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Response of Okra (*Abelmoschus esculentus*) to Lime and Phosphorus Fertilization in an Acid Soil

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Abstract: A pot experiment was conducted to determine the effect of lime ($CaCO_3$) and phosphorus (P) application on the growth and yield of okra (*Abelmoschus esculentus)* on an acid soil. This was followed by a field trial to validate the findings from the pot study. Three rates of lime equivalent to 0, 500 and 1000 kg $CaCO_3$ ha^{-1} and five rates of P equivalent to 0, 10, 20, 30 and 40 kg P ha^{-1} of single super phosphate were applied in combinations as treatments. Pot study results obtained showed that plant growth, dry matter and fruit yields of okra were significantly increased due to application of low rates of lime or P and varying combinations of both, when compared with the control (no fertilizer, no lime). Combination of the lowest rates of lime and P (10 kg P and 500 kg $CaCO_3$ ha^{-1}) was found to be optimum for plant growth. Dry matter yield of plant shoot and root increased with increasing rates of both lime and P applied. However, highest fruit yields were obtained when lime was applied with or without P, while P increased fruit yield to the highest values only in the presence of lime. The results obtained in the field were similar to the trend observed in the pot study. Lime had significantly positive effect on P concentration in plant and actually reduced the amount of fertilizer P required for optimum yield. Therefore, for good performance of okra on acid soils it is beneficial to apply low level of lime along with low rates of P.

Key words: Lime · okra yield · phosphorus · soil acidity

INTRODUCTION

Soil acidity is common in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface of soil. In Nigeria acid soils cover about 17 million hectares of land. This represents about 18% of total land area [1]. These soils are prevalent in areas experiencing high annual rainfall (about 1500 mm or more). This is in line with the observation of Conyers [2], that the amount of neutral salt exchangeable aluminum in surface soils tends to increase with increasing annual rainfall. Acid soils, especially the Ultisols and Oxisols usually have problems associated with aluminum toxicity, low nutrient status, nutrients imbalance and multiple nutrient deficiencies [3].

Liming is an ancient agricultural practice for rehabilitating acid soils it continues to be accepted as an essential step to effective agricultural production in several areas of the humid tropics. The overall effects of lime on soils include among others, increased soil pH, Ca and Mg saturation, neutralization of toxic concentrations of aluminum, increase in pH dependent CEC resulting in absorption and hydrolysis of Ca^{2+} (Mg^{2+}), increase in P availability and improved nutrient uptake by plants [1, 4]. Kamprath and Foy [5] reported that liming effect on P availability of highly weathered soils varied from favourable to detrimental. Liming to pH 7 however drastically reduced P uptake from acid, aluminous Latosols. Neutralization of exchangeable Al reduced by 50% the P fertilizer required for optimum growth on North Carolina soils. However, liming had an effect on P uptake when initial pH was 5.8 very little response was obtained from 80 ppm P for Oxisol in Natal, until liming neutralized exchangeable Al. Similar result was obtained with an Oxisols from Colombia [6]. Phosphorus is often described as the second limiting nutrient in crop production after nitrogen [7]. Unfortunately this highly essential nutrient usually found to be deficient in a number of soil types. The deficiency is not due to low level of total P alone but rather to its fixation as a result of soil acidity. Phosphorus is readily available to plants at pH ranges of 5. 6 - 6.7 [8].

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MATERIALS AND METHODS

Greenhouse experiment: Greenhouse study was conducted at Moor Plantation Ibadan. The soil used was an acid sand classified as Udipsamment (USDA) and was collected from a cultivated land in Epe, near Lagos. The soil was air dried and sieved to pass through a 2 mm screen and later analyzed in the laboratory.

Three rates of lime equivalent to 0 (L_0), 500 (L_{500}) and 1000 (L_{1000}) kg $CaCO_3$ ha^{-1} and five rates of P equivalent to (P_0), 10 (P_{10}), 20 (P_{20}) and 30 (P_{30}) and 40 (P_{40}) kg P ha^{-1} of single super phosphate were applied accordingly to each pot containing 5 kg soil. Urea was applied at 50 kg N ha^{-1} to supply adequate nitrogen to okra. Each of the pots was provided with two drainage holes and a saucer. The treatments were thoroughly mixed with the soil and moistened with water for one week for proper equilibration. The treatments were replicated three times in a Completely Randomized Block Design (CRBD). Three seeds of okra (Abelmoschus escluentus, 47-4 early maturing variety) were sown in each pot and thinned to two plants per pot one week after planting. Leaf samples were taken at 5 weeks after planting for chemical analysis. The growth parameters taken were plant height, number of leaves, number of flowers and fruit weight. At maturity, the fruits were harvested and fruit yield was determined. The plant tops and roots were taken separately and oven-dried at 65°C for dry matter yield determination. Post crop soil samples were taken for chemical analysis.

