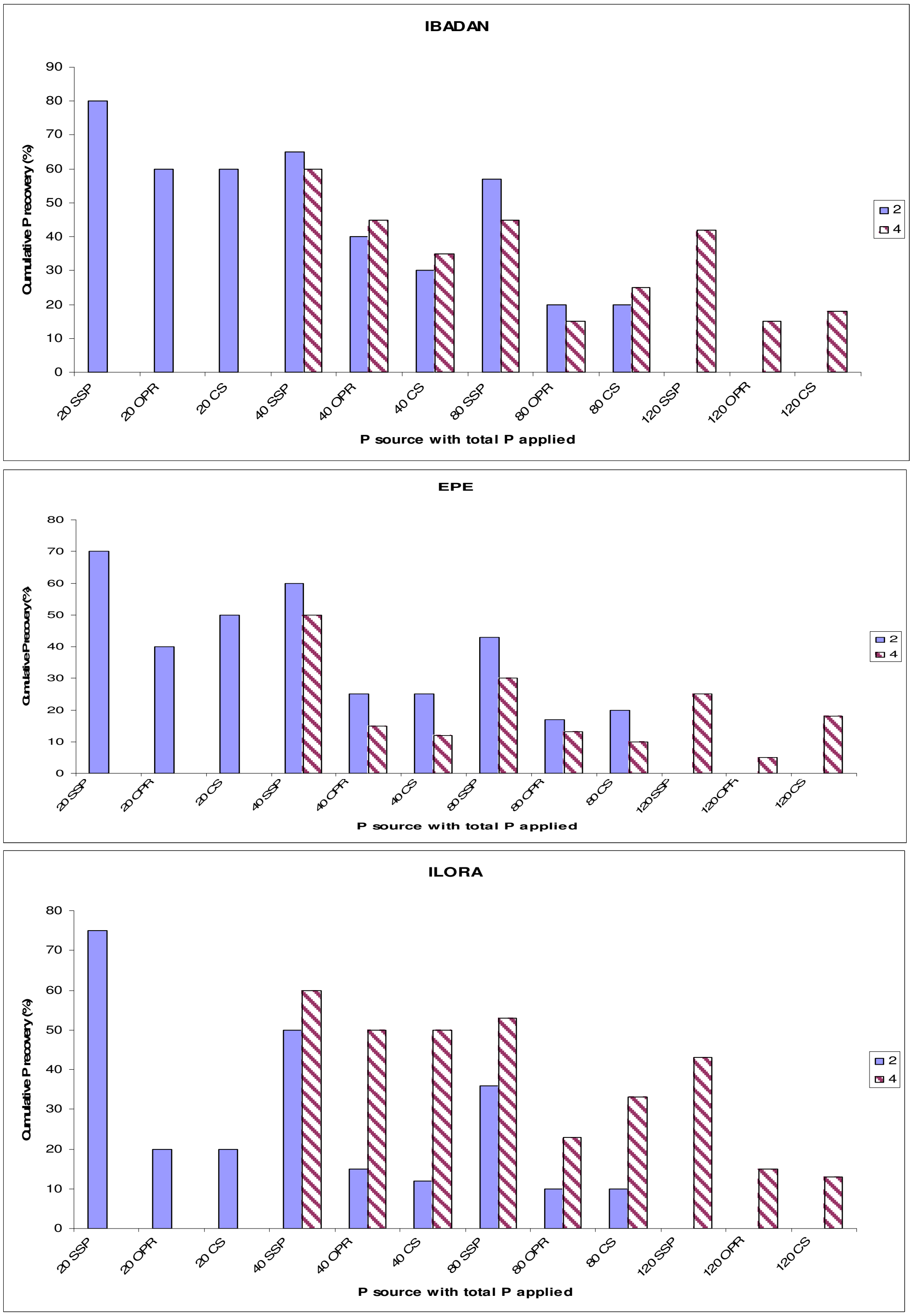

Figure 1. Effect of frequency and P rate on P recovery in maize and cowpea.

sources. This is probably due to its solubility that made it readily available for plant uptake, unlike PRs that slowly release the nutrients.

Conclusion

Results from this study have shown that application of

Ogun rock phosphate and crystallizer can also be effective in increasing the dry matter yields of maize and cowpea as single super phosphate. Alternating maize with cowpea proved to be superior to continuous maize. Regular frequency of application was superior to alternate frequency of application. Increasing levels of P decreased the apparent P recovery. Highest apparent P recovery was obtained with the lowest rate and vice versa.

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