Response of okra (*Abelmoschus esculentus* (L.) *moench.*) to different rates of nitrogen and lime on an acid soil

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Abstract- Field experiments were conducted in 2007 and 2008 at Calabar in the south eastern rainforest zone of Nigeria to evaluate the response of okra (*Abelmoschus esculentus* (L.) *Moench*) to four rates of nitrogen (0, 40, 80 and 120kg/ha) and three rates of lime (0, 5 and 10t/ha). Factorial combinations of the treatments were laid out in a randomized complete block design with three replications. Nitrogen had significant effects on plant height, number of leaves and branches/plant, number of pods/plant, fresh pod weight and total fresh pod yield. The 80kgN/ha rate maximized all the growth and yield attributes. Lime application had no consistent effect on plant height and number of branches/plant; but significantly improved all other growth and yield attributes. Total fresh pod yield was highest at 5t/ha lime rate, and this was 91% higher than the control. Significant interactions were recorded between nitrogen and lime on number of leaves/plant and fresh pod yields, with the combination of nitrogen and lime at 80kg/ha and 5t/ha giving the highest values.

Key words: Acid soils, okra, growth, pod yield, lime, nitrogen, rates.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) *Moench*), is a popular vegetable grown for its immature fruits and young leaves throughout the tropical and sub-tropical parts of the world, and consumed all over the world. In Nigeria and other parts of West and Central African, it is often grown in backyard gardens or in mixture with other staple crops [1]. Okra occupies about 1.5 million hectares of the arable land in Nigeria alone [2]; while the World production of common okra as fresh fruit vegetable is estimated at 1.7 million t/year [3].

The importance of okra lies in the "draw" or mucilaginous properties of the immature fruits and young leaves which aid easy consumption of bulky staple foods like pounded yam, gari, fufu etc. Okra is particularly rich in calcium, ascorbic acid, and iodine which helps control goitre [4].

Although okra has great potential both as domestic and commercial crop in Nigeria, its yield on peasant farmer's fields is often very low, hardly up to 7t/ha [3]. Inadequate knowledge of the management of the soils, improved varieties and some of the necessary cultural practices such as optimum plant density, nutrient requirements etc, might have contributed to the low okra yield obtained by these farmers.

Soils of the rain forest zone of Nigeria are acidic in nature, classified as ultisols and oxisols which are inherently low in pH, organic matter, nitrogen, potassium and other nutrients [5, 6]. These soils are prevalent in areas experiencing high annual rainfall (above 1500mm) and usually have problems associated with aluminium toxicity, low nutrient status, nutrient imbalance and multiple nutrient deficiencies [7] and therefore require fertilization and liming for good crop growth and yield.

Nitrogen is the main limiting nutrient for most crops on these soils because of heavy leaching as a result of high rainfall, exacerbated by the

sandy nature of the soils [8]. Recommended rates of N for okra appear to vary greatly depending on cultivars, climatic conditions and soil types. [9], recommended 112 kg N/ha for maximum okra fruit yield. Other recommendations included 135kg/ha [10], 67kg/ha [11]. [12] recommended either 35 or 70 kg N/ha depending on cultivar and observed that the optimum rate of N for okra plant dry matter production (100 kg N/ha), was higher than that for maximum edible fruit yield (50 kg N/ha), [13]. [14,15], however, suggested 60 kg N/ha for enhanced okra pod production.

Liming is an ancient agricultural practice for rehabilitating acid soils. The overall effects of lime on soils include among others, increased soil pH, Ca, Mg and P availability, neutralization of toxic concentrations of Al and Mn, increase in pH dependent CEC and improved nutrient uptake by plants [16, 17]. Furthermore, lime counteracts the acid forming tendency of nitrogen containing fertilizers, the use of which has increased markedly in several areas of humid tropics. [18], reported that lime reduced the amount of fertilizer P required for optimum growth and fruit yield of okra and obtained the highest yield at 0.5t/ha lime rate. [19], equally obtained the highest grain yield of popcorn at 0.5t/ha lime rate. This rate however falls short of the 4 to 6t/ha CaCO₃ recommended by [20].

