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INFLUENCE OF LIMING ON THE PERFORMANCE OF HIGH-YIELDING SOYBEAN VARIETIES IN SOUTHEASTERN NIGERIA.

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ABSTRACT

Field experiments were conducted during the 2003 and 2004 cropping seasons at Umudike, Southeastern Nigeria, to assess the effect of liming on the performance of four high yielding soybean [Glycine max (L.) Merril] varieties (early maturing TGX 1485-1D, TGX 1799-8F, TGX 1805-8F and medium maturing TGX 1440-1E). In each year, the experiment was laid out as a split plot in a randomized complete block design using three replications. Five lime rates of 0, 0.5, 1.0, 1.5 and 2.0 t/ha were applied to the main plots while the four soybean varieties were planted in the sub-plots. Liming significantly increased soil pH, number of nodules and number of pods per plant and grain yield, especially in 2004 but did not significantly influence plant height, shoot dry matter, days to 50% flowering and 100-seed weight. The 1.0 t/ha lime rate proved to be optimum and is thus recommended for high grain yield in soybean. Mean grain yield at 1.0 t/ha lime rates was higher than the yield in the control (no lime) by 66%. The medium maturing TGX 1440-1E gave, on the average, significantly higher number of leaves and number of pods per plant and grain yield than other varieties. There were generally no significant effects of lime and crop variety interactions on soybean growth and yield.

Keywords: Liming, soybean varieties, growth, grain yield, southeastern Nigeria.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is an important source of high quality but inexpensive protein and oil. It contains about 41% protein and 21% oil (Wilcox, 1987). About 95% of the oil is used as edible oil in salad or cooking oils, margarine and shortenings. Soybean oil is also rich in essential fatty acids and contains no cholesterol (Ogundipe and Weingarther, 1992). Soybean cake, a by-product of soybean oil production, is used as a high-protein animal feed. Like other grain legumes, soybean plays an important role in biological nitrogen fixation and when included in cropping system improve soil fertility (Asiegbu and Okpara, 2002).

The rainforest agroecological zone of Nigeria is characterized by highly weathered and acidic soil conditions that have been responsible for the poor yield of soybean (FAO, 1989). Okereke (1986) evaluated eleven soybean varieties of varying maturity groups at Nsukka, and reported a low grain yield, which was partly attributed to low soil pH. Carter and Hartwig (1963) noted that nitrogen-fixing bacteria do not function effectively under low soil pH condition of 4.2 and below and recommended a pH of 6-6.5 for optimum soybean growth.

With the continual introduction of new soybean varieties, it is necessary to assess their tolerance to soil pH level. Some soybean varieties (TGX 1485-1D, TGX 1799-8F, TGX 1805-8F and TGX 1440-1E) have been found to be high-yielding in Southeastern Nigeria (Okpara and Ibiam, 2000; Ofor and Okpara, 2005) but there is a dearth of published information on their response to liming in the region. Considerable variations have been shown to exist among varieties in their response to environment (Jennifer and Edmeades, 1997) and soil amendments (Ano, 2003). Obtaining some information on lime use for soybean production, especially for high-yielding varieties in Southeastern Nigeria, is necessary as part of the management programme to boost soybean production in the region. The objective of this study was to determine the optimum rate of lime [$Ca(OH)_2$] application for growth and yield of high yielding soybean varieties in Southeastern Nigeria.

MATERIALS AND METHODS

The experiment was conducted in the 2003 and 2004 cropping seasons at the research farm of Michael Okpara University of Agriculture, Umudike (Long. 07° 33'E, Lat. 05° 29'N; 122 m above sea level). Some of the soil characteristics and rainfall data of the experimental site are shown in Table 1.

