Research Journal of Agriculture and Biological Sciences, 5(5): 858-863, 2009

Growth and Yield Response of Okra to Lime and Compost on an Acid Soil in the Humid Tropics

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Abstract: Acid sands occur commonly in the high–rainfall areas along the coastal plains of Nigeria as a serious constraint to crop production and a primary yield-limiting factor. Pot and field experiments were conducted to determine the effects of lime ($CaCO_3$) and compost application on the growth and yield of okra [*Abelmoschus esculentus* (L) Moench] on an acid soil. Treatments comprised three levels of compost (0, 2.5 and 5.0 Mt·ha^{-1}) and two levels of lime (0, 250 kg ha^{-1} $CaCO_3$) applied solely and in combination with compost. Okra growth was most favoured with application of 5 Mt·ha^{-1} compost. Lime application also gave comparable growth and the highest yield of 4.4 Mt·ha^{-1}. A yield of 4.1 Mt·ha^{-1} from application of 5 Mt·ha^{-1} compost was also comparable. Addition of compost to lime gave lower but comparable growth and seed yield and reduced the soil acidity more than either sole lime or sole compost applications. Combined application of compost and lime increased the available P and the exchangeable K; Ca and Mg. Liming of acid soils in the tropics can be complimented with compost application to achieve greater release of K, P and Mg along with increase in release of Ca.

Key words: *Abelmoschus esculentus,* acid soil, compost, Epe, Ibadan, lime.

INTRODUCTION

In farming systems of the humid tropics, acid soil is a serious constraint to crop production and a primary yield-limiting factor[4]. Soil acidification arises from leaching of bases down the profile through the action of rainfall, continuous cropping, frequent application of high doses of mineral fertilizers, especially N carriers and crop removal of basic cations. Acid soils, especially the Ultisols and Oxisols usually have problems associated with aluminium toxicity, low nutrient status, nutrient imbalance and multiple nutrient deficiencies[14] that contribute to poor crop yields. Liming is a common method for raising soil pH and ameliorating phytotoxicity in acid soils. Effects of liming on soils include, increased soil pH, Ca and Mg saturation, neutralization of toxic concentrations of aluminium, increase in pH-dependent CEC, resulting in absorption and hydrolysis of Ca^{2+} and Mg^{2+},increased P availability and improved nutrient uptake by plants [11,13]. However, P and Mg deficiencies can be induced by over liming[9]. Reduction of Zn, B, Mg and Mn uptake by corn has been reported when soils were limed to neutral pH.[5,12].

Two major problems that can militate against the effective use of lime are high cost of commercial liming materials and the detrimental effects of over liming the fragile soils of the humid tropics. Organic materials, like crop residues and animal wastes, are promising as liming sources. Soluble and exchangeable A1 are substantially reduced by organic amendments of acid soils[6,7]. Tandon[15] reported that animal manure neutralized soil acidity and supplied essential micronutrients. Application of *Calliandra callothyrsus Meissn*. leaves to an acid soil decreased total and monomeric aluminium concentration to a level similar to that observed with 0.75 Mt·ha^{-1} $CaCO_3$[3]. In a field study, comparing the effects of green manure and lime on an acid soil, Hunter *et al.,*[8] reported growth and yield increase of sweet corn as well as an increase in soil pH and extractable phosphorus. Similarly, Akande *et al.,*[1], reported growth and dry matter yield increase of maize as well as increase in soil pH when effects of lime and cowpea residue on acid soils were compared. Use of compost has the advantage of higher nutrient concentration, ease of application and better agronomic effect than crop residues or animal wastes. This project was undertaken to evaluate the effects of combining a low level of hydrated lime with compost on the performance of okra (*Abelmoschus esculentus* (L) Moench*)* and on soil chemical properties.