Although soil acidity is so widespread, records of the rates of lime for optimum crop yield in the tropics are very sparse. The essence of this research therefore, was to give an insight on the significance of liming acid soils, combined with efficient use of N fertilizer such that maximum benefits are derived from both crops and fertilizer.

MATERIALS AND METHODS

Field experiments were conducted during the 2007 and 2008 rainy seasons in Calabar in the south eastern rainforest zone of Nigeria (4° 57' N, 8° 19' E; 100m above sea level). Calabar has a bimodal annual rainfall distribution that ranges from 3,000mm to 3500mm with a mean annual temperature range of 27°C to 35°C [21]. The experiments investigated the response of common okra (*Abelmoschus esculentus* (L.) *Moench*) variety LD 88, to four levels of nitrogen (0, 40, 80 and 120 kg N/ha), applied as urea (46%N), and three levels of lime (0, 5 and 10t/ha) applied as CaCO₃. Each rate of N was applied in two – split doses. The first dose of N together with all the lime rates, single super phosphate (25 kg P/ha) and muriate of potash (50 kg K/ha) were broadcast and worked under a day before planting. The second dose of N was placed as side-dressing about 8cm deep and 8 – 10cm away from the plants at 6 weeks after sowing (WAS).

The experiment was a 4 x 3 factorial arrangement fitted into a randomized complete block design with three replications. Each gross plot was 2.4m x 1.8m and the net plot from which growth and yield attributes were estimated, was 1.2m x 1.2m. Soil samples were collected from the sites at depths of 0 – 30cm prior to fertilizer and lime applications and analyzed for physico-chemical properties using standard procedures described by [22]. Relevant soil physico-chemical analyses of the sites are summarized in Table 1.

The sites were cleared, ploughed and harrowed manually using machete, spade and rake before planting on the flat on 20th March in 2007 and 23rd March in 2008. Three seeds were planted per stand with a spacing of 30cm x 40cm. The seedlings were later thinned to one per stand two weeks after sowing to give 36 plants per plot. Two manual weeding were done at 4 and 7 WAS using native hoe. Harvesting of immature pods was carried out on alternate days from nine randomly tagged plants from the net plot areas in each plot until all the plants withered and died. From the nine tagged plants the following growth and yield attributes were determined; plant height, number of leaves per plant, number of branches per plant, number of pods per plant, fresh pod weight and total fresh pod yield (t/ha). Data collected for each year were subjected to analysis of variance as described by [23] and treatment means were compared using the Duncan's Multiple Range Test [24].

RESULTS

Effect of Nitrogen

Plant height and number of leaves per plant were all significantly influenced by the N treatments at all the sampling periods in the two years (Table 2). In all, the 80 kg N/ha rate performed significantly better than the other N rates in terms of plant height and number of leaves produced per plant. The number of branches produced per plant at 40 kg N/ha and

80 kg N/ha rates, did not differ significantly, but were both higher than those at 120 kg N/ha and the control for both years (Table 3).

Similarly, the number of pods/plant, fresh pod weight (g/pod) and total fresh pod yield (t/ha), were all significantly influenced by N application (Table 4). The number of pods per plant and fresh pod weight obtained at the 80 kg N/ha rate, were both significantly higher than those obtained at other N rates in both years. Increasing the rates of N from either 0 to 40 or 40 to 80kg/ha, significantly increased total fresh pod yield and the mean fresh pod yield for both years, but a further increase in N rate to 120kg/ha, resulted in a significant decrease in total fresh pod yield.

Effect of Lime

Lime had significant effects on plant height in 2007, and number of leaves per plant in both years (Table 2). The applied rates of lime produced plants that were statistically similar in height, but taller than those at the control. The 5t/ha lime rate, produced on the average, plants with more number of leaves at the two sampling periods in both years. The effect of lime on number of branches per plant was only significant at all the sampling periods in 2007 (Table 3). The applied lime rates produced plants with statistically similar number of branches but higher than those at the control.

