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# Phosphorus-use Efficiency by Pepper (*Capsicum frutescens)* and Okra (*Abelmoschus esculentum)* at Different Phosphorus Fertilizer Application Levels on Two Tropical Soils

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**Abstract:** Crop growth is continuously threatened by Phosphorus (P) limitation on most tropical and temperate soils. Besides P fertilizer management, soil type could significantly determine the efficiency of P use by specific crop species. In this study, the influence of 0, 50, 100, 150 and 200 mg $P_2O_5$ $kg^{-1}$ soil on the growth, P nutrition and production of two fruit vegetables (hot pepper, *Capsicum frutescens* and okra, *Abelmoschus esculentum*) were evaluated. The goal was to ascertain and compare P use efficiency by the crops on typical tropical soils (a medium acid, Oxic Paleustalf and a slightly acid, Typic Paleudalf). Growth in height, number of leaves and leaf area as well as biomass production, fruit yield, P content and uptake were determined. Increasing rates of P supply had insignificant ($p<0.05$) effect on the growth of the crops on both soil types within the first four Weeks After Planting (WAP). Phosphorus at 50 mg $P_2O_5$ $kg^{-1}$ application level, however, produced the tallest pepper plants (27.0 cm) on the Oxic Paleustalf after five weeks while it was the 150 mg $P_2O_5$ $kg^{-1}$ level that produced the tallest plants (40.0 cm) at the 6th week on the Typic Paleudalf. Soil available P values obtained after cropping increased significantly with increasing rates of added P. Okra plants were more efficient in their use of P than the pepper plants on the two soil types. It was evident that okra could be produced more successfully on soils with relatively low native or added P compared with pepper.

**Key words:** P-use efficiency, *Capsicum frutescens*, *Abelmoschus esculentum*, Typic Paleudalf, Oxic Paleustalf

## INTRODUCTION

Fruit vegetables are outstanding in the provision of flavour, appeal and desired taste besides supplying minerals and vitamins (carotene/vitamin B, ascorbic acid/vitamin C, calcium, etc.) required by the human body. Their protein has better proportion of amino acids compared with cereals and some leguminous crops[1]. Vegetable production could be highly profitable if the correct amount of fertilizer is applied and the crop species grown utilizes the fertilizer nutrients very efficiently. However, their production like that of the other tropical and temperate crops is continuously being threatened by Phosphorus (P) deficiency.

Among the soil nutrient elements, P is the second most essential after nitrogen[2]. Many studies[3,4] have shown that application of phosphoric fertilizers generally has a great impact on crop yields because P deficiency limits the response of plants to other nutrients[5], especially on highly weathered and leached soils of both tropical and temperate regions of the world where soil acidity causes infertility and general limitation to crop production[6]. According to Jones[5], soils from the forest and guinea savannah agro-ecological zones are deficient in P and application of phosphate fertilizers to build up the soil P reserve is imperative if the annual and long-term requirements of P by crops will be met.

Several research[7,8] have shown that different plant species and varieties vary in their behaviour to acquire and utilize nutrients for biological and/or economic yield production. The identification of crop species that can effectively utilize soil P would assist in improving the yield of such crops on acid P-deficient Alfisols. Consequently, this experiment was conducted to evaluate the response of pepper and okra to different levels of P and determine P use efficiency by the crops at various P application levels.

## MATERIALS AND METHODS

The study involved a greenhouse soil culture experiment with two soil-types, a medium acid Oxic Paleustalf from Zaria and another slightly acid Typic Paleustalf from Ibadan in the Southern Guinea Savannah and Rainforest agro-ecological zones of Nigeria, respectively. The soil samples were passed through a 2 mm sieve to remove plant roots, stones and other debris before 3.0 kg samples were weighed into each plastic pot.

