IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 9, Issue 12 Ver. I (Dec. 2016), PP 40-46
www.iosrjournals.org

Effect of Phosphorus Sorption Indices on Pertilizer Recommendations and Its Relation with Soybean (Glycine Max (L) Merr.) Yield in Some Tropical Ultisols in Benue State. Nigeria

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Abstract: *Four Ultisols in Benue State were used to examine the influence of sorption indices on P fertilizer recommendations and their relationship with properties and yield of soybean. Soil inorganic P was fractionated using standard procedures. Sorption characteristics were determined in 0.01 M CaCal2 solution of various P concentrations. For each soil, the amounts of P that gave 0.025, 0.05, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, 0.225, 0.250 mg kg^{-1} solution concentration and the buffering capacity were estimated from adsorption curves. In the greenhouse, 4 kg of soil from each location was placed in plastic pots. Amount of P estimated from sorption study was added as KH2PO4. The treatments were laid out in Randomized Complete Block Design (RCBD) and soybean seed variety (TGx 1448 – 2E) was panted and growth and development observed to maturity. At harvest, the shoot was dried, weighed, milled and digested in a 4:1 NHO_3:$NClO_4$ mixture and analyzed for P. Optimum solution P concentration (SPC) was determined for each soil in relation to yield. A field trial was conducted at Vanam. Phosphate fertilizer quantity that resulted in 0.0, 0.5 SPC, 1.0 SPC, and 2.0 SPC (as estimated from pot experiment) was added per plot and replicated thrice in RCBD. Soybean seeds were planted by drilling. At harvest, SPC that gave highest grain was yield was evaluated and the quantity of P required (SPR) to achieve this concentration, calculated. The average P adsorption capacities (K) of the soil was 20.24 and related significantly to P in biomass (r=0.661). High grain yield (t ha^{-1}) was obtained at 0.025 mg P kg^{-1} SPC in Vanam (23.1), Abaji – Kpav (17.3), while 15.3 t ha^{-1} was obtained in Ogyoma at 0.05 mg P kg^{-1} SPC. The estimated SPC values also gave high grain yield (t ha^{-1}) in the field trial at Vanam (4.4). The soil pH related significantly with SPC (r=-0.99) and SPR (r=-0.953) Buffering capacities of soils was highest (181.70 mg kg^{-1}) at Vanum and related significantly with seed weight (r=0.605) and P in biomass (r=-0.667). Consequently, Ofugo would require the highest fertilization (67.64 kg P ha^{-1}), Abaji-Kpav (22.97 KgPha^{-1}), while Vanam (2.25 Kg P ha^{-1}) would require the least.*

Keywords: *Phosphorous Sorption Indices, Fertilization, Soybean, Tropical Utisols*

I. Introdution

An estimated 50,000 hectares of soybeans *Glycine max (L) Merr*. is cultivated annually in Nigeria, most of this being in Benue State. Farmers' yields average 300 – 1,030 kg ha^{-1} of threshold grain. Under research condition, yields of over 3000 kg ha^{-1} have been recorded (Aduayi, *et al eds.* 2002). The dearth and high cost of inorganic P fertilizers has greatly reduced farmers' output in recent years thus necessitating the need to manage P dynamics in these soils so as to increase yield and boost the income of these small holder farmers. Higher yield values and better quality of the crop are probable if phosphate interaction in soils is well understood and properly managed as P is the limiting nutrient element for the production of this crop. This is particularly so as soils in Benue State are considered to highly weathered with its attendant effect on phosphorus fixation.

Soil tests which measure the concentration of P in solution actually measure availability rather than available P and their efficacy on range of soils will depend on the uniformity of the soils' buffer capacities (Holford, 1997). Buffering capacity is thought to be an important factor influencing the P-supplying capability of soils to plants, because it controls the ease of P release from labile pool into the soils solution (Holford, 1980[b]). Critical soil test determination and fertilizer recombination for phosphorous are usually conducted based on quantity of P extracted from the solid phase, neglecting differences in soil characteristics affecting phosphorus availability. Amrani *et al*. (1999) showed that, depending on the buffering capacity of the soil, the amount of phosphorus required to achieve optimum yield varied significantly for soils having the same intake soil test values. Nair and Mengel (1984) observed that correlation of uptake with quantity or intensity factors were improved when indices of buffering capacity were included. Similar results have been reported by other researchers (Holford and Matting, 1976; Probert and Moody, 1998; Moughli *et al*., 1993).
This study was there fore undertaken with the objectives to

1. Determine the relationship between soil properties and P sorption characteristics in the soils under study.

2. Determine the effect of phosphorus sorption indices on P fertilizer recommendations for soybean growth and yield.

II. Materials and Methods

The study involved laboratory, pot and field experiments. The laboratory experiment consisted of routine soil analysis, phosphorus fractionation study, total oxides and P sorption experiment.Surface soil samples (0-20 cm) were collected from four bench mark Utisols in Benue State (FDALR, 1990) as shown in Table 1. All the sampled locations fall within the Southern Guinea Savannah zone of Nigeria.