MATERIALS AND METHODS

Greenhouse trial: The study was conducted at the Institute of Agricultural Research and Training

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(I.A.R&T) Moor Plantation, Ibadan, Nigeria. The two soils used for the study were collected from Epe, in the coastal region of Lagos State and Ibadan, in the rain forest zone of Oyo State. The Epe soil is an acid sand classified as Udipsamment from a cultivated land while the Ibadan soil was an Ultisol from the Horticulture Unit of the IAR&T. The soils were air-dried and sieved to pass through a 2mm screen and later analyzed in the laboratory. The Epe soil was acidic (pH 4.4) and contained 0.2 Ca, 1.02 Mg, 0.24 Na and 0.03 K (cmol kg^{-1}). The available P was 7.45 mg kg^{-1} and total carbon was 0.53%. The Ibadan soil had 4.5 pH (1:25 soil: water) and contained 1.5 Ca, 0.53 Mg, 0.14 Na and 0.19 K (cmol kg^{-1}). The available P was 9.6 mg kg^{-1} and total carbon was 0.68%. Nutrient composition of the compost obtained from the IAR&T was 35.2 C, 1.20 N, 0.30 P, 1.20 K, 2.56Ca, 0.50 Zn (%) and 27. 4 Fe, 0.75 Mn, 0.02 Pb and 0.21 Cu (mg kg^{-1}).

Soil samples were taken from pots and fields immediately after harvest for chemical analysis. Three rates of compost (0, 2.5 and 5.0 $Mt{\cdot}ha^{-1}$) and two rates of lime (0 and 2.5 $Mt{\cdot}ha^{-1}$ $CaCO_3$) were applied to each pot containing 3 kg of each soil type using a 2×2×3 factorial completely randomized design (CRD) with twelve treatments and 3 replications. Urea was applied to supply 50 kg ha^{-1} of N in all treatments. Each pot was provided with two drainage holes and a saucer. The treatments were thoroughly mixed with the soil, moistened with water and allowed to equilibrate for a week. Three seeds of NH 47-4 okra cultivar, a variety that flowers in 35 days were sown per pot and thinned to two plants per pot, one week after sowing. Water was applied when necessary. Five youngest mature leaves were taken at 5 weeks after sowing for chemical analysis. Plant height, number of leaves, stem circumference and fruit weight were determined. At maturity, the fruits were harvested and fresh yield was determined.

Field Trial: Evaluation of the materials used in the greenhouse was carried out in the field at I.A.R&T. The soil on the site was same as the Ibadan soil used in the greenhouse trial. The land was ploughed and disc harrowed. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Blocks were spaced 1m apart and each contained six plots, with each plot measuring 3 x 3 m. Lime and compost were spread evenly in the plots and worked into the soil with West African hoe, according to the treatment rates and left for four weeks before planting. The same okra cultivar used in the greenhouse was sown at the rate of three seeds per hill, at an inter-row spacing of 60cm and intra-row spacing of 30cm. Seedlings were thinned to two plants per hill, one week after sowing. Weeding was done manually at 2, 6 and 9 weeks after sowing. Plant parameters taken were similar to those in the greenhouse study.

Data Collection and Analysis: Marketable size pods were harvested at three day intervals and weighed. Pods were harvested, nine times. Data were subjected to analysis of variance using the GLM procedure of SAS version 8 [15]. If interactions were significant they were used to explain results. If interactions were not significant main effect means were separated using Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

Okra Growth, Fruit Yield and Yield Components in the Greenhouse: Plant height was significantly ($P \leq 0.05$) increased by compost and lime, applied either singly, or in combination (Table 1). In the Epe soil, combined use of 250 kg $CaCO_3$ + 5 $Mt{\cdot}ha^{-1}$ compost and application of 5 $Mt{\cdot}ha^{-1}$ compost alone produced the tallest plants. Also in Ibadan soil, the tallest plants were obtained from treatments that received sole 5 $Mt{\cdot}ha^{-1}$ compost and also plants treated with a combination of lime + 2.5 and 5 $Mt{\cdot}ha^{-1}$ compost. Stem circumference was highest (15 mm) with application of 5 $Mt{\cdot}ha^{-1}$ compost alone in Epe soil while the treatment that received 250kg lime + 5 $Mt{\cdot}ha^{-1}$ of compost had the tallest plants (17mm) in Ibadan soil.

Plant leaf area was significantly smaller in Epe soil relative to performance in Ibadan soil. The largest leaves (140 cm^2) were obtained from the treatment that received sole 5 $Mt{\cdot}ha^{-1}$ compost and was closely followed by that which received 2.5 $Mt{\cdot}ha^{-1}$ of compost (120 cm^2) in Ibadan soil.

