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# DETERMINATION OF PHOSPHORUS REQUIREMENTS OF COWPEA (*VIGNA UNGUICULATA*) IN THE ACID SOILS OF SOUTHEASTERN NIGERIA USING SORPTION ISOTHERMS

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ABSTRACT

This study was conducted to determine the phosphorus requirement of cowpea in two locations in southeastern Nigeria (Bende and Umudike) using sorption isotherm. The method used involved equilibrating 3g of soil in 30mls of 0.01m $CaCl_2$ containing various levels of phosphorus at room temperature for 5 days. From the P sorption curves constructed, the standard P requirement for the two soils were calibrated. The values were very low at 21.5 and 45$\mu gg^{-1}$ for Bende and Umudike soils respectively. Different phosphorus levels were calibrated from the sorption isotherm curves and used in fertilizing cowpea in potted experiment. The experiment was laid out in split-plot experimental design. The soil type occupied the main plots while the P levels were assigned to the subplots. The results obtained indicated that solution P concentration level of 0.2$\mu gg^{-1}$, equivalent to 21.5$kgha^{-1}$ in Bende and 45$kgha^{-1}$ in Umudike gave the best nodulation while grain yield was produced when solution P concentration of 0.4$\mu gg^{-1}$ equivalent to 65$kgha^{-1}$ in Bende and 125 $kgha^{-1}$ in Umudike was applied. The grain yield at this level was not significantly different from those at 0.2$\mu gg^{-1}$ solution concentration of P in both locations. Higher yield were recorded in the soils of Umudike compared to that of Bende.

**KEYWORDS:** Phosphorus, Sorption Isotherms, Cowpea

## INTRODUCTION

Phosphorus is one of the primary nutrient elements essential for plant growth and development. It plays a major role in energy transfer, stimulation of early growth and development, fruiting and seed formation (Warren 1992). Phosphorus has been identified as one of the most limiting nutrient elements in crop production in the tropical soils (Ahn, 1970, Warren 1992, Osodeke 2000). Widespread P deficiencies have been reported in acid sands of Nigeria (Ayaduba and Adepetu 1983, Uyovbisere and Chude 1995, Osodeke 2000). The major problem associated with P fertilization in these soils is its high fixation, thereby making applied P unavailable to crops. High P fixation had been reported in these acidic soils (Enwezor 1977, Nnoke 1980).

An effective soil test can help to predict the fertilizer requirements of crops using appropriate extractants as have been recommended by several authors (Enwezor 1977, Kamprath and Whatson 1980, Sahratwat et al 1997). These extractants only assess the P status of the soil but not the amount of phosphate required to make up any deficiency of P needed by crops (Warren 1992). A more direct method of estimating the plant P requirement has been recommended. Consequently, P-sorption isotherm which relates P concentration in the solution with P sorbed by the soil have been used to predict fertilizer P requirement of crops (Beckwith 1965, Warren 1992, Osodeke 1999).

This is based on the principle that P requirement of crops is directly related to a standard supernatant solution of P concentration in soil (Beckwith 1965). He found a supernatant solution of 0.2ppm to be adequate for most crops. There is no information in this area for cowpea in these soils. This study was therefore initiated to provide the vital information for cowpea production in these soils.

## MATERIALS AND METHODS

### Soil Sampling and sample analysis

The soil samples for the study were collected from Umudike (Coastal Plain Sand Formation) and Bende (Shale Formation). The samples were collected from 0–15cm depth to represent the two locations. Bulk soil samples were also collected for pot experiment. The samples were air dried and sieved through 2 mm mesh. The physical and chemical properties of the soils were determined. Particle size analysis was done by the hydrometer method as described by Juo (1979), pH was determined in 1:2.5 soil to water ratio using a pH meter (Mclean, 1965). Organic carbon was by the wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by the micro kjeldahl method of Bremner (1965). Exchangeable calcium, magnesium, potassium and sodium were determined using Atomic Absorption spectrophotometer. Exchangeable acidity was determined by the method of Kamprath (1967). Effective cation exchange capacity (ECEC) was taken as the sum of the exchangeable cations

### Sorption Study

The sorption isotherm curves were determined by equilibrating 3g of soil in 30ml of 0.01M, $CaCl_2$ containing various levels of P in 50ml centrifuge tubes for five days at room temperature (Fox and Kamprath, 1970). The samples were shaken twice daily for 30 minutes. Few drops of toluene were added to suppress microbial growth. Phosphorus in the supernatant solution after the equilibrium period was determined by the Murphy and Riley (1965) method. From the isotherm curves constructed from the result, P rates required to give 0,0.1,0.2,0.3,0.4 and 0.5$\mu gg^{-1}$ were calibrated. These values were equivalent to 0, 22, 45, 65, 125 and 178$kgha^{-1}$ for Umudike and 0, 5, 21.5, 30.0, 65 and 85$kgha^{-1}$ for Bende soils.