Laboratory Studies

The soil samples were air dried and passed though a 2 mm sieve for laboratory studies and pot experiment. Soil pH was determined by the glass electrode in a 1:2 soil: water ratio. Particle size analysis was determined by the hydrometer method of Bouyoucos, (1951), organic carbon by the chromic acid oxidation procedure of Walkley and Black, 91934). Exchangeable bases by the neutral ammonium acetate saturation. Solution and K in the extracts were determined by the flame photometer while Ca and Mg were determined by the Atomic Absorption Spectrophotometer (AAS). Exchange acidity by the IM KCI extraction and 0.01M NaOH titration. Nitrogen in the samples was determined by the macro – Kjeldahl method.

Table 1: Classification of Sampled sites

S/NO	LOCATION	SOIL CLASS
1.	Ogyoma	Oric haplustult (USDA)
		Orthic acrisol (FAO)
2.	Ofugo	Oxic haplustult (USDA)
		Orthic acrisol (FAO)
3.	Abaji – Kpav	Oxic haplustult (USDA)
		Orthic acrisol (FAO)
4.	Vanam	Oxic haplustult (USDA)
		Orthic acrisol (FAO)

Source federal Department of Agricultural Land Resources (FDALR, 1990)

Phosphorus Fractionation

Phosphorus fractionation was done by the modified procedure of Chang and Jackson, (1957) as modified by Peterson and Corey, (1966) and reported by Page *et al.*, (1954). Total and organic P was determined by the NaOH digestion method Mehra et al., (1954). Available P was extracted by 0.5 M NaHCO3 buffered at pH 8.5, Olsen *et al.,* (1954) and by 0.03M NH4F + 0.025 M HCI, Bray and Kutz, (1945). Phosphorus in the extracts was determined calorimetrically by the Ascorbic acid method of Murphy and Riley, (1962) as modified by Watanabe and Olsen, (1965) and reported by Page *et al.*, (1982). Free Fe and Al oxides (Total oxides) were extracted by the citrate dithionate – bicarbonate method, Mebra and Jackson, (1960). Iron and aluminum oxide oxides in the extracts were determined with an absorption spectrophotometer.

Phosphorus Sorption Study

This experiment was carried out in the Laboratory. Phosphate Sorption characteristics of the soils were determined by placing eight separate 5 g sub- samples of the 2 mm size sieved soils in 50 ml polypropylene centrifuge tubes. Volume of 40 cm^3 of 0.01M CaCl2 solution containing 0, 15, 25, 40, 100, 200,400 and 800mg 1^{-1} P as KH2**PO4** were distrusted to the tubes as described by Dear *et al.,* (1992). The samples were then shaken for 24 hrs and then centrifuged for ten minutes at 1200 rpm at 4^{o} C in a refrigerated centrifuge. The supernatant was through a Whatman's number 42 filter paper. Phosphorus in solution was determined by a modification of the Murphy and Riley method as modified by Watanabe and Olsen, (1965) and reported by Page *et al.,* (1982). A plot of P in equilibrium (supernatant) solution was constructed against the amount of P added. For each soil the amount of P that gave the following levels of solution P concentration in the soil 0.025, 0.05, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, 0.225, 0.250 mg kg^{-1} was estimated from these plots. Phosphate sorbed (Ps) was calculated as the difference between the concentration of the added P and in solution.

The Freundlich adsorption equation which expresses an empirical relation between the amount of a substance adsorbed (K) per unit mass of the adsorbent (Q) and the aqueous concentration (C) was used to evaluate the adsorption data the freundlich equation is give by:

Log Q = Log K + 1/n Log C (Russel and Prescott, 1916)
Where:
Q is the amount of P adsorbed in mg kg^{-1}
C is the equilibrium concentration in $mg1^{-1}$

K and n are empirical constants, as K is a measure of the adsorption capacity.

Phosphorus buffering capacity (PBC) was calculated from sorption curves as the slope of the regression equation relating P sorbed to the logarithm of the P concentration of the supernatant solution (Moody *et al*., 1990; Moody, 2007).