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Using single super phosphate, SSP (18% $P_2O_5$) five P levels (0, 50, 100, 150 and 200 mg $P_2O_5$ $kg^{-1}$ soil) were applied by thoroughly mixing the fertilizer material with the soil. Seeds of two fruit vegetables, hot pepper (*Capsicum frutecens* var. Serrano chilli) and okra (*Abelmoschus esculentum* var. 47 – 2) were subsequently planted. Thirty - plastic pots were used for each test crop, (fifteen for each of the two soil types) giving 20 experimental pots for the 2 x 2 x 5 treatment combinations that were replicated 3 times in a Completely Randomised Design to make a total of 60 experimental units.

The pepper seedlings were raised in a nursery tray for two weeks before transplanting but the okra seeds were planted directly into the respective pots. In both cases, four seedlings were allowed per pot until thinning to two seedlings per pot after one week of establishment. Data were taken on parameters like plant height (cm), number of leaves, leaf area ($cm^2$), shoot weight/biomass (g $pot^{-1}$), post cropping soil available P (mg $kg^{-1}$), P use efficiency as well as P contents and uptake by pepper and okra plants. The data were subjected to analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) was used in detecting differences between means at 5% confidence level.

For pre-cropping physico-chemical soil analysis, one representative sample for each of the two soil types were air dried for five days under ambient temperature, passed through 2 mm sieve. Soil pH was measured using a 1:2 (m $v^{-1}$) soil water suspension ratio. Total-N was determined by the Kjeldahl method while organic carbon was determined by the 'Walkey and Black' procedure[6]. Available-P was determined by Bray-1 method[9] Potassium, Ca and Mg were extracted using neutral normal $NH_4OAC$. Thereafter, K was determined by flame spectrophotometer while Mg, Ca and the other exchangeable bases were read with the atomic absorption spectrophotometer according to Juo[10]. Particle size distribution was determined by the hydrometer method[11].

Shoot biomass was recorded immediately after harvesting at 7 WAP. Shoots were subsequently oven-dried at about 75⁰C and milled after attaining a constant weight. The ground materials were wet-digested using nitric ($HNO_3$) and perchloric ($HClO_4$) acid mixture of ratio 2:1. The P concentration of each digest was determined colorimetrically[12] while P uptake (mg $pot^{-1}$) was estimated by multiplying the concentration by the Dry Matter (DM) produced per pot.

Table 1: Physico-chemical properties of the experimental soils

| Properties | Soil type<br>A (Zaria location)<br>Oxic paleustalf | <br>B (Ibadan location)<br>Typic paleudalf |
|---|---|---|
| pH ($H_2O$) | 5.70 | 6.70 |
| Organic C (g $kg^{-1}$) | 1.46 | 3.40 |
| Total N (g $kg^{-1}$) | 1.42 | 0.30 |
| Bray-1 P (g $kg^{-1}$) | 2.11 | 5.46 |
| Exchangeable bases and micronutrients (cmol $kg^{-1}$) | | |
| Ca | 2.30 | 0.27 |
| Mg | 2.14 | 0.12 |
| K | 0.25 | 0.04 |
| Na | 0.84 | 0.80 |
| Mn | 30.01 | 0.12 |
| Cu | 2.41 | |
| Fe | 6.04 | |
| Zn | 14.40 | |
| Sand (g $kg^{-1}$) | 332.00 | 812.00 |
| Clay (g $kg^{-1}$) | 188.00 | 120.00 |
| Silt (g $kg^{-1}$) | 480.00 | 68.00 |