The experimental site was slashed on 3 August, 2003, ploughed on 10 August and harrowed in on 11 August. In 2004, the land used was slashed on 21 July, 2004, ploughed on 2 August and harrowed on 3 August. A composite soil sample was obtained from a depth of 0-20 cm from representative locations after harrowing. The experiment was a split plot laid out in a randomized complete block design (RCBD) with three replications. The main plots contained five lime rates (0, 0.5, 1.0, 1.5 and 2.0 t/ha) while the sub plots contained four soybean varieties, namely the early maturing TGX 1485-1D, TGX 1799-8F, TGX 1805-8F and the medium maturing TGX 1440-1E Lime was applied on 18 August, 2003 and 11 August, 2004 and thoroughly worked into the soil. Ridges were made at 50 cm apart on 19 August, 2003 and 13 August, 2004. Soil pH was measured four weeks after liming.

Soybean seeds were planted on the crest of the ridges at a spacing of 5 cm to maintain a plant population of 400,000 plants/ha (50 cm x 5 cm). Unemerged stands were supplied at one week after planting (WAP). NPK (20:10:10) fertilizer at 30 kg N/ha (Okpara *et al.* 2003) was applied at 3 WAP. Weeding was done manually sing a hand hoe at 4 and 8 WAP. Fencing was done to a height of 50 cm with plastic sheets at the podding stage (8 WAP) in 2003 to protect the plants from further attack by rodents, which attacked some plots. In 2004, fencing was done earlier at 2 WAP.

Soil pH was measured in 1:2.5 soil: water. Total N in soil was analysed using the micro-kjeldahl method (Pearson, 1976). Available P and K were determined by the Bray I method and flame photometry respectively (Black, 1965). Days to 50% flowering was recorded, and at 7 WAP four plants from each subplot were randomly selected for the determination of the number of nodules/plant, plant height, number of leaves/plant, and shoot dry weight in 2003. Pod harvesting was done when the leaves had senesced and the pods turned brown, and data were recorded on the number of pods/plant, number of seeds/pod, 100-seed weight and seed yield in 2003 and 2004. All data collected were subjected to analysis of variance (ANOVA) and differences among treatment means tested with Fisher's Least Significant Difference (Little and Hills, 1978).

RESULTS

The soil texture at both sites was a sandy clay loam (Table 1). Soil N, K and organic matter were 100, 31 and 43% higher in the soil used for the 2004 experiment than those for 2003. Soil P was, however, higher by 23% in the soil used for the 2003 experiment than for the 2004. A monthly rainfall of over 300 mm occurred in August and September (vegetative growth period) in both years.

Liming significantly increased soil pH at 2.0 t/ha than in the control (no lime), and 0.5 and 1.0 t/ha lime rates (Table 2). The differences in soil pH of plots treated with 1.5 and 2.0 t/ha lime were not statistically significant. The increase in pH per unit weight of lime applied indicated that liming efficiency was, on the average, highest with the first level of lime, decreasing unappreciably thereafter.

Table 1: Soil properties of the sites and monthly rainfall for the experimental periods

	2003	2004
Soil Properties		
Sand (%)	67.7	75.7
Clay (%)	22.9	12.9
Silt (%)	9.4	11.4
Texture	Sand clay loam	Sandy clay loam
OM (%)	1.01	1.44
Total N (%)	0.03	0.06
Available P (ppm)	14.75	11.98
K (Cmol/kg)	0.16	0.21
Monthly rainfall (mm)		
July	447.5	309.5
August	372.6	304.3
September	340.8	324.9
October	180.2	249.1
November	69.2	52.5
Total for period	1410.3	1240.3

Data on the number of nodules per plant and plant height are shown in Table 3. The average number of nodules per plant increased progressively with incremental application of lime up to 1.5 t/ha. However, significant differences in nodules per plant occurred only between the 1.5 t/ha lime rate and the control. At the lime rate of 2.0 t/ha, the number of nodules decreased distinctly compared with 1.5 t/ha rate. Interactions between lime and variety did not influence the number of nodules per plant.