Pot Experiment

Four kg of the 2mm sieved soil from each location was placed in each of the 33 plastic pots used in the pot study. For each soil the amount of P that was equivalent to; 0.025, 0.05, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, 0.225, 0.250 mg kg^{-1}, was added to the pots as KH_2PO_4 in $50cm^3$ of distilled water and mixed thoroughly, the amount of P were estimated for each soil. All the pots initially received equivalents of 60 kg N ha^{-1} as urea, and 30 kg ha^{-1} K Yusuf and Idowu, (2001) as KCI. There were pots without P addition that served as control bringing the total number of pots to one hundred and thirty two. Three soybean seeds of the variety TGX 1448-2E were planted per pot and later thinned to two and the pots were laid out in a Randomized Complete Block Design (RCBD) and the crop was grown to maturity with the normal agronomic practices carried out.

At harvest (12 WAP), the above ground plant material was dried and weighed. The plant materials were milled and digested in a 4:1 HNO_3:$HClO_4$ mixture and analyzed for P using the method of Murphy and Riley, (1962). The optimum solution concentration was determined for each soil both in terms of grain and dry matter yield by subjecting the yield data to the analysis of variance. The critical equilibrium solution P concentration (SPC) was estimated as the amount of P in an equilibrium concentration needed to achieve maximum yield. The Standard Phosphate Requirement (SPC) was estimated as the amount of fertilizer P that gave the equilibrium solution concentration required to achieve maximum yield.

Field Trial

A field trial was conducted at Vanam. The experimental site was ploughed and harrowed. The size of each treatment plot was 5m X 5m (or $25m^2$) and each plot was treated with equivalents of 60 kg ha^{-1} N as Urea, 30 kg ha^{-1} K as KCL. Phosphate fertilizer quantity that resulted in 0.0, 0.5 SPC, 1.0 SPC, and 2.0 SPC (as estimated from the pot experiment) was added per plot as KH_2PO_4 and the four treatments were replicated three times in a randomized complete block design (RCBD). Soybean seeds of variety TGX 1448-2E were drilled into the various plots at the rate of 50 kg ha^{-1} aduayi et al., eds. (2002). Planting was done on the 18^{th} of July, 2010.

At harvest, the soybean grains were dried and weighed. Data generated was subjected to analysis of variance and the solution concentration that gave the best yield was taken as the SPC. The solution phosphate concentration (SPC) that gave maximum grain yield was evaluated and the quantity of P required (SPR) to achieve this solution concentration was calculated.

Data Collection

The following Agronomic data was collected:
Dry matter yield at harvest in both the pot and field experiments
Number of pods per plant
Weight of seeds per pot/plot.

Statistical Analysis

Data generated in both the pot experiment and the field trial was subjected to the analysis of variance. Means were separated using the Duncan multiple range text (DMRT). Correlation analysis was carried out to determine the association between the studied (sorption) parameters and some soil properties. Regression analysis was carried out to study the relationship between the P sorbed and the logarithm of P concentration in the supernatant solution in the laboratory experiment. The SAS statistical package was used for these analyses.

III. Results and Discussion

Physical and Chemical Properties of the Soils

Some selected properties of the soils studied are shown on Table 2. The result showed that the soils are acid ranging in pH (H_2O) from 5.8 at Ofugo, 5.9 at Ogyoma and 6.0 at Abaji-Kpav and Vanam. Clay content was variable with Vanam having the least content of 6%, Ogyoma 9%, 11 and 12% at Ofugo and Abaji-Kpav respectively. The soils are loam, sandy loam and loamy sand. Total nitrogen content varied from 0.07% at Abaji-Kpav, 0.08% at Ofugo, 0.09% at Ogyoma and 0.11% at Vanam. Organic matter content also varied with the least value of 2.03% at Ofugo, 2.13% at Ogyoma, 2.36% at Abaji-Kpav and 9.46% at Vanam. The effective cation exchange capacity (ECEC) values was least at Ogyoma (2.36 c mol kg^{-1}). This was followed by 3.45 c mol kg^{-1} at Abaji-Kpav, Ofugo 3.97 c mol kg^{-1} and the highest value of 5.03 c mol kg^{-1} at Vanam. Total oxide content was least at Vanam 1.6% Ogyoma 2.1%, Ofugo 2.4% and the highest value of 2.6% at Abaji-Kpav.