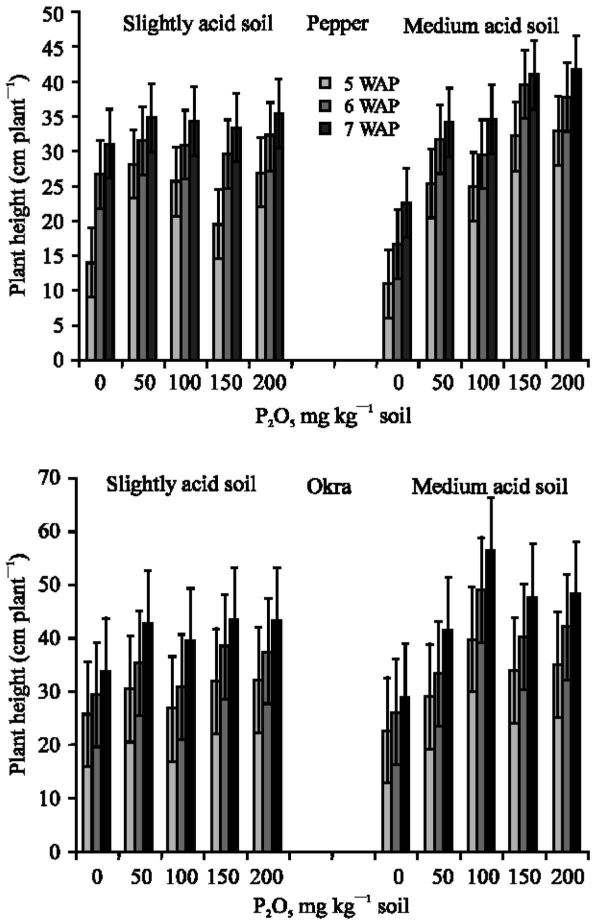

Fig. 1: Height of pepper and okra plants (at successive growth periods and various phosphorus supplies) on the slightly acid and the medium acid Alfisols

## RESULTS AND DISCUSSION

**Properties of the experimental soils:** The Zaria and Ibadan location soils had pH values of 5.7 and 6.7,

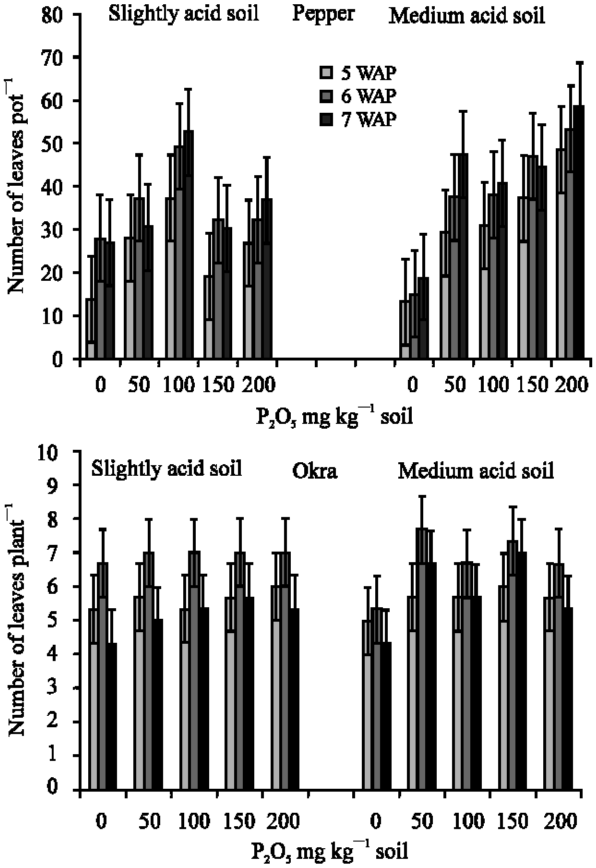

Fig. 2: Number of Leaves of pepper and okra plants (at successive growth periods and various phosphorus supplies) on the slightly acid and the medium acid Alfisols