### P-requirement of Cowpea

Ten kilogram portion of the top soil from the two locations were weighed and placed in 12-litre plastic pots. Cowpea (Ife Brown) was planted at the seed rate of 3 seeds per pot and later thinned down to one seedling per pot at 2 weeks after planting. The P rates calibrated from the isotherm curves were applied at two weeks after germination. The treatments were arranged in a split-plot experiment in a randomized complete block design (RCBD) with four replications. The soil type occupied the main plot while the P rates were assigned to the sub plots. Nitrogen and Potassium were applied at the rate of 20 and 35kg per hectare respectively. The pots were irrigated every other day. Data on the number of nodules per plant, nodule dry weight, plant height, and grain yield were collected and analysed statistically using the method outlined by Wahua (1999).

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**Table 1: The physical and chemical characteristics of the soils**

| Soil Properties | Umudike | Bende |
|---|---|---|
| Clay(%) | 21.9 | 25.9 |
| Silt(%) | 10.3 | 18.3 |
| Sand(%) | 67.8 | 55.8 |
| pH(%) | 4.50 | 5.80 |
| Organic carbon(%) | 2.67 | 2.20 |
| Total Nitrogen | 0.21 | 0.22 |
| Available Phosphorus (ppm) | 23.0 | 8.00 |
| Ca ($Cmolkg^{-1}$) | 2.80 | 6.00 |
| Mg ($Cmolkg^{-1}$) | 1.60 | 2.40 |
| K ($Cmolkg^{-1}$) | 0.18 | 0.32 |
| Na ($Cmolkg^{-1}$) | 0.16 | 0.24 |
| Exchange Acidity ($Cmolkg^{-1}$) | 3.68 | 2.80 |
| ECEC ($Cmolkg^{-1}$) | 8.42 | 11.76 |
| Base saturation(%) | 56.30 | 76.19 |
| Standard P Requirement (ppm) | 45.00 | 21.50 |

**Table 2: Effect of the phosphorus levels on the height of the cowpea in the two locations**

| P solution Conc. ($\mu gg^{-1}$) | Umudike | Bende | Mean |
|---|---|---|---|
| 0 | 18.45 | 16.15 | 17.48 |
| 0.1 | 19.39 | 18.51 | 18.76 |
| 0.2 | 21.89 | 19.40 | 20.65 |
| 0.3 | 22.09 | 20.01 | 21.73 |
| 0.4 | 20.94 | 18.52 | 19.73 |
| 0.5 | 24.50 | 20.04 | 22.26 |
| Mean | 21.21 | 18.77 | |

LSD = 6.77

**Table 3: Effects of the various phosphorus levels on grain yield of the cowpea in the two locations. (g/plant).**

| P solution Conc. ($\mu gg^{-1}$) | Umudike | Bende | Mean |
|---|---|---|---|
| 0 | 1.30 | 1.05 | 1.18 |
| 0.1 | 2.61 | 2.18 | 2.40 |
| 0.2 | 2.73 | 2.58 | 2.66 |
| 0.3 | 3.95 | 1.96 | 2.96 |
| 0.4 | 4.64 | 1.95 | 3.63 |
| 0.5 | 5.31 | 2.12 | 3.38 |
| Mean | 3.42 | 1.97 | |