Field trial: Evaluation of the liming materials used in the greenhouse was carried out on the field at I.A.R&T Moor Plantation Ibadan. The soil used is an Iwo series. Prior to field experimentation bulked samples were randomly collected from the surface soil (0-15 cm depth) for physical and chemical analysis. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The blocks were spaced 1m apart and each consisting of 15 plots and each plot measuring 2.4 m x 2.1 m. The same treatments used in the greenhouse were tested on the field.

Lime ($CaCO_3$) was thoroughly and evenly distributed to the plots according to the treatment rate and was left for four weeks before planting the okra seeds. Variety 47-4 used in the greenhouse was planted at the rate of three seeds per hill at a spacing of 60 cm x 30 cm inter and intra row, respectively. Seedlings were thinned to two plants per stand one week after planting. Phosphorus was applied 2 weeks after planting. Weeding was done with hoe at 2, 6 and 9 weeks after planting. Parameters taken were similar to greenhouse data. Leaf samples were taken eight weeks after planting for laboratory tissue analysis. Fresh fruits were harvested and weighed at three days interval until fruiting declined drastically. A total of nine harvestings were done. Post harvest soil samples were taken from all plots for laboratory chemical analysis.

Soil and plant analysis: Mechanical analysis of the soil was done by the hydrometer method using sodium hexametaphosphate as dispersing agent [9]. Soil pH was determined in distilled water at soil to water ratio 1:1 (w/v) using the glass electrode on an EIL 7020 pH meter. Organic carbon was determined by wet oxidation with sulphuric acid [10]. Exchangeable cations were determined by extraction with neutral normal ammonium acetate at soil solution ratio 1:10 and measured on the Flame photometer. Magnesium was determined by Atomic Absorption Spectrophotometry after extraction with NH_4OAc-EDTA (pH 4.65). Exchangeable aluminum was determined by the aluminon method of Barnished and Bertsch [11]. Available P was determined using 0.03N NH_4F in 0.025NHCl as extractant (Bray P No 1test) and measuring the extracted P colorimetrically by the Molybdenum Blue method [12].

Statistical analysis: Data generated were subjected to analysis of variance procedure and means were separated by Duncan multiple range test.

RESULTS AND DISCUSSION

Soil physical and chemical properties prior to cropping: The soil physical and chemical properties prior to cropping are presented in Table 1. The Epe soil used for greenhouse study is acidic in nature (pH 5.3), while the soil on which the field study was carried out is highly acidic (pH 4.30). The soils are characterized by low levels of organic matter and nitrogen. The fertilities of the soils were low as indicated by the generally low values of exchangeable bases and other nutrients including P.

Plant height, number of leaves, flower and fruits of okra plant: The results on Table 2 show that plant height was significantly ($p = 0.05$) increased by the application of all rates of lime and P applied either singly or in combination both in the greenhouse and field studies. Control plants were remarkably shorter than treated ones in both cases. The tallest were obtained using 10 kg P combined with 500 kg $CaCO_3$ ha^{-1} in the greenhouse. This was closely followed by treatments having the highest rate of lime (1000 kg ha^{-1}) and P (40 kg ha^{-1}) in combination.

Table 1: Some selected soil physical and chemical properties prior to cropping

Properties	Greenhouse soil	Field soil
Sand (%)	93.20	88.20
Salt (%)	1.60	6.00
Clay (%)	5.20	4.80
pH (H_2O)	5.30	4.30
Exchangeable bases (cmol kg^{-1})		
Ca	0.20	0.63
Mg	0.02	0.43
K	0.03	0.17
Na	0.24	0.04
Acidity cmol kg^{-1}	1.67	1.67
Exch. Al cmol kg^{-1}	0.07	0.88
CEC cmol kg^{-1}	2.07	2.91
C g kg^{-1}	8.60	4.20
N g kg^{-1}	0.9	0.46
Avail. P mg kg^{-1}	9.80	7.92