Lime had significant effect on all the yield attributes namely the number of pods per plant, fresh pod weight, total fresh pod yield and the mean fresh pod yield (Table 4). The 5t/ha lime rate significantly increased fresh pod weight, total fresh pod yield and mean fresh pod yield when compared with other lime rates except 10t/ha rate for number of pods per plant in both years. Increasing the lime rates from zero to 5t/ha, increased number of pods per plant by 35% and 41% in 2007 and 2008 respectively, while the mean fresh pod yield was increased by 91 percent.

Interactions

The interactions between nitrogen and lime, had no significant effects on plant height and number of branches per plant in both years. However, the interaction between N and lime on number of leaves per plant, total fresh pod yield and mean fresh pod yield were highly significant, while those of number of pods per plant and fresh pod weight, were significant for both years (Table 2 and 4).

In 2007, the highest number of leaves per plant was obtained at 80 kg N/ha with either 5t/ha or 10t/ha lime rate, while the combination of 80 kg N/ha and 5t/ha lime rate gave the best result in 2008 (Table 5). The best performance in terms of number of pods per plant, fresh pod weight, total fresh pod yield and the mean fresh pod yield were obtained at 80 kg N/ha and 5t/ha lime rate. This was followed in all cases by the combination of 80 kg N/ha and 10t/ha lime rate (Table 6).

DISCUSSION

The positive response exhibited by plant height, number of leaves and branches per plant to N application up to the 80 kg N/ha rate, is indicative of the role of N in the vegetative growth of plant. This agrees with the findings of [13], and [25]. The increase in pod yield with increasing levels of N up to 80 kg N/ha was probably as a result of the significant increases in almost all the yield contributing characters especially number of leaves and branches per plant which enhanced greater photosynthetic activity and translocation of assimilates. This is in consonance with the reports of [9] and [13]. The application of 40, 80 and 120 kg N/ha, from the study, increased mean fresh pod yield by 165%, 376% and 222% respectively compared to zero application (Table 4). [9], observed that N fertilizer rates above 112kg/ha adversely affected okra yield. [13], recommended 35-70 kg N/ha for okra depending on cultivar and soil N status. The inability of N to increase fresh pod yield further than 80 kg N/ha rate in this study might be due to the application of lime which reduced the amount of fertilizer N required for optimum crop performance. This is in conformity with the findings of [26].

The leaf number in both years, plant height and number of branches in 2007 were significantly increased by lime application. This is in agreement with the findings of [18], who observed significant increases in plant height, number of leaves and fruits of okra with the application of all rates of lime up to the 1000kg/ha rate used. This also agrees with the assertion that liming provides a chemical and physical environment that encourages the growth of most common plants [27, 6]. The mean for the two years, showed that lime at 5 and 10t/ha rates, increased fresh pod yield by 93% and 56%, respectively when compared to zero application. This agrees with the reports of [28], and [20] that generally, the application rates of liming materials are in the order of about 3 to 4t/ha CaO or 4 to 6t/ha CaCO₃ on poorly buffered sandy soils. In general, all yield – contributing characters were influenced positively by lime up to the 5t/ha rate. Increasing the lime rate to 10t/ha, resulted in significant yield reduction which could be attributed to over liming effect.

Significant interaction between lime and nitrogen was observed in the study. The mean for the two years indicated that highest number of leaves was achieved by a combination of 5t/ha of lime with 80kgN/ha. Equally, the combination of 5t/ha of lime with 80kgN/ha, gave significantly higher number of pods per plant, fresh pod weight, total fresh pod yield and mean fresh pod yield than all other combinations. This combination produced more than twice the total fresh pod yield obtainable when 80kgN/ha was applied alone, and more than seven times the pod yield obtainable by the untreated control. This confirms the importance of the two treatments in the

vegetative and reproductive life of the okra plant. Furthermore, the result is indicative of the ability of lime to enhance the release of nutrients for plant use [26]. A general decline in yield attributes was observed with combined use of high rate of both lime and nitrogen. This probably was an indication of some over liming effect, which might have caused nutrient imbalance in the soil [6].

CONCLUSION

The results from this study showed that for optimum performance of okra on acid soils of the rain forest zone of Calabar, the application of lime and nitrogen at 5t/ha and 80kg/ha respectively is beneficial as this gave the highest pod yield.