LSD = 1.34

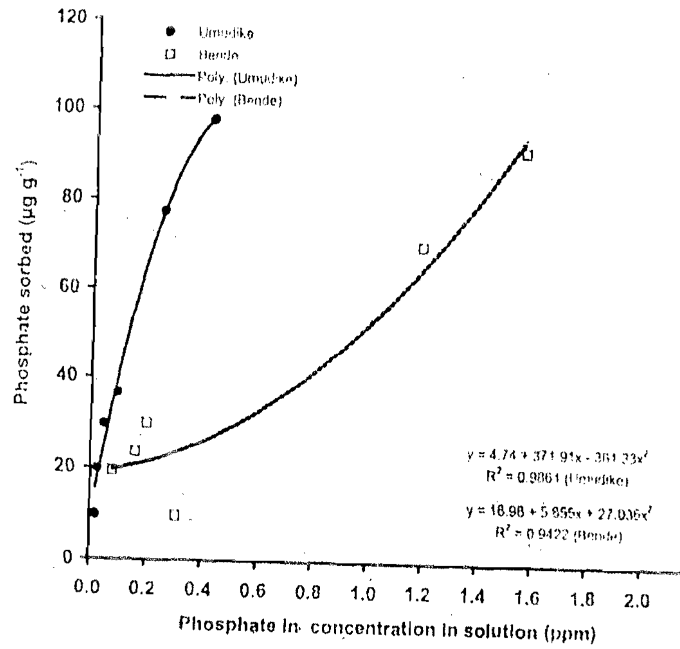


**Figure 1. Phosphate sorption isotherms curves for soils.**

## RESULTS AND DISCUSSIONS

### Soil Properties

The physical and chemical properties of the soils are presented in Table 1. the texture of Umudike soil is sandy-clay loam while that of Bende is clay loam. The soils of both locations were acidic, this is one of the characteristics of the acid sands of southeastern Nigeria (Enwezor et al 1988). The two soil types were relatively high in organic carbon and total nitrogen, with total nitrogen being above the critical level set by Adeoye and Agboola (1981) for soils of the humid tropics. The soils of Umudike had available P above the critical level of 12-15ppm (Enwezor et al 1988) while the Bende soil had P lower than the critical level. Exchangeable bases were generally higher in Umudike compared to Bende.

### Sorption Characteristics

The phosphate sorption curves are presented in Figure 1. These curves relate the amount of P sorbed by the soils to the concentration of P in equilibrium solution (Beckwith 1965). From the isotherm curves, the standard P requirements (SPR) of the soils were calculated. The SPR was taken as the quantity of P required to attain a standard supernatant P concentration of 0.2$\mu gg^{-1}$ in equilibrium solution. The values were 45.0 and 21.5$\mu gg^{-1}$ for Umudike and Bende soils respectively. The values fall with the very low SPR in the scale of Juo and Fox (1974). The low P sorption capacity as indicated by the low SPR values showed that these soils have low capacity to retain applied P fertilizer (Osodeke 1996).

### Effects of P on Nodulation

Figure 2 shows the effects of the various P level calibrated from the isotherm curves on the nodulation of cowpea in the two locations. From the curve, there was a significant response of the crop to P fertilizer application in terms of nodulation. This is in agreement with the report of Danso (1992). The effects of phosphorus on nodulation/nitrogen fixation have been well documented (Attiogbevi – Somado 2000). He indicated that phosphorus act as fuel in the nitrogen fixation process. From the Figure, P added to the soil to give 0.2$\mu gg^{-1}$ solution concentration gave the optimum number of nodules in Umudike. The difference