The yield of fruits presented a somewhat different trend. Lime and compost applied either singly or in combination significantly increased fruit yield. When compost was applied without lime, yields increased with increasing rates of compost. The highest yield was obtained when lime was combined with 5 $Mt{\cdot}ha^{-1}$ compost, in each of the soils in the greenhouse.

There was no significant difference in number of pods among treatments. The highest number of pods was obtained from pots treated with sole application of 5 $Mt{\cdot}ha^{-1}$ of compost and from the combination of lime and the two levels (2.5 and 5 $Mt{\cdot}ha^{-1}$) of compost in the two soils in greenhouse study. Results from other treatments were similar.

Okra growth was generally favoured with compost application at 5 $Mt{\cdot}ha^{-1}$. Sole liming gave shorter plants with smaller leaves. This is an indication that enough nutrients were not released with sole lime to support growth as well as 5 $Mt{\cdot}ha^{-1}$ compost application. However, nutrients released with this sole compost application at 5 Mt·ha^{-1} seemed not enough to sustain the yield. A complementary application of 250kg CaCO3 + 5 Mt·ha^{-1} compost gave a growth performance comparable with sole compost application at 5 Mt·ha^{-1} and also fruit yields that were significantly higher. This is an indication that enough nutrients to support both the growth and fruit yield of okra were supplied with the combined application of 250kg CaCO3 + 5 Mt·ha^{-1} compost.

Okra Growth, Fruit Yield and Yield Components on the Field: Plant height was significantly ($P \leq 0.05$) increased by single and combined application of compost and lime (Table 2). The tallest plants were obtained from plants treated with 5 Mt·ha^{-1} compost without lime and was closely followed by treatment with lime alone. With the stem circumference, there was significant ($P \leq 0.05$) increase by application of all rates of compost and lime applied either singly, or in combination. 2.5 Mt·ha^{-1} compost applied sole had the highest effect, closely followed by treatment that received sole application of 5 Mt·ha^{-1} compost. Leaf area was also significantly ($P \leq 0.05$) increased by application of all rates of compost and lime, either singly or in combination. Largest leaf area was produced in plants treated with sole application of 5 Mt·ha^{-1} compost. Values obtained with compost applied alone were generally higher than lime, either applied alone or combined with compost, in most of the parameters considered.

Results showed that all the treatments significantly ($P \leq 0.05$) increased the fruit yield of okra. The highest yield of 4.4 Mt·ha^{-1} was obtained from treatment with lime alone. This was closely followed by yields from application of 5 Mt·ha^{-1} compost without lime and a combination of lime and 2.5 Mt·ha^{-1}compost which gave statistically similar yields. Thus, the use of lime, either alone or in combination with a low rate of compost would produce similar effect as compost applied sole, at a higher rate of 5 Mt·ha^{-1}. All the treatments, except high rate of compost (5 Mt·ha^{-1}) combined with lime significantly ($P=0.05$) increased number of pods per plant above the control. The highest was produced by plants to which lime alone was applied. This was closely followed by plants treated with highest rate of compost without lime. This confirms the importance of the two nutrient sources in the vegetative and reproductive life of okra plants.

The result is also indicative of the ability of lime to release soil nutrients for plant use. The presence of a low rate of lime reduced the amount of compost required for optimum crop performance. This agrees with the report of Kamprath and Foy (1971). A decline in number of pods was observed with combined use of high rate of both lime and compost. This could be an indication of some over - liming effect, which might have caused nutrient imbalance in the soil. It is worthy of note that while the combination of the highest rate of compost and lime significantly increased okra yield in the greenhouse, it drastically reduced yield on the field. The drastic reduction is probably due to interactions of lime with compost, at these high rates, which might have caused detrimental effect on fruit production.