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Table 1-Physico-chemical properties of top soil (0 – 30cm) of experimental fields at Calabar

Composition	Year	
	2007	2008
Physical composition (g/kg)		
Clay	134	70
Silt	34	46
Sand	832	884
Textural class	Sandy loam	Sandy soil
Chemical characteristics		
pH (H ₂ O)	5.50	5.26
Organic carbon (g/kg)	11.83	16.07
Available P (mg/kg)	21.00	24.00
Total N (g/kg)	0.5	0.6
Exchangeable bases (cmol/kg)		
Ca	3.10	4.80
Mg	1.70	1.60
K	0.08	0.09
Na	0.06	0.06
EA	2.66	2.10
ECEC	7.60	8.65
BS (g/kg)	650.00	757.20

Table 2- Plant height (cm) and number of leaves per plant as affected by nitrogen and lime levels in 2007 and 2008 at Calabar

Treatment	Plant height				Number of leaves			
	2007 9WAS	11WAS	2008 9WAS	11WAS	2007 9WAS	11WAS	2008 9WAS	11WAS
Nitrogen (kgN/ha)								
0	30.22d	43.56c	29.78c	42.00c	15.56c	19.11c	15.67c	16.67c
40	51.56b	64.89b	48.89b	61.56b	24.00b	26.56b	22.56b	24.44b
80	64.56a	94.22a	60.67a	85.44a	30.44a	36.44a	28.22a	32.11a
120	39.56c	45.22c	32.89c	42.56c	24.67b	26.22b	22.00b	24.67b
SE±	2.655	3.782	3.632	5.991	0.672	1.011	1.153	1.794
Lime (t/ha)(L)								
0	41.25b	50.83b	42.17	52.08	19.58c	19.42b	19.25b	18.25c
5	48.83a	66.00a	43.75	60.75	26.67a	32.17a	24.83a	29.92a
10	49.33a	69.08a	43.25	60.83	24.75b	29.67a	22.25a	25.25b
SE±	2.299	3.275	3.145	5.189	0.582	0.875	0.998	1.553
Interaction								
N x L	NS	NS	NS	NS	**	**	**	*

Means followed by the same letter(s) within a treatment group and column are not statistically different at 5% level of significance.

*, ** and NS = Significant and highly significant at 5 and 1 percent levels; and not significant, respectively.

Table 3- Number of branches per plant as affected by nitrogen and lime levels in 2007 and 2008 at Calabar

Treatment	2007 WAS			2008 WAS		
	7	9	11	7	9	11
Nitrogen (kgN/ha)						
0	3.44b	4.56b	4.56d	3.67b	4.22b	4.33c
40	5.67a	6.78a	6.78b	5.78a	6.89a	6.89a
80	6.00a	7.33a	7.56a	5.89a	6.67a	6.78a
120	4.00b	5.11b	5.33c	3.33b	4.67b	5.33b
SE±	0.221	0.191	0.216	0.309	0.292	0.285
Lime (t/ha)						
0	3.92b	5.42b	5.42b	4.42	5.42	5.50
5	5.33a	6.33a	6.58a	4.92	6.00	6.25
10	5.08a	6.08a	6.17a	4.67	5.42	5.75
SE±	0.191	0.166	0.187	0.268	0.253	0.247
Interaction						
N x L	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically different at 5% level of significance.

NS: not significance

Table 4- Number of pods per plant, fresh pod weight (g/pod), total fresh pod yield (t/ha) and mean fresh pod yield (t/ha) as affected by nitrogen and lime levels in 2007 and 2008 at Calabar