Table 2: Effect of lime application on soil pH measured in water in 2003 and 2004

Lime rate ($Ca(OH)_2$ t/ha	pH in Water		pH increase per t/ha of lime applied		
	2003	2004	2003	2004	Mean
0	5.09	4.81	-	-	-
0.5	5.54	5.02	0.90	0.42	0.66
1.0	5.58	5.20	0.49	0.39	0.44
1.5	5.90	5.28	0.54	0.31	0.43
2.0	6.16	5.38	0.54	0.29	0.42
$LSD_{(0.05)}$	0.36	0.28			

Plant height was not affected by liming but there was a significant difference in the height of the varieties. Soybean TGX 1485-1D gave significantly taller plants than other varieties except TGX 1440-1E. Lime x variety interactions did not significantly affect plant height.

The number of leaves per plant and shoot dry weight were not significantly affected by lime application (Table 4). However, the number of leaves was significantly higher in TGX 1440-1E than in other varieties. Interaction effects of lime and variety were significant. Soybean TGX 1440-E produced higher number of leaves than other varieties at virtually all lime rates. Also, shoot dry weight was distinctly higher with TGX 1485-1D at the control (no lime) or lower lime rate of 0.5 t/ha and with TGX 1440-1E at the lower rate of 0.5 t/ha.

Days to 50% flowering were not affected by liming contrasting the varietals response (Table 5). It took fewer days (38) to attain 50% flowering in TGX 1485-1D than in other varieties. Interaction effects of lime and variety were significant. Variety TGX, 1485-1D flowered earlier in the control or when lime was applied at 0.5 to 1.5 t/ha compared to the same variety with lime applied at 2.0 t/ha or other varieties at all lime rates. Generally, TGX 1440-1E took significantly the highest number of days (45) to attain 50% flowering at all lime rates.

Table 3: Effect of lime application on number of nodules per plant and plant height of four varieties of soybean in 2003

	Lime rate (t/ha)					
Variety	0	0.5	1.0	1.5	2.0	Mean
Number of nodules per plant						
TGX 1485-1D	2.2	4.5	5.3	4.3	2.0	3.7
TGX 1799-8F	1.0	0.8	3.0	2.3	0.8	1.6
TGX 1805-8F	0.5	1.3	1.0	7.0	1.7	2.3
TGX 1440-1E	1.0	3.8	6.0	9.0	1.3	4.2
Mean	1.2	3.6	3.8	5.7	1.5	
Plant height (cm)						
TGX 1485-1D	44.8	48.5	44.2	46.5	37.1	44.2
TGX 1799-8F	36.6	37.2	42.3	34.7	37.3	37.6
TGX 1805-8F	27.2	32.8	39.8	44.7	40.2	36.9
TGX 1440-1E	38.7	40.1	39.8	44.0	44.6	41.4
Mean	36.8	39.6	41.5	42.5	39.8	

		Number of nodules	Plant height
$LSD_{(0.05)}$ for lime (L) means	=	2.6	NS
$LSD_{(0.05)}$ for variety (V) means	=	NS	4.6
$LSD_{(0.05)}$ for LXV means	=	NS	NS

At harvest, the number of pods per plant did not vary significantly with lime rates and varieties (Table 6). However, in 2004, the 1.0 t/ha lime rate gave significantly higher number of pods than the control and 0.5 t/ha, while soybean TGX 1440-1E produced significantly more pods than other varieties. There were no significant effects of the interactions between lime rates and soybean varieties on the number of pods per plant.

Table 4: Effect of lime application on number of leaves per plant and shoot dry weight of four varieties of soybean at 7 WAP in 2003.