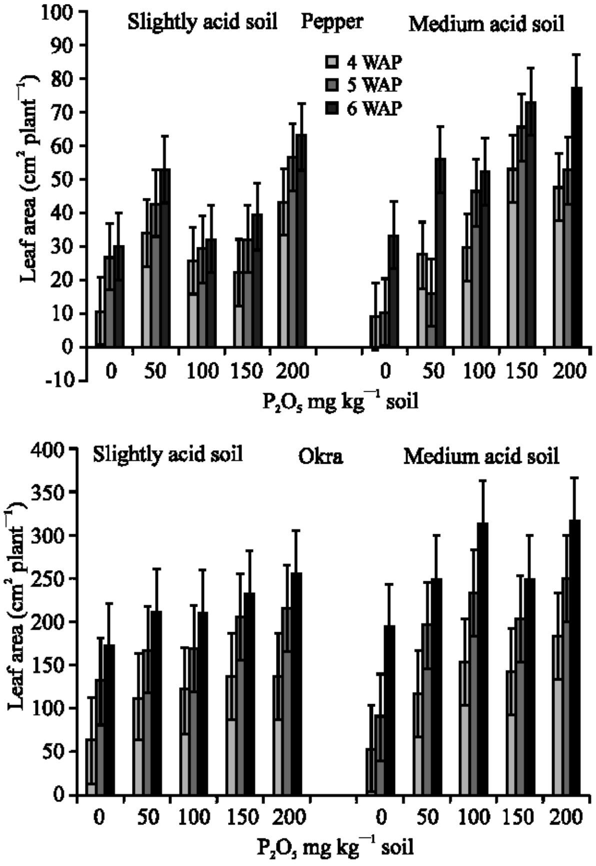

Fig. 3: Leaf area of pepper and okra plants (at successive growth periods and various phosphorus supplies) on the slightly acid and the medium acid Alfisols

indicating that they were medium and slightly acid soils, respectively (Table 1). Total N was higher in Zaria location soil (1.42 g kg$^{-1}$) than in Ibadan location soil (0.30 g kg$^{-1}$). However, available P was deficient in the two soils-being 5.46 mg kg$^{-1}$ in Ibadan location and 2.11 mg kg$^{-1}$ in Zaria location[13].

**The influence of phosphorus application levels on the growth parameters:** The differences between the treated and the untreated plants were not significant during the first four weeks of growth as the native soil fertility was adequate to supply the minimum amounts of the various essential nutrient elements needed for crop growth at this period (Fig. 1-3). Between the fifth and seventh weeks however, the crops' response to applied P varied significantly at the various fertilizer levels and in the two soil types.

It is evident from Fig. 1 that on the two soils, unfertilised pepper plants were consistently shorter than the fertilized ones. In the case of okra plants, P fertilization had no significant influence on plant height at all the successive growth periods on the slightly acid soil whereas 100 mg P$_2$O$_5$ kg$^{-1}$ soil produced taller plants than the unfertilised ones on the medium acid soil. It was revealed that only a little amount of fertilizer P was needed to complement the native soil available P to meet the increasing demand of the crops, as they grow older.

Production of leaves in pepper was optimum at 100 mg P$_2$O$_5$ kg$^{-1}$ soil on both soil types while 50 mg P$_2$O$_5$ kg$^{-1}$ proved sufficient for okra on the medium acid soil but fertilization had no influence on the number of okra leaves produced on the slightly acid soil Fig. 2. The highest mean number of pepper leaves per pot at the 5th, 6th and 7th WAP (37, 50 and 52 leaves pot$^{-1}$, respectively) were produced with 100 mg P$_2$O$_5$ kg$^{-1}$ on the slightly acid soil. Similarly, 50 mg P$_2$O$_5$ kg$^{-1}$ soil produced the highest mean number of okra leaves per pot at 6th WAP on the medium acid soil. On the medium acid soil, unlike on