Selected P fractions of the Ultisols are shown on Table 3. Total P values were variable with the least value of 275.4 mg kg^{-1} at Abaji-Kpav, 318.7% mg kg^{-1} at Vanam, 442.6 mg kg^{-1} at Ogyoma and the highest value of 448.6 mg kg^{-1} at Ofogo. Organic P was least at Abaji-Kpav (132.2 mg kg^{-1}) this was followed by 152.9 mg kg^{-1} at Vanam, 202.6 mg kg^{-1} at Ogyoma while the highest value of 215.3 mg kg^{-1} was obtained with the Ofugo soil. Generally the organic P fraction constituted about 48% of total P. the Fe-P fraction was highest at Ogyoma with 125.0 mg kg^{-1} and constituted about 29.61% of total P. Ofugo followed with 118.3 mg kg^{-1} and constituted about 26.34% of total P, 91.2 mg kg^{-1} was obtained with the Vanam soil and constituted about 28.61% of total P. the least value of 83.6 mg kg^{-1} was obtained with the Abaji-Kpav soil and constituted about 26.23% of total P. Al-P fraction was highest at Ofugo with 81.1 mg kg^{-1} and constituted about 13.07% of total P. Ogyoma followed with 55.2 mg kg^{-1} and constituted about 13.07% of total P of the soil. 36.4 mg kg^{-1} was obtained with the Abaji-Kpav soil and constituted about 13.22% of the total P of the soil. The least value of 32 mg kg^{-1} was obtained at Vanam and constituted about 10.04% of total P. The Ca-P fraction was the least P fraction in all the soils except Vanam where this fraction had a higher value than the Al-P fraction and was 42.1 mg kg^{-1} and constituted about 13.24% of the total P. this was followed by 39.3 mg kg^{-1} obtained at Ogyoma and constituted about 9.31% of total P. Ofugo followed with 23.8 mg kg^{-1} and constituted about 5.31% of the total while the least value of 23.2% mg kg^{-1} was obtained at Abaji-Kpav and constituted about 8.35% of the total P Bray-1P values varied widely with the Vanam soil having the highest value of 9.0 mg kg^{-1} and was followed by 5.2 mg kg^{-1} obtained with the Ogyoma soil. 2.3 mg kg^{-1} and 2.1 mg kg^{-1} was obtained at Abaji-Kpav and Ofugo respectively. Olsen P values also varied widely with 2.1 mg kg^{-1}, 4.4 mg kg^{-1} 5.2 mg kg^{-1} and 7.3 mg kg^{-1} for Vanam, Ofugo, Abaji-Kpav and Ogyoma respectively.

Sorption parameters and yield of soybean on the Soils in the pot experiment

Table 4 shows the values of the phosphorus Sorption parameters and yield of soybean of the soils under investigation. Their buffering capacity ranged from 46.29 mg kg^{-1} at Ofugo which was the least to 181.7 mg kg^{-1} at Vanam. The Ultisols were strongly buffered with an average PBC value of 101.60 mg P kg^{-1} soil. The PBC values were however highly variable. The phosphorus adsorption capacities of the soils used in the experiment are also shown in Table 4. The values were variable and ranged from 15.6 at Vanam to 24.83 at Ofugo. The Ultisols had an average adsorption capacity of 20.24.

Effect of solution P concentration on yield parameters from the field experiment

Table 5 shows the effect of solution P concentration on yield parameters from the field experiment conducted at Vanam. This shows that the highest value of 12.84 kg per plot was obtained at solution concentration equivalent to 2.0 SPC. This is equivalent to 5.14 tons per hectare. This was however not significantly different from 4.40 tons per hectare obtained with a solution concentration equivalent to 1.0 SPC. The control, (0.0 SPC) and 0.5 SPC treatments did not differ significantly from each other but had yield values that were significantly lower than the other treatment levels.
No significant difference was observed in terms of dry matter yield in all the treatments.