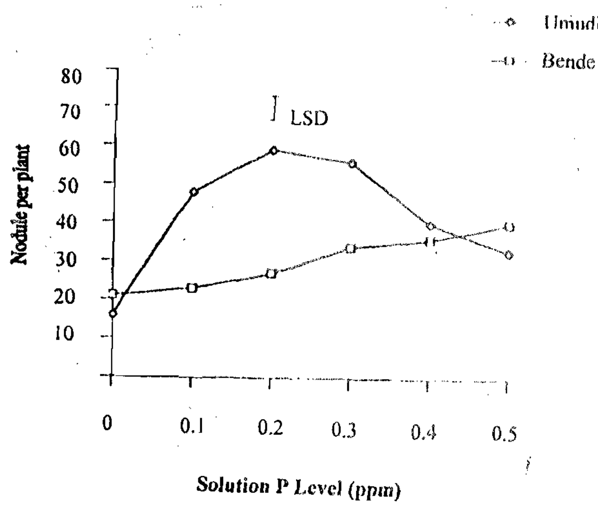


**Figure 2: Effects of the phosphorus levels on Number of nodules per plant in Umudike and Bende.**

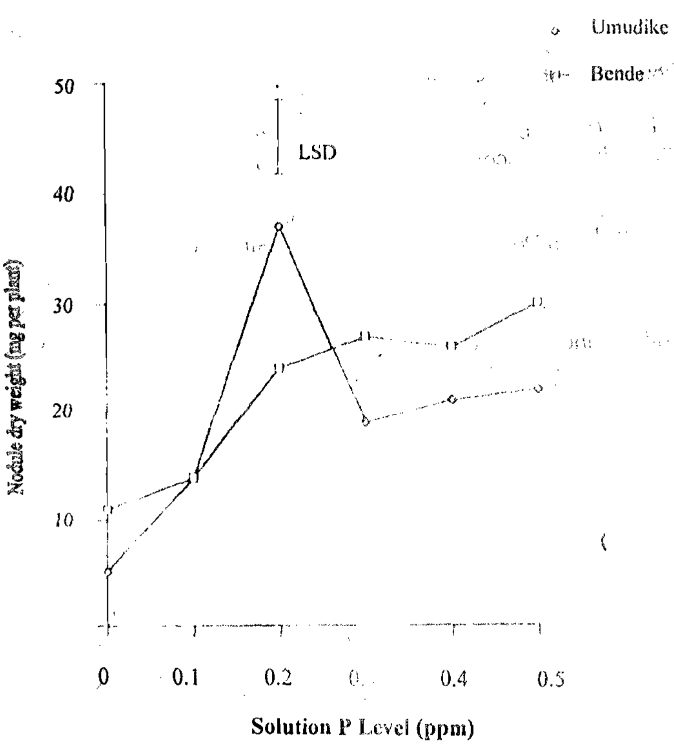


**Figure 3: Effects of the phosphorus levels on number of nodule dry weight per plant in Umudike and Bende.**

between the 0 application and the 0.2µgg$^{-1}$ solution P is significant (P≥0.05). In Bende, although P added to the soil to give 0.5µgg$^{-1}$ gave the highest number of nodule, the value is, however, not significantly different from that of 0.2µgg$^{-1}$ P application. The above trend was also observed for nodule dry weight. (Figure 3), therefore, P solution concentration of 0.2µgg$^{-1}$ equivalent to 45kgha$^{-1}$ in Umudike and 21.5kgha$^{1}$ in Bende is the optimum P requirement for nitrogen fixation in the two soil types.

**Effect of P on Growth and Yield Parameters**

Tables 2 and 3 represent the effect of P on height and grain yield of the cowpea respectively. From the table, application of phosphorus did not significantly affect the height of the crop in both locations. However, the tallest plants were recorded when P solution concentration of 0.5µgg$^{-1}$ was applied to the soils in locations. As indicated in Table 3, there was a significant response of the cowpea to phosphorus in both soil types in terms of grain yield. Phosphorus level of 0.4µgg$^{-1}$ gave the highest grain yield at Umudike. The yield at this level is significantly (P<0.05) different from that of zero, 0.1 and 0.2µgg$^{-1}$ P application, but not from other treatments. This is in agreement with the work of several workers that phosphorus is essential for grain yield in crops especially the legumes (Warren, 1992, Sahrawat et al 1999). However, the highest yield was recorded in Bende when 0.2µgg$^{-1}$ was applied. The cowpea produced higher grain yield at Umudike. The high yield of the crop at Umudike could be attributed to the low pH of the soil, and the relatively higher nutrient status of the soil of Umudike.

## CONCLUSION

The study indicated that the soils of the study area had very low phosphorus adsorption capacity. The cowpea also responded to the applied phosphorus with concentration, solution P of 0.2µgg$^{-1}$ giving the best in terms of nodulation while 0.4µgg$^{-1}$ P solution gave the optimum grain yield in both locations. Therefore, P rate of 45kgha is recommended for Umudike, and 21.5kgha$^{-1}$ for the soils of Bende .

## REFERENCES

Adeoye, G. O. and A.A. Agboola, 1984. Critical level for soil pH, available P, K, Zn, and Mn and Maize content of P, Cu, and Mn in the Sedimentary soils of Southwestern Nigeria. Fertilizer Research, 6: 65 – 71.