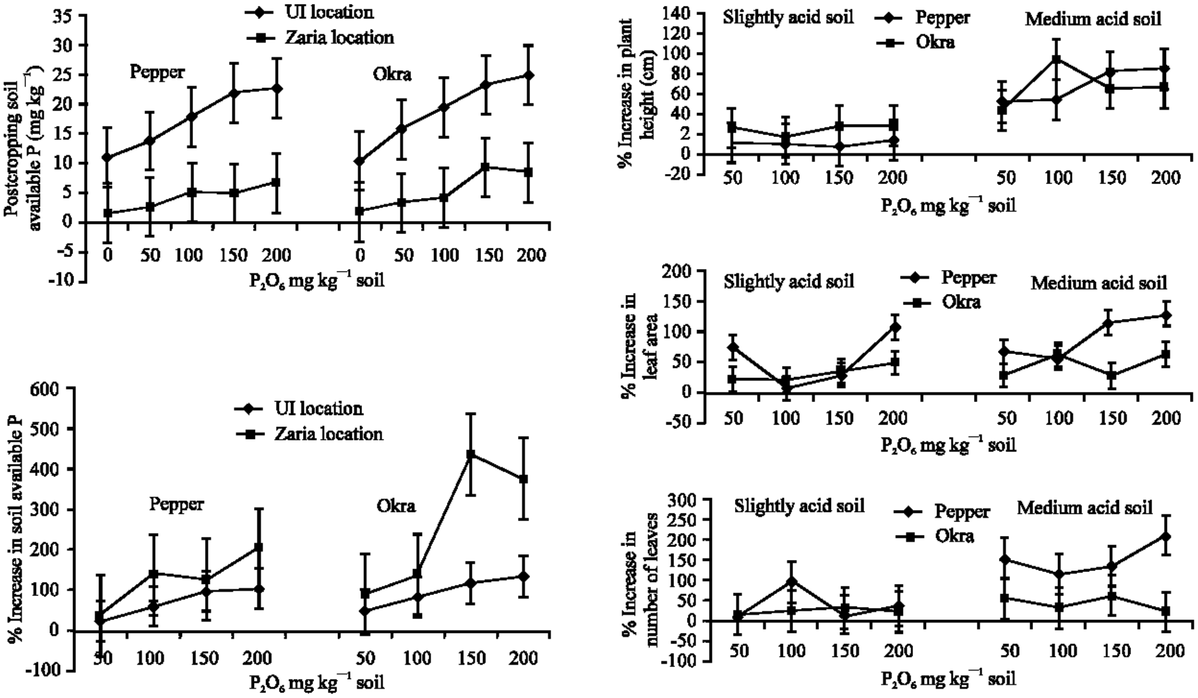

Fig. 4: Changes in soil available phosphorus, height, leaf area and number of leaves of pepper and okra with increase in phosphorus supply. [UI location = Slightly acid soil; Zaria location = Medium acid soil]

the slightly acid soil, fertilized plants consistently had larger leaves than control plants (Fig. 3). Depending on the period of growth, optimal rate varied between 100 and 150 mg $P_2O_5$ kg$^{-1}$ on the medium acid soil. On the slightly acid soil, 50 mg $P_2O_5$ kg$^{-1}$ fertilization was optimal for leaf expansion in pepper plants. It was evident that the crops did not respond positively to higher increasing P rate after 50 mg $P_2O_5$ kg$^{-1}$ on the slightly acid soil.

**Percent increases in soil phosphorus and growth parameters of pepper and okra with increase in phosphorus supply:** Expectedly, residual P increased with the P application levels after the growth of the two test crops on both soil types (Fig. 4). Only small proportions of P applied were actually absorbed and utilized by the crops while the various proportions remaining after crop harvest were used in building up soil P reserve. Thus, very small rather than large amounts of P could boost the production of pepper and okra on slightly and medium acid Alfisols.

The 150 and 200 mg $P_2O_5$ kg$^{-1}$ fertilization levels significantly increased post-cropping soil available P above the control in the slightly acid soil type irrespective of the crop grown (Fig. 4). It was clear, however, that the slightly acid soil (UI location) had higher amounts of available P than the medium acid soil (Zaria location) at each of the P fertilizer levels. The% increases in soil available P (due to fertilizer treatment) were, however, significantly higher for the medium acid soil than for the slightly acid soil and was when up to 150 or 200 mg $P_2O_5$ kg$^{-1}$ was added in the production of okra. Comparing the increases in the growth parameters for pepper and okra, the relative (%) increases in the growth parameters of the plants fertilized compared with the control plants were not significantly different at all the P fertilization levels for both soil types and test crop, except for number of leaves and leaf area when 150 or 200 mg $P_2O_5$ kg$^{-1}$ was applied on the two soil types.