	Lime rate (t/ha)					
Variety	0	0.5	1.0	1.5	2.0	Mean
Number of leaves/plant						
TGX 1485-1D	19.7	20.8	20.8	16.0	16.7	18.8
TGX 1799-8F	16.0	22.9	20.2	15.3	20.2	18.9
TGX 1805-8F	9.8	12.7	15.8	19.2	15.7	14.6
TGX 1440-1E	26.5	26.0	18.8	28.5	28.5	25.7
Mean	18.0	20.6	18.9	19.5	20.3	
Shoot dry weight (g/plant)						
TGX 1485-1D	89	7.6	6.0	4.7	2.9	6.0
TGX 1799-8F	56	5.0	6.5	3.3	4.5	5.0
TGX 1805-8F	5.2	3.6	4.5	6.7	3.2	4.7
TGX 1440-1E	3.3	7.4	4.6	5.3	5.3	5.2
Mean	5.8	5.9	5.4	5.0	4.0	

		Number of leaves	Shoot dry weight
$LSD_{(0.05)}$ for lime (L) means	=	NS	NS
$LSD_{(0.05)}$ for variety (V) means	=	3.1	NS
$LSD_{(0.05)}$ for LXV means	=	7.0	3.0

The number of seeds per pod was not significantly affected by lime and variety in 2003. However, in 2004, variety and interaction of both factors significantly influenced the number of seeds per pod (Table 7). Soybean TGX 1799-8F produced more seeds per pod than other varieties. TGX 1485-1D at the control, TGX 1799-8F at 1.0 to 2.0 t/ha or TGX 1805-8F at 1.5 t/ha gave higher number of seeds per pod compared with other lime rates.

Lime application did not affect 100-seed weight, but there were significant differences in 100-seed weight of the varieties (Table 8). TGX 1485-1D and TGX 1799-8F had significantly higher seed weight than both TGX 1805-8F and TGX 1440-1E, which had the lowest value. Lime rate and variety interactions had no effect in both years.

Liming and lime x variety interaction had no effect on grain yield in 2003 (Table 9). On the contrary, in 2004 soybean grain yield was significantly affected by liming and crop variety and not by lime x variety interactions. Also, grain yields were considerably higher in 2004 than in 2003. Grain yield,

Table 5: Effect of lime application on days to 50% flowering of four varieties of soybean in 2003.

	Lime rate (t/ha)					
Variety	**0**	**0.5**	**1.0**	**1.5**	**2.0**	**Mean**
TGX 1485-1D	36.0	36.3	38.0	37.3	43.0	38.1
TGX 1799-8F	43.0	44.7	43.3	43.3	42.3	43.4
TGX 1805-8F	42.7	46.0	44.3	41.3	42.3	43.3
TGX 1440-1E	44.7	45.7	45.3	44.0	45.3	45.0
Mean	41.7	43.2	42.8	41.5	43.3	

$LSD_{(0.05)}$ for lime (L) means = NS
$LSD_{(0.05)}$ for variety (V) means = 1.4
$LSD_{(0.05)}$ for LXV means = 3.1

averaged over two years, increased progressively and significantly with incremental application of lime up to 1.0 t/ha (Table 10). Application of 1.5 t/ha lime gave no appreciable advantage of higher grain yield over 1.0 t/ha whereas the 2.0 t/ha lime rate significantly reduced mean grain yield of soybean by 16 and 18% compared with the 1.0 or 1.5 t/ha lime rates, respectively. Furthermore, TGX 1440-1E produced significantly higher mean grain yield than other varieties. Interaction of lime and soybean variety did not significantly influence mean grain yield.

Table 6: Effect of lime application on number of pods per plant of four varieties of soybean in 2003 and 2004

	Lime rate (t/ha)					
Variety	**0**	**0.5**	**1.0**	**1.5**	**2.0**	**Mean**
	2003 cropping season					
TGX 14485-1D	26.5	26.8	25.1	20.7	22.3	24.3
TGX 1799-8F	15.9	25.4	21.2	20.9	17.9	20.2
TGX 1805-8F	22.3	18.3	18.0	34.8	19.6	22.6
TGX 1440-1E	18.1	33.8	19.0	29.4	20.3	24.1
Mean	20.7	26.1	20.8	26.5	20	
	2004 cropping season					
TGX 14485-1D	20.8	36.1	36.4	42.8	43.1	35.8
TGX 1799-8F	23	33.8	39.3	47.8	30.1	34.8
TGX 1805-8F	27.6	41.1	51.8	35.3	43.5	39.8
TGX 1440-1E	32.6	63.7	87.0	77.8	65.2	65.2
Mean	26	43.6	53.6	50.9	45.5	