Table 2: Effect of lime and P application an the growth of okra

Treatments (kg ha^{-1})		Height (cm)		No. of leave	
Lime	P	Greenhouse	Field	Greenhouse	Field
0	0	9.5f	12.50c	4b	7.0e
	10	12.4e	18.80b	6a	9.0d
	20	15.6b-d	14.00b	6a	9.0d
	30	16.2a-c	18.50b	6a	9.0d
	40	16.9a-c	21.11ab	7a	9.0d
500	0	14.0de	26.30ab	6a	10.0c
	10	18.5a	38.60a	7a	14.0a
	20	18.5a	27.20ab	6a	12.0c
	30	16.4a-c	16.60b	7a	9.0d
	40	17.1ab	18.50b	6a	9.0d
1000	0	14.4b-d	29.30ab	7a	13.0b
	10	14.1c-e	24.00ab	6a	10.0c
	20	15.8b-d	16.30b	6a	7.0e
	30	17.4ab	17.30b	6a	7.0e
	40	18.3a	18.60b	7a	9.0d

Mean(s) having the some letter(s) are not significantly different according Duncan Multiple Range Test (DMRT)

In the field the highest value of plant height was also obtained from 500 kg ha^{-1} lime plus 10 kg ha^{-1} P. It was observed that lime alone increased plant height significantly and comparably with the above combination. Value obtained with P alone were generally lower than with lime either alone or combined with P except at 40 kg ha^{-1} which gave 21.11 cm.

The results also showed some increase due to application of lime or P or both on number of leaves produced. However, statistical analysis on the data shows no significant difference due to application of different rates of lime and P when applied either singly or in combined form in greenhouse study. Significant difference was observed on the number of leaves produced in the field, the highest number being obtained from 500 kg ha^{-1} lime combined with 10 kg ha^{-1} P. This was closely followed by 1000 kg ha^{-1} lime applied solely. There was no significant difference between number of leaves when lime 500 kg were applied alone or combined with 20 kg P ha^{-1} and when 1000 kg ha^{-1} lime was applied in combination with 10 kg P ha^{-1}.

Table 3: Effect of lime and P on the dry matter and fruit yield of okra

Treatments		Greenhouse			Field trial	
Lime (kg ha^{-1})	P (kg ha^{-1})	Dry matter yield (g)	No. of fruit	Fruit yield (g)	No. of fruit	Fruit yield (kg ha^{-1})
0	0	2.14d	1.4c	1.41d	4.9c	426.10d
	10	5.70c	1.9b	3.04bd	12.8b	1099.20bc
	20	8.33bc	1.9b	4.73a	14.5b	986.70c
	30	8.40bc	2.0a	4.56a	11.9b	949.80c
	40	8.48bc	2.1a	4.32a	12.96	932.80c
500	0	9.63.bc	1.9b	4.02ab	20.5ab	1036.20bc
	10	11.80b	2.0a	4.65a	30.0a	3001.90a
	20	12.98ab	1.9b	3.27bc	15.7b	1463.30b
	30	12.50ab	1.9b	4.34a	15.6b	1080.00bc
	40	11.83b	2.0a	4.87a	17.9b	1037.10bc
1000	0	8.94bc	2.1a	4.73a	14.5b	1154.30bc
	10	10.02bc	1.8b	4.72a	13.7b	1031.80bc
	20	10.67b	1.9b	4.37a	15.7b	16.00b
	30	12.96ab	1.9b	3.94a	17.3b	924.90c
	40	16.66a	1.9b	2.59c	14.1b	863.3c

Mean(s) having the some letter(s) are not significantly different according Duncan Multiple Range Test (DMRT)

Dry matter and fruit yield: Result of dry matter yield showed that P increased dry matter significantly in Table 3. However this effect was boosted by combining lime with P applied .For instance, dry matter produced by combining 500 kg lime with 10 kg P about double the dry matter obtained from 10 kg P applied alone. The same trend occurred between 40 kg P applied without lime and in combination with 1000 kg lime. The highest dry matter yield was obtained by combining 1000 kg ha^{-1} lime with 40 kg P but no significant difference was observed between this and results recorded from 500 kg ha^{-1} lime plus 20 kg P ha, 500 kg ha^{-1} lime plus 30 kg P ha^{-1} and 1000 kg ha^{-1} lime plus 30 kg P ha^{-1}.