**Biomass production, phosphorus contents and uptake by pepper and okra plants:** Absolute and relative biomass production were more on the medium acid soil than on the slightly acid soil, particularly with 150 or 200 mg $P_2O_5$ kg$^{-1}$ fertilization (Fig. 5). A similar trend was observed for the P uptake values while the reverse was the case for the absolute P contents in the tissues of both test crops but %increases in P contents were also more for the medium acid soil.

The P contents in the tissues of pepper and okra revealed a rapid response by the plants treated to 50 mg $P_2O_5$ kg$^{-1}$ relative to the control ones (Fig. 5). Afterwards (between 100 and 200 mg $P_2O_5$ kg$^{-1}$), the trend changed with noticeable fluctuations and insignificant

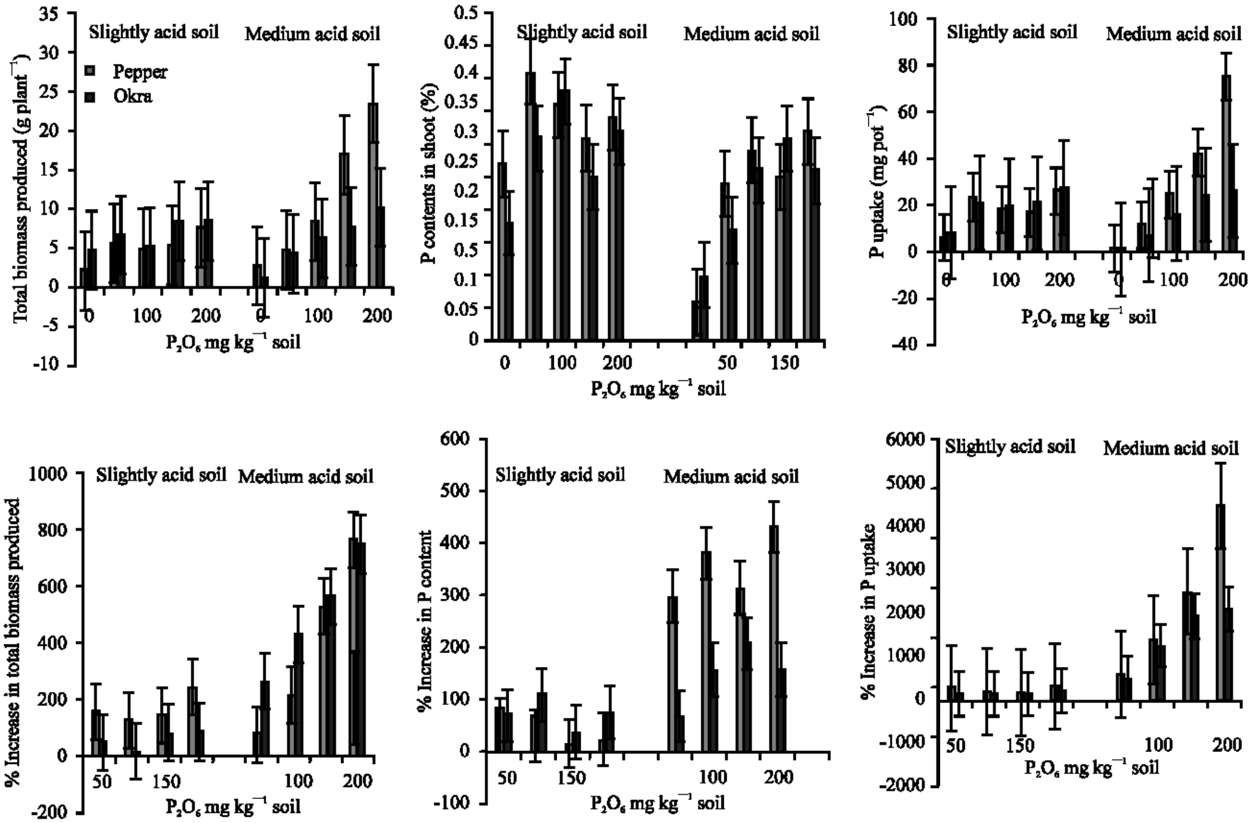

Fig. 5: Total biomass production, phosphorus contents and uptake by paper and okra plants and the relative (%) increases at the various phosphorus application levels in the two soil types

response. On the slightly acid soil, highest mean tissue P content of pepper was 0.40% with 50 mg$P_20_5$ kg$^{-1}$. With respect to okra plants the highest was 0.38% with 100 mg $P_20_5$ kg$^{-1}$.