Table 2: Some Properties of the Experimental Soils

Location	pH (H_2O)	pH (KCl)	Clay (%)	Texture	O.M (%)	TotN	K	Na	Ca	Mg (cmol	E.acid kg-1	ECEC	Fe_2O_3 (%)	Al_2O_3 (%)
Ogyoma	5.9	4.9	9	L	2.13	0.09	0.26	0.13	2.07	0.78	0.02	3.26	1.2	0.9
Ofugo	5.8	5.5	11	LS	2.03	0.08	0.36	2.20	2.56	0.86	0.02	3. 97	1.1	1.3
Abaji	6.0	5.1	12	LS	2.36	0.07	0.33	0.13	2.11	0.86	0.01	3.45	1.6	1.0
Vanam	6.0	4.8	6	SL	9.46	0.11	0.47	0.22	3.10	1.24	0.02	5.03	0.5	1.1

Table 3: Selected Phosphorus Fractions of the Experimental Soils (mg kg-1)

Location	Total P	Organic P	Fe-P	Al –P	Ca - P	Bray – 1P	Olsen – P
Ogyoma	422.2	202.6	125	55.2	39.3	5.2	7.3
Ofugo	448.6	215.3	118.3	81.1	23.8	2.1	4.4
Abaji	275.4	132.2	83.6	36.4	23.2	2.3	5.6
Vanam	318.7	152.9	91.2	32	42.1	9.0	2.1

Table 4: Sorption Parameters and yield of Soybean on the Soils in the Pot experiment

S/NO	LOCATION	SPC (mg kg^{-1})	SPR (g kg^{-1})	PBC (mg kg^{-1})	K	Pod No	Seed wt (g pot^{-1})	DMY (g pot^{-1})
1	OGYOMA	0.050	0.31	53.09	24.4	115.67	27.37	11.84
2	OFUGO	0.075	0.53	46.29	24.8	62.0	24.26	16.45
3	ABAJI	0.025	0.02	125.3	16.1	80.0	22.87	15.90
4	VANAM	0.025	0.02	181.70	15.6	124.3	41.27	31.90

Table 5: Effect of Solution P Concentration on Yield Parameters in the Field Trial at Vanam

Target conc. (mg kg-1)	Seed wt (kg)	DMY (kg)	100 Seed wt (g)	Seed wt. (t ha-1)
0.0 SPC	6.92b	1.97a	10.22c	2.77b
0.5 SPC	7.52b	2.71a	11.18ab	3.01a
1.0 SPC	11.01a	2.98a	11.29a	4.40a
2.0 SPC	12.84a	2.86a	10.68bc	5.13a

Within each column, means with the same letter are not significantly different according to Duncan Multiple Range Test.

Relationships between Sorption Parameters and Soil Properties in the Experimental Soils

The standard phosphate requirement, SPR of the Ultisols related positively and significantly with the solution phosphate concentration SPC (r = 0.953) as shown on Table 6, while the relationship between the pH and SPC of these soils was highly significant but negative (r = - 1.00). The relationship between the pH and SPR was however negative and significant (r = - 0.953). The iron oxide content of the soils related negatively and significantly with the organic matter content (r = - 0.969) while the total P related positively and significantly with the adsorption capacity K, (r = 0.962). The same relationship existed between the organic P fraction and the adsorption capacity, K (r = 0.962). the relationship between the Al-P fraction and the SPC was positive and highly significant (r = 0.995) while that with the SPR was significant and positive (r = 0.973). Bray -1P showed a negative and significant relationship with the clay content of the soils.

Relationships between Soil Properties, Sorption and Yield Parameters in the Soils

Correlation coefficients between the sorption and yield parameters in the experimental soils are shown on Table 7. There was no significant relationship between the SPC and the SPR with any of the yield parameters. However, the PBC related negatively and significantly with total P in the plant biomass (r = - 0.667) and showed a positive and significant relationship with the seed weight (r = 0.605). The phosphate adsorption capacity, K showed a positive and significant relationship with the total P in the plant biomass (r = 0.661).

Variations in organic matter content, clay content, pH, phosphate added as fertilizer have been responsible for variations in P adsorption in soils, (Litaor *et al*., 2005; Brady and Weil, 2008).In the present study, variation could not be ascribed to such factors as pH as the pH of all the soils ranged between 5.6 and 6.3 with a very small difference and might have not affected the variation in phosphate adsorption to a greater extent. Similarly, phosphate added as fertilizers might have little effect as most of the farmers use no (phosphatic) fertilizers. Variations in P adsorption between the soils could have been due to various reasons such as the initial P contents of the soils, their clay contents which could have provided the active sites for the adsorption, the organic matter content etc. in some cases, adsorption was higher in soils that had lower organic matter content as was observed at Ogyoma, Ofugo, Abaji-Kpav and Vanam. Holford and Patrick, (1979) however reported that lower adsorption in such surface samples might be owing to occupation of sites in the surface soils by organic anions.