Ahn, P. M., 1970, West African Soils. Vol. 1. West African Agriculture. Oxford.

Anyaduba, E.T and Adepetu, J.A ., 1983. Predicting the phosphorus fertilizer need of tropical soils: significant of the relationship between critical soil solution P, requirement of cowpea sorption potential. Ph.D. Thesis O.A.U. Ile-Ife.

Attiogbevi-Somado, E., 2000. The use of phosphate rock in a rice-legume rotation system on the acid soils in the humid forest zone of the West Africa. Ph.D Thesis, the University of Goettingan, Germany.

Beckwith, R. S., 1965. Sorbed phosphate need of soils. Australian Journal of Experimental Agriculture and Animal Husbandry, 5: 52-58.

Bray, R. H. and Kurtz L. T., 1945. determination of total, organic and available forms of Phosphorus in soils. Soil Sci. 59: 39 – 45.

Bremner, R., 1965. Fabric and mineral analysis of soils. John Wiley and sons Inc. NY 470pp

Danso S K A ., 1992. Biological nitrogen fixation in tropical agro ecosystem: Twenty years of Biological Nitrogen fixation research in Africa. In Bilogical Nitrogen fixation and sustainability on tropical Agriculture. K.Mulonfoy et al (eds).pp3-13. John Wiley and sons Ltd Chichester U.K.

Enwezor W.O., 1977. Soil testing for phosphorus in some Nigerian soils.2.Predicting responses to phosphate application for soils of southern Nigeria. Soils Science, 123:111-116.

Enwezor W.O and Ohiri, A . C., Opuwaribo, E.E. and Udo, E.J., 1988.. Literature Review on Soil Fertility instigation in Nigeria (Five volume) Fertilizer procurement and distribution Division. Pp 281.

Fox, R.L. and Kamprath, E. J., 1970. Phosphate sorption isotherm for evaluating the phosphate requirements of soils. Soil Science Society of America Proceedings 34:902-907.

Juo, A .S. R., 1979. Selected methods for soil and plant Analysis. IITA. Manual Series No 1

Juo, A.R.S. and Fox, R. H., 1977. Phosphate Sorption characteristic of some benchmark of soils of West Africa. Soil Science 124:37-376.

Kamprath, E. J., 1967. Soil acidity and Response to lining. Tech. Bull. No 4 Int.

Kamprath, E.J. and Watson, M. E., 1980. conventional soil and tissue tests for assessing the phosphorus in Agriculture In: Khasawnch F.E (ed) pp 433-469 Agronomy Society of America. Madison 'Wisconsin'.

Mclean, E. O. 1965. Exchangeable aluminium. In: C.A. Black (ed). Methods of soil Analysis. Part II. *Agron.* 9: 985 – 990

Murphy J. and J.D. Riley 1965. A modified single solution for the determination of phosphorus in natural waters. Anal. Chem. Acta. 27:31-36.

Nnoke, F.N., 1980. The use of phosphorus sorption capacity of soils in the determination of phosphorus requirement of maize in some acid soils of southern Nigeria, PhD Thesis Nsukka.

Osodeke, V.E., 2000. Determination of the residual value of applied phisphorus in some soils of southern Nigeria. J.Sustain Agric. Environ. 1:73-79.

Osodeke, V. E., 1999. Determination of phosphorus requirements of Rubber Seedlings Using Sorption Isotherms. J. Sustain. Agric. Environ. 2(1): 139-143.

Sahrawat K. H. M. P. Jones, and ultisols of the humid forest zone in West Africa. *Commun. Soil Sci. Plant Anal.*,28(9-10) 711-716.

Uyovbisere, E. O. and Chude, O.C., 1995. Phosphate sorption characteristics of three typical soils from Nigeria as influenced by organic matter and Fe-oxides. Proceedings 3rd all Africa Soil Science Society Conference. Pp 461.

Walkley, A. and Black I. A. 1934. Determination of Organic Carbon in *Soil Sci*. 37;: 27 – 38.

Warren, G. P., 1992. Fertilizer phosphorus sorption and residual values in Tropical African Soils.N.R Bull. 37pp.

Wahua, T.A.T., 1999. Appliied statistics for scientific studies, Africa-link books, Ibadan, Nigeria 162-214 pp.