**Phosphorus use efficiency by pepper and okra plants at various phosphorus supplies:** On total dry weight (biomass) basis, okra was more efficient than pepper in the use of P on the two soil types (Fig. 6). The P-use efficiency by pepper was highest at 0 mg $P_2O_5$ kg$^{-1}$ and insignificant at the various P addition levels, particularly on the medium acid soil. Okra plants grown on medium acid soil had increasing linear response to fertilizer P application in the order: 200 mg $P_2O_5$ kg$^{-1}$ >150 mg $P_2O_5$ kg$^{-1}$ > 100 mg $P_2O_5$ kg$^{-1}$ > 50 mg $P_2O_5$ kg$^{-1}$ >0 mg $P_2O_5$ kg$^{-1}$, the respective P use efficiency values being 480, 370, 300, 200 and 50 mg mg$^{-1}$. The P –use efficiency values on fresh and dry fruit weight bases for both crops on the two soil types followed the same pattern with the control (0 mg $P_2O_5$ kg$^{-1}$ soil) having the highest and there were insignificant differences in the level of P-use efficiency at 50, 100, 150 and 200 mg $P_2O_5$ kg$^{-1}$ for okra and pepper for the medium acid soil.

## CONCLUSIONS

Soil available P management permits judicious use of fertilizers as production inputs. It is the key for sustainable soil fertility maintenance essential for optimum crop production on acid P-deficient Alfisols. The increasing costs and inaccessibility of chemical fertilizers to small and medium scale farmers in developing nations coupled with possible environmental pollution make it imperative that research efforts should focus on maximum production of good quality crops while avoiding excessive and indiscriminate fertilizer use. Soil types should also be specified when screening crop species/varieties for their requirement of nutrients, in general and P requirement in particular.

From this preliminary study, it can be suggested (for further trial on the field) that as little as 50 mg $P_2O_5$ kg$^{-1}$