Significant increases in number of fruits were produced by all the treatments. The highest numbers of fruits were obtained from pots treated with highest rate P (40 kg P ha^{-1}) without lime application, highest rate of lime (1000 kg $CaCO_3$ ha^{-1} .) without P and from a combination of low levels of both P (10 kg ha^{-1}) and lime (500 kg ha^{-1}) in the greenhouse study. Results from all other treatment were similar. In the field study, there was no significant difference among the levels of P when applied with or without lime. The only exception was the combination of 500 kg ha^{-1} of lime with 10 kg P ha^{-1}, which gave significantly higher number of fruits than all

Table 4: Leaf Nutrient concentration as affected by lime and P application

Treatments (kg ha^{-1})		Greenhouse (%)			Field (%)		
Lime	P	Ca	K	P	Ca	K	P
0	0	0.25c	0.51b	0.026c	0.42c	0.26c	1.35c
	10	0.23d	0.03c	0.020cd	0.62b	0.32c	1.45c
	20	0.38b	0.04c	0.030bc	0.51bc	0.33a	1.45c
	30	0.36b	0.14b	0.048b	0.51bc	0.35c	1.47c
	40	0.40b	0.26a	0.063a	0.75ab	0.40c	1.44c
500	0	0.33bc	0.05c	0.043b	0.72ab	0.51b	1.43c
	10	0.31bc	0.16b	0.026c	0.70ab	0.42c	2.74a
	20	0.33bc	0.20ab	0.016b-d	0.67b	0.61a	1.67b
	30	0.44ab	0.21ab	0.036bc	0.63b	0.63a	1.55c
	40	0.52a	0.23ab	0.053ab	0.75ab	0.61a	1.53c
1000	0	0.46ab	0.05c	0.043b	0.81a	0.28c	1.42c
	10	0.27c	0.09bc	0.026c	0.63b	0.34c	1.37c
	20	0.33bc	0.14b	0.036bc	0.60b	0.37c	1.44c
	30	0.27c	0.09bc	0.039b	0.52bc	0.37c	1.41c
	40	0.21d	0.05c	0.043b	0.43c	0.30c	1.40c

Mean(s) having the some letter(s) are not significantly different according Duncan Multiple Range Test (DMRT)

other treatments. This treatment gave more than twice the number of fruit produced when 10 kg P ha^{-1} was applied alone and about six times the number produced by the untreated control. There was no significant difference in the number of fruits when lime or P was applied alone, though figures obtained for lime alone were higher P alone. A higher rate of lime with and without different rates of P were not more beneficial statistically speaking than lime without P or P without lime. Thus a low level of P combination with a low level of lime significantly enhanced okra fruiting. This confirms the importance of the two treatments in the vegetative and reproductive life of okra plants. Furthermore, the result is indicative of the ability of lime to release soil P for plant use. The presence of a low rate of lime has reduced the amount of fertilizer P required for optimum crop performance. This is consonance with the report of Kamprath and Foy [5]. A decline in number of fruits was observed with combined use of high rate of both lime and P. This is probably an indication of some over liming effect, which might have caused nutrient imbalance in the soil.

The yield of fruits presented a somewhat different trend. Lime and Phosphorus applied either singly or a combination significantly increased fruit yield. When P was applied without lime, yield increased with increasing rate of P but there was no significant difference aiming P at rates 20, 30 and 40 kg ha^{-1}. However, when combined with 500 kg $CaCO_3$ ha^{-1}, the results showed that application of P fertilizer above 10 kg ha^{-1} was not necessary. This is in line with the findings of Kamprath and Foy [5], that neutralization of exchangeable Al reduced fertilizer P required by 50% and that of Adinigshi *et al*. [13], that P fertilizer efficiency is increased by lime application. The results also showed that lime rates higher than 500 kg $CaCO_3$ ha^{-1} was not significantly different from yield obtained with 1000 kg $CaCO_3$ ha^{-1} lime. It is interesting that the highest rates of both lime and P in combination drastically reduced yield. The drastic reduction is probably due to interaction lime x Phosphorus, at these high rates, which might have caused detrimental effect on fruit production.

Nutrient concentration in leaf tissue: In the greenhouse study, application of phosphorus fertilizer alone showed inconsistent results on Ca concentration of leaf tissue. On the other hand, the presence of lime significantly increased leaf Ca, most especially at 500 kg $CaCO_3$ ha^{-1} lime, in combination with P applied at 40 kg ha^{-1}. Notably, the least concentration of leaf Ca was obtained when the highest rates of P and $CaCO_3$ were applied together. This is most likely due to the formation of insoluble compounds of Ca and P at such low soil reaction which consequently could cause reduction in their uptake by plant. No regular trend was observed in the treatment effects of leaf K, but lime at 20 kg ha^{-1} (with or without P) significantly increased the concentration on K in plant. Higher rates of lime were not beneficial. Kemmler [14] reported that large quantities of lime even depress K uptake because liming increases soil concentration of Ca which depresses K uptake. Lime had obvious effect in increasing leaf concentration of P. For instance, 500 kg $CaCO_3$ ha^{-1} applied without P gave a significantly higher P than the treatment in which 10 kg P ha^{-1} was applied without lime. Ivoilov *et al*. [15] reported increase in P uptake with lime. This could be a pointer to the solubilizing effect of lime on soil P and the consequent uptake of the latter by plant as reported by Naidu *et al*. [16].