Treatment	No of pods plant		Fresh pod wt(g/pod)		Fresh pod yield(t/ha)		Mean fresh pod yield (t/ha)
	2007	2008	2007	2008	2007	2008	
N(kgN/ha)							
0	8.67c	7.64c	10.29c	8.84c	6.34d	5.48d	5.92d
40	16.89b	15.11b	14.63b	12.96b	16.60c	14.72c	15.68c
80	26.22a	22.44a	18.29a	15.93a	29.24a	27.13a	28.19a
120	19.56b	17.33b	15.59b	13.06b	20.31b	17.83b	19.07b
SE±	1.049	1.142	0.737	0.757	0.746	0.719	0.718
Lime (t/ha)							
0	14.58b	12.67b	11.78c	10.28c	12.07c	10.91c	11.50c
5	19.75a	17.92a	17.55a	15.19a	23.28a	21.04a	22.17a
10	19.17a	17.08a	14.77b	12.62b	19.03b	16.92b	17.98b
SE±	0.908	0.989	0.638	0.656	0.646	0.622	0.622
Interaction							
N x L	*	*	*	*	**	**	**

Means followed by the same letter(s) within a treatment group and column are not statistically different at 5% level of significance.

*, ** and NS = Significant and highly significant at 5 and 1 percent levels; and not significant, respectively.

Table 5- Interactions between nitrogen and lime in 2007 and 2008 for number of leaves per plant at 9 and 11 WAS at Calabar

Treatment	Nitrogen (kg/ha)				Nitrogen (kg/ha)			
	0	40	80	120	0	40	80	120
	2007				2008			
	Number of leaves				Number of leaves			
	9WAP				11WAP			
Lime (t/ha)								
0	15.00g	19.33ef	21.33de	22.67de	18.33ef	18.33ef	20.00def	20.33def
5	16.33fg	25.00cd	35.33a	30.00b	14.00f	24.00cde	33.33a	28.00abc
10	15.33g	27.67bc	34.67a	21.33de	14.67f	25.33bed	31.33ab	17.67ef
SE±	1.165				1.997			
Lime (t/ha)								
0	16.00f	20.00ef	20.67ef	21.00ef	15.33e	18.00de	18.33de	21.33cde
5	20.67ef	28.33cd	45.00a	34.67b	18.33de	27.00bcd	42.00a	32.33b
10	20.67ef	31.33bc	43.67a	23.00de	16.33e	28.33bc	36.00ab	20.33de
SE±	1.750				3.107			

Means followed by the same letter(s) within a treatment group and column are not statistically different at 5% level of significance.

Table 6- Interactions between nitrogen and lime in 2007 and 2008 for number of okra pods per plant, fresh pod weight (g/pod), total fresh pod yield (t/ha) and mean fresh pod yield (t/ha) at Calabar.

Treatment	Nitrogen (kg/ha)				Nitrogen (kg/ha)			
	0	40	80	120	0	40	80	120
	2007				2008			
	Number of pods/plant				Number of pods/plant			
Lime (t/ha)								
0	8.33d	12.67cd	18.00bc	19.33b	7.33e	11.67cde	14.33bcd	17.33bc
5	9.00d	18.33bc	31.00a	20.67b	8.00de	16.67bc	28.33a	18.67b
10	8.67d	19.67b	29.67a	18.67bc	7.67de	17.00bc	27.67a	16.00bc
SE±	1.817				1.978			
					Fresh pod weight (g/pod)			
Lime (t/ha)								
0	7.50g	9.23fg	14.43b-e	15.97bcd	6.53h	8.27gh	13.07c-g	13.28c-f
5	12.03def	17.80b	22.27a	18.10b	10.33fgh	15.77a-d	18.59a	16.08abc
10	11.33efg	16.87bc	18.17b	12.70c-f	9.67fgh	14.82a-e	16.13ab	9.83fgh
SE±	1.277				1.311			
					Total Fresh pod yield (t/ha)			
Lime (t/ha)								
0	5.37e	8.60e	13.77d	20.53c	4.86f	7.53ef	12.76d	18.50c
5	7.63e	21.17c	38.20a	26.10b	6.29f	18.91c	35.52a	23.44b
10	6.03e	20.03c	35.77a	14.30d	5.29f	17.73c	33.11a	11.55de
SE±	1.292				1.245			
					Mean pod yield (t/ha)			
Lime (t/ha)								
0	5.13e	8.10e	13.27d	19.50c				
5	6.97e	20.07c	36.87a	24.77b				
10	5.67e	18.87c	34.43a	12.93d				
SE±	1.244							

Means followed by the same letter(s) within a treatment group and column are not statistically different at 5% level of significance.