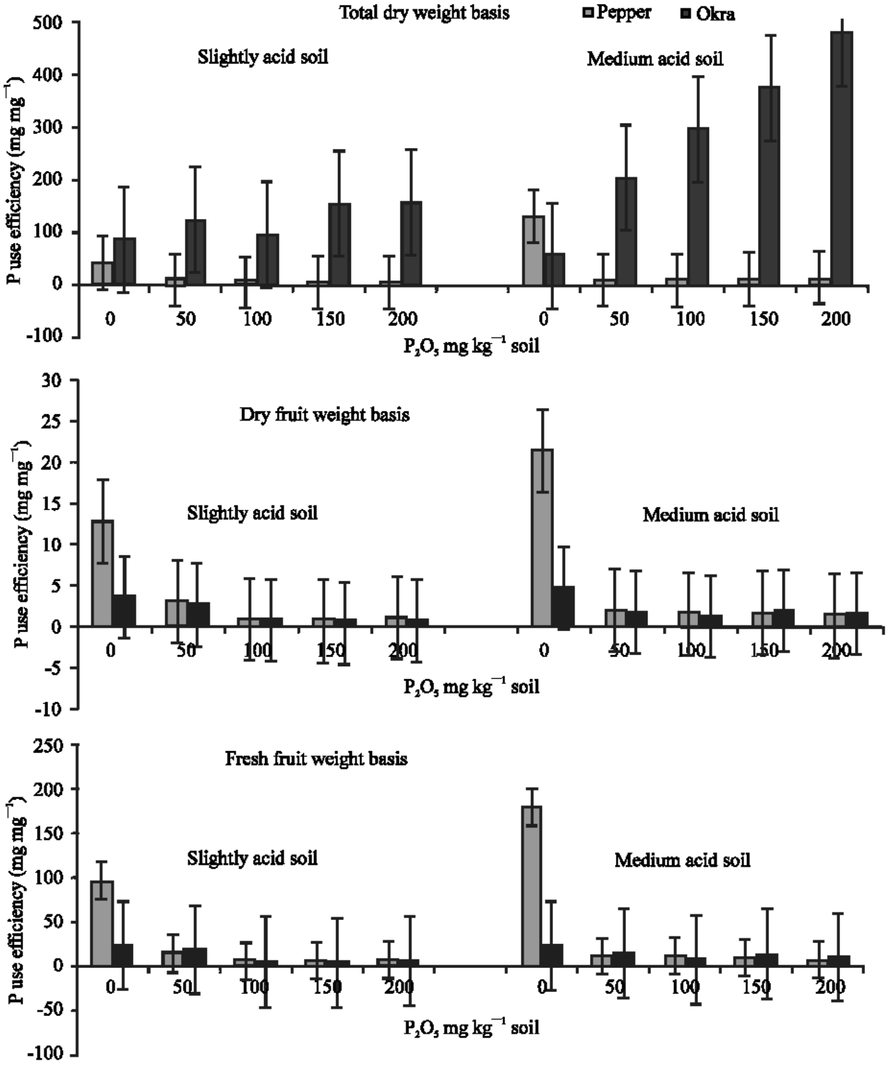

Fig. 6: Phosphorus use efficiency by pepper and okra plants (estimated on total biomass and fruit weight basis) at various phosphorus supplies

soil could be sufficient for pepper and okra on slightly acid Alfisols and between 50 mg $P_2O_5$ kg$^{-1}$ and 100 mg $P_2O_5$ kg$^{-1}$ for medium acid Alfisols. The more the quantities of fertilizer used, the less the efficiency of the crops to use the nutrient element.

## REFERENCES

1. Anonymous, 1991. Yearbook of Production. FAO Rome, Italy, 45: 24- 44.
2. Anonymous, 2002. Nutrient deficiency symptoms in rice. Better Crops Intl., 16: 2-25.
3. Alaam, S.M., A. Latif and I. Zafar, 2002. Wheat yield and phosphorus use efficiency as influenced by method of phosphorus and zinc application. Pak. J. Sci. Ind. Res., 45: 117-119.
4. Nisar, A., M.T. Saleem and I.T. Twyford, 1992. Phosphorus research in Pakistan: A review. Proceeding of Symposium on the, The Role of Phosphorus on Crop Production. NFDC, Islamadad, pp: 59-92.
5. Jones, U.S., 1982. Fertilizers and Soil Fertility. 2nd Edn. Reston Publishing Coy, Inc., pp: 421.
6. Walkey, A. and I.A.C. Black, 1934. An examination of degit jareff method for determining soil organic matter and a proposal modification of the chronic acid titration method. Soil Sci., 37: 29-28.
7. Fageria, N.K. and V.C. Baligar, 1997. Phosphorus-use efficiency by corn genotypes. J. Plant Nutr., 20: 1267-1277.

8. Hogh-Jensen, H. and M.B. Pedersen, 2003. Morphological plasticity by crop plants and their potassium use efficiency. J. Plant Nutr., 26: 969-984.
9. Bray, R.H. and L.T. Kurz, 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci., 59: 39-45.
10. Juo, A.S.R., 1979. Automated and Semi-automated Methods for Soil and Plant Analysis. Manual Series No. 7, IITA, Ibadan, Nigeria, pp: 1-22.
11. Day, P.R., 1965. Particle Fractionation and Particle Size Analysis. Methods of Soil Analysis Inc. Mattison Wisconsin 9: 545-567.
12. Murphy, J. and J.P. Riley, 1962. Analytical chemistry. Acta, 29: 31-36.
13. Kadiata, B.D. and K. Lumpungu, 2003. Differential phosphorus uptake and use efficency among selected nitrogen-fixing tree legumes over time. J. Plant Nutr., 26: 1009-1022.