Nutrients Concentration in the Leaf Tissue of Okra in Greenhouse Study: Application of lime and compost had significant effect on nutrient content of okra plant in the greenhouse study (Table 3). Addition of compost alone showed consistent results on Ca concentration of leaf tissue. On the other hand, the presence of lime significantly increased leaf Ca, most especially, when combined with 5 Mt·ha^{-1} compost. A similar trend was observed in leaf K. As the rate of compost increased, there was corresponding, but not significant increase in the value of K. However, compost at 5 Mt·ha^{-1} + lime significantly increased the concentration of K in plant in Ibadan soil. Compost addition had an increasing effect on leaf concentration of P. Application of 5 Mt·ha^{-1} compost, without lime gave a significantly higher P than the untreated plants.

Post-harvest soil chemical properties:

Greenhouse Study: There was a general increase in pH by additions of lime and compost, either separately or in combination (Table 4). In Epe soil, lime application increased the soil pH from an initial 4.40 to 5.60 while addition of compost increased the pH to 4.90 and 5.10 with 2.5 and 5.0 Mt·ha^{-1}, respectively. The highest pH of 5.93 was obtained with application of 250kg $CaCO_3$ + 5.0 Mt·ha^{-1} compost. The pH of Ibadan soil was increased to 5.70 from an initial value of 4.50 with addition of lime while addition of compost at 2.5 and 5.0 Mt·ha^{-1} gave a pH of 5.63 and 5.86, respectively. The highest pH of 6.00 was also obtained with the combined application of lime and 5.0 Mt·ha^{-1} compost. Available P increased with all the treatments, with the highest values of 8.44 and 10.30 mg kg^{-1} being obtained with the combination of the highest rates of lime and compost, in Epe and Ibadan soils, respectively.

The treatments applied had remarkable effects on soil exchangeable Ca and Mg because they were increased. Application of lime and compost appeared not to have any remarkable effect on soil exchangeable Na and K.

Field Trial: In the field trial, the trend of nutrient change was similar to what was observed in the green house. Soil pH was observed to be increased also, with

Table 1: Effect of soil type, soil additive and rate of soil additive on growth and yield of okra in a greenhouse.

Soil type	Lime (kg ha^{-1})	Compost (Mt·ha^{-1})	Height (cm)	Stem circumference (mm)	Leaf area (cm^2)	Fruit yield/plant (g)	No. of fruit/ plant
Epe	0	0	15.3 c	5c	31.2e	18.3d	3
	0	2.5	22.7bc	13ab	86.0c	24.9c	3
	0	5.0	26.0ab	15ab	85.0c	87.5b	5
	250	0	21.0bc	12ab	82.0c	21.9cd	3
	250	2.5	20.7bc	12ab	83.3c	102.5b	5
	250	5.0	25.0ab	13ab	86.3c	180.0a	6
Ibadan	0	0	9.6d	6c	46.0d	17.2d	4
	0	2.5	19.7c	15ab	120.4ab	36.5cd	5
	0	5.0	25.0ab	14ab	140.0a	60.4bc	4
	250	0	17.3c	9bc	107.0b	31.8c	3
	250	2.5	24.7ab	14ab	115.0b	106.0b	5
	250	5.0	28.7a	17a	113.7b	143.7ab	5

Mean values followed by same letter in a column are not significantly different: P ≤ 0.05, DMRT.

Table 2: Effect of soil additive and rate of soil additive on growth and yield of okra on the field.

Lime (kg ha^{-1})	Compost (Mt·ha^{-1})	Height (cm)	Stem circumference (mm)	Leaf area (cm^2)	No. of fruit	Fruit yield (Mt ha^{-1})
0	0	26.0c	30.0b	150.0c	114bc	2.88c
0	2.5	33.2b	40.0ab	249.0ab	137ab	3.24b
0	5.0	39.2a	45.0a	265.0a	140ab	4.14ab
250	0	37.1ab	33.0b	220.0bc	142a	4.41a
250	2.5	30.3b	40.0ab	235.0b	134ab	3.87ab
250	5.0	31.2b	37.0b	242.0ab	120b	3.63ab

Mean values followed by same letter in a column are not significantly different: P ≤ 0.05, DMRT.

Table 3: Leaf nutrient content as affected by lime and compost application in a greenhouse.