In the field study, the trend observed was similar to the greenhouse results. The only exception was that, there was no significant increase in leaf P concentration with varying rates of applied P. However, the combined application of 500 kg ha^{-1} lime with 10 and 20 kg P ha^{-1} significantly improved leaf P content showing that low level of lime improves fertilizer use efficiency by the plant. This result is in line with the findings of Oguntoyinbo [4], that low rate of application of lime had a positive effect on the concentration of P in plant tissue. This observation confirmed the claims that lime improves P availability to crop.

Table 5: Effect of lime and P on selected chemical properties of soils

Treatments		Greenhouse				Field			
Lime (kg ha^{-1})	P (kg ha^{-1})	pH	Ca (cmol kg^{-1})	P (mg kg^{-1})	Al (cmol kg^{-1})	pH	Ca (cmol kg^{-1})	P (mg kg^{-1})	Al (cmol kg^{-1})
0	0	5.87b	0.30b	8.24cd	0.061a	4.30b	0.17d	4.66c	0.85a
	10	6.27a	0.33b	12.47c	0.061a	5.00a	0.42b	5.34bc	0.77a
	20	6.27a	0.33b	25.42b	0.056a	5.00a	0.25c	6.65bc	0.67ab
	30	6.25a	0.31b	32.33ab	0.032ab	5.20a	0.33bc	5.62bc	0.54b
	40	6.25a	0.31b	37.02a	0.024b	5.30a	0.58b	6.51bc	0.49b
500	0	6.37a	0.37b	9.26cd	0.019bc	5.70a	0.50b	8.22b	0.34bc
	10	6.45a	0.46a	12.96c	0.017bc	6.70a	0.50b	6.92b	0.26c
	20	6.38a	0.24c	26.09b	0.018bc	5.90a	0.50b	9.25ab	0.19cd
	30	6.40a	0.39ab	33.42ab	0.016bc	5.30a	0.50b	12.19a	0.14cd
	40	6.42a	0.46a	39.56a	0.015bc	5.40a	1.42a	12.10a	0.09d
1000	0	6.37a	0.25c	11.73c	0.006d	5.50a	1.25a	7.74b	0.06d
	10	6.45a	0.50a	14.9bc	0.007d	6.30a	1.99a	7.19b	0.05d
	20	6.57a	0.48a	19.36bc	0.011c	6.30a	1.25a	7.33b	0.02e
	30	6.40a	0.40ab	29.28b	0.009c	6.30a	1.50a	7.26b	0.03e
	40	6.32a	0.35b	35.69a	0.009c	6.30a	1.67a	8.29b	0.01e

Mean(s) having the some letter(s) are not significantly different according Duncan Multiple Range Test (DMRT)

Post harvest soil chemical properties: Table 5 shows a little increase in pH and a corresponding decrease in exchangeable Al occasioned by additions of P. Expectedly, lime application increased pH from 5.87 to a maximum of 6.37 and reduced exchangeable Al drastically from 0.061 to 0.006. Addition of P did not appear to have any remarkable effect on the neutralizing effect of lime. Increasing rates of P in the presence or absence of lime expectedly increased soil available P. Lime increased soil available P only when combined with P. It is obvious that available P was sharply reduced by application of 1000 kg ha^{-1} $CaCO_3$. This could be adduced to complexation of P at high PH soil. P increased with P rates applied singly or in combination with lime. Varying rates of P combined with 500 kg $CaCO_3$ ha^{-1} lime gave better values of residual soil P than P combined with 1000 kg $CaCO_3$ ha^{-1} lime. This suggests that the soil has been over limed at this high application rate.

The treatments applied appeared not to have any remarkable effect on soil exchangeable Na and K except that K was somewhat improved by high rate of lime, while P application presented no obvious effect on exchangeable Ca. However, lime either applied alone or in combination with P improved the Ca status of the soil. This is not unexpected, giving the high Ca content of lime.

CONCLUSIONS

The result of the present study showed that for optimum performance of okra, on acid soil application of lime and P fertilizer at 500 kg ha^{-1} and 10 kg ha^{-1}, respectively is beneficial. The presence of lime ameliorates soil acidity and adequate lime reduces the amount of fertilizer P required for good crop growth and fruit yield. This, it does through its ability to neutralize soil acidity and the subsequent effects of increasing available P and Ca.

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