Table 6: Correlation coefficients (r) between sorption parameters and soil properties in the Ultisols

	SPC	SPR	PBC	K	pH	Clay	O.M	Fe_2O_3	Al_2O_3	Total P	Org.P	FeP	AlP	CaP	Bray	Olsen
SPC																
SPR	-953															
PBC	-862	-926														
K	-917	-882	-947													
pH	-1.000**	-953*	-862	-917												
Clay	.329	.596	-549	.265	-329											
O.M	-544	-756	.850	-637	.544	-865										
Fe_2O_3	.503	1687	-865	.687	-503	.727	-969*									
Al_2O_3	-255	-018	.195	-462	.255	.701	-257	.056								
TotalP	.931	.819	-832	.962*	-931	.053	-415	.463	-582							
Org.P	-327	.819	-832	.962*	-931	.053	-415	.463	-582	1.000**						
FeP	.828	.736	-852	.967*	-828	.030	-473	.576	-671	.963	.963*					
AlP	.995**	.973*	-867	-895	-995**	.412	-591	.530	-161	.894	.894	.782				
Cap	-327	-552	.363	-115	.327	-924	.645	-439	-824	.021	.021	.142	-417			
Bray	-491	-727	.654	-404	.491	-948*	.886	-745	-614	-216	-216	-167	-568	.925		
Olsen	.300	.456	-739	.596	-300	.504	-833	.940	-141	.374	.347	.563	.305	-143	-495	

* Significant at 1% ** significant 5%

Table 7: Correlation Coefficients between Sorption and Yield Parameters in the soils

	P biomass	Pod No	Seed wt	DMY
SPC	0.509	-0.226	-0.52	-0.41
SPR	0.172	-0.455	-0.421	-.0.568
PBC	-.667*	0.28	0.605*	0.473
K	0.881*	-0.077	-0.198	-0.042

Table 8: Correlation Coefficients between soil Properties and Yield Parameters

	P biomass	Pod No	Seed wt	DMY
pH	0.241	0.31	0.218	0.379
Clay	0.55	-0.602*	-0.650*	-0.658*
Fe-p	0.587*	0.045	-0.579*	-0.023
Al-P	0.31	0.077	0.145	0.085
Ca-P	-0.278	0.633*	0.687*	0.755**
Bray –P	-0.257	0.538	0.439	0.736**
Olsen-P	0.453	-0.025	-0.266	-0.258

It has been observed that soil texture is responsible for variation in phosphate adsorption behavior. Fine textured soils adsorbed more phosphate than coarse textured soils. Such behavior can be explained by the fact that fine textured soil exposes larger surface area than the coarse textured soils the fine textured soils could also have stronger reactive sites than the coarse textured soils. Low affinity for P by sandy soils had earlier been reported by (Sibbbenssen, 1978) higher P adsorption maxima were recorded with greater clay content of soils. The adsorption pattern observed at Ofugo could be partly attributed to this factor.

The PBC values of the Ultisols were very variable with average values at 101.60 and 74.52 mg P kg^{-1} soil respectively. This could probably be as a result in the differences in their organic matter content, as well as the total oxide content of these soils (Agbenin and Tiessen, 1994; Borggaard et al., 1990) had reported similar results. The relationship between the SPC and SPR of the soils indicate that the P fertilizer requirement would increase as the SPC increases. Thus soils requiring low P in solution would require low P fertilization for optimum yield. The implication of the relationship between pH and SPC is that acid ultisols would require more P in solution thus requiring grater fertilization.

IV. Conclusion

Significant relationships were observed between sorption characteristics such as the PBC, SPC and SPR and some routinely analyzed soil properties such as the organic matter and clay content. The phosphorus buffering capacity (PBC) related positively and significantly with the seed weight but related negatively and significantly with P in the plant biomass. The phosphate adsorption capacity (K) related negatively and significantly with the dry matter yield. Consequently, PBC and K could have accounted mostly for the variation in grain and dry matter yield of soybean respectively. The optimum soil solution concentration of P for soybean yield varied across the soils with the Vanam soil attaining optimum yield with a solution concentration of 0.025 mg P kg^{-1} soil, Ogyoma 0.05 mg P kg^{-1} soil, the Ofugo soil attained optimum yield with a solution P concentration of 0.075 mg P kg^{-1} soil. Based on their phosphate buffering capacities and its influence on the solution phosphate concentrations and yield of soybean in these soils, it was concluded that Ofugo, would require 61.26 kg P ha^{-1}. Low fertilization would be required in Ogyoma (39.56 kg P ha^{-1}) and Abaji-Kpav (22.97 kg P ha^{-1}) while the Vanam soil would require the least P fertilization (2.55 kg P ha^{-1}).

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