Soil Type	Lime (kg ha^{-1})	Compost (Mt·ha^{-1})	Ca (%)	K (%)	P (%)
Epe	0	0	2.56bc	0.74bc	0.40b
	0	2.5	2.92b	0.84bc	0.55ab
	0	5.0	3.66ab	1.20ab	0.59a
	250	0	2.99b	0.84bc	0.44b
	250	2.5	3.11b	1.16b	0.47b
	250	5.0	3.86a	1.77a	0.55ab
Ibadan	0	0	2.94b	0.52c	0.31c
	0	2.5	3.20b	0.59c	0.37bc
	0	5.0	3.39b	0.78bc	0.45b
	250	0	3.10b	0.76bc	0.49b
	250	2.5	3.25b	1.06b	0.52ab
	250	5.0	3.74ab	1.41ab	0.56ab

Mean values followed by same letter in a column are not significantly different: P ≤ 0.05, DMRT.

Table 4: Effect of lime and compost application on selected soil chemical properties after cropping (Greenhouse).

Soil type	Lime (kg ha^{-1})	Compost (Mt·ha^{-1})	pH	Na	K	Ca	Mg	P
				(Cmol kg^{-1})			(mg kg^{-1})	
Epe	0	0	4.35	0.25b	0.11b	0.28c	1.26b	5.20bc
	0	2.5	4.90	0.25b	0.12b	0.48bc	1.30b	6.78b
	0	5.0	5.10	0.26b	0.12b	0.58b	1.77ab	8.15ab
	250	0	5.60	0.34a	0.15ab	0.77ab	1.98ab	6.62b
	250	2.5	5.46	0.24b	0.13ab	0.72ab	1.74ab	7.24ab
	250	5.0	5.93	0.28ab	0.13ab	1.01a	2.05a	8.44b
Ibadan	0	0	5.30	0.27ab	0.11b	0.23c	1.34b	8.04ab
	0	2.5	5.63	0.28ab	0.12b	0.67b	1.89ab	9.36ab
	0	5.0	5.86	0.29a	0.13ab	0.58b	1.93ab	9.50ab
	250	0	5.70	0.28ab	0.11b	0.42bc	1.65ab	7.07b
	250	2.5	5.90	0.30a	0.14ab	0.64b	1.85ab	8.88ab
	250	5.0	6.00	0.32a	0.17a	0.88a	1.86ab	10.30a

Mean values followed by same letter in a column are not significantly different: P ≤ 0.05, DMRT.

Table 5: Effect of lime and compost application on selected soil chemical properties after cropping (Field).

Lime (kg ha^{-1})	Compost (Mt·ha^{-1})	pH	Na	K	Ca	Mg	P
				Cmol kg^{-1}			mg kg^{-1}
0	0	5.46	0.16a	0.20c	1.49b	1.44c	7.23b
0	2.5	5.82	0.14a	0.22b	1.57ab	2.52b	9.89ab
0	5.0	6.12	0.09b	0.23b	1.72ab	2.68ab	11.73ab
250	0	6.04	0.15a	0.20c	1.84a	2.78ab	13.95a
250	2.5	6.13	0.14a	0.27a	1.75ab	2.89ab	10.22ab
250	5.0	6.35	0.15a	0.26a	1.96a	2.97a	13.48a

Mean values followed by same letter in a column are not significantly different: P≤0.05, DMRT.

addition of lime and compost. Lime application increased pH from 4.76 to a maximum of 6.35 while compost addition increased the pH to 6.12 (Table 5). Increasing rates of compost in the presence or absence of lime increased soil available P. Similarly, K, Ca and Mg were increased from their initial values of 0.19, 1.5 and 0.53 cmol kg^{-1} prior to cropping, to a maximum of 0.27, 1.96 and 2.97 cmol kg^{-1}, respectively. Lime, either applied alone or in combination with compost considerably improved the soil Ca status. This is not unexpected, given the high Ca content of lime. Soil exchangeable Na was not remarkably affected by either lime or compost application.

In conclusion, it could be inferred from the results of both the greenhouse and the field trials that application of compost alone or in combination with lime, is as effective as lime to increase soil pH and ameliorate the detrimental effects of soil acidity on the growth and yield of okra. Compost application could therefore reduce the demand for lime on acid soils.

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