		2003	2004
$LSD_{(0.05)}$ for lime (L) means	=	NS	9.8
$LSD_{(0.05)}$ for variety (V) means	=	NS	8.7
$LSD_{(0.05)}$ for L x V means =		NS	NS

DISCUSSION

The increased nodulation due to lime application could be attributed to favourable conditions created by higher pH values. These conditions in turn favoured the proliferation of nodule forming *Rhizobium* bacteria. France and Day (1980) had reported that liming an acid soil to pH of 5.0 increased nodulation and nitrogen fixation of *Phaseolus vulgaris* (L.) in the acid soils of Brazil. This observation agrees with the results obtained in this study, as average soil pH values of 5.4 to 5.8 in water were obtained with liming at 1.0 to 2.0 t/ha.

Generally, the large increase in pH with the first increment of lime suggests that the soil was poorly buffered as observed by Asiegbu (1989), Edward and Kang (1978) and Friessen *et al.* (1980) in similar low activity clay soils. Asiegbu (1989) noted that employing a moderate but regular lime dressing could be a more beneficial management practice than a single heavy dressing intended to last for a long time.

Table 7: Effect of lime application on number of seeds per pod of four varieties of soybean in 2003 and 2004

Variety	Lime rate (t/ha) 0	0.5	1.0	1.5	2.0	Mean
			2003 cropping season			
TGX 1485-1D	2.2	2.1	2.1	2.1	1.9	2.1
TGX 1799-8F	2.0	2.2	2.0	2.0	2.0	2.0
TGX 1805-8F	2.1	2.1	2.2	2.0	2.0	2.1
TGX 1440-1E	1.9	2.1	1.8	1.9	1.8	1.9
Mean	2.1	2.1	2.0	2.0	1.9	
			2004 cropping season			
TGX 1485-1D	2.3	2.1	2.2	2.0	2.1	2.1
TGX 1799-8F	2.2	2.2	2.3	2.3	2.3	2.3
TGX 1805-8F	2.2	2.1	2.3	2.3	2.2	2.2
TGX 1440-1E	2.2	2.2	2.1	2.2	2.2	2.2
Mean	2.2	2.2	2.2	2.2	2.2	

		2003	2004
$LSD_{(0.05)}$ for lime (L) means	=	NS	NS
$LSD_{(0.05)}$ for variety (V) means	=	NS	0.05
$LSD_{(0.05)}$ for LXV means	=	NS	0.11

Table 8: Effect of lime application on 100-seed weight (g) of four varieties of soybean

Variety	Lime rate (t/ha) 0	0.5	1.0	1.5	2.0	Mean
			2003 cropping season			
TGX 1485-1D	12.0	12.1	10.9	11.8	11.0	11.5
TGX 1799-8F	10.2	11.0	10.0	9.7	9.8	10.1
TGX 1805-8F	9.0	8.9	9.0	9.4	9.2	9.1
TGX 1440-1E	7.8	8.1	8.1	7.9	8.3	8.1
Mean	9.8	10.0	9.5	9.7	9.6	9.7
			2004 cropping season			
TGX 1485-1D	13.3	14.6	14.0	14.4	14.7	14.2
TGX 1799-8F	14.0	13.7	15.6	13.6	13.4	14.1
TGX 1805-8F	13.0	12.1	12.8	13.2	11.9	12.6
TGX 1440-1E	11.3	11.5	11.4	11.4	10.7	11.3
Mean	12.9	13.0	13.4	13.1	12.7	

		2003	2004
$LSD_{(0.05)}$ for lime (L) means	=	NS	NS
$LSD_{(0.05)}$ for variety (V) means	=	0.8	0.8
$LSD_{(0.05)}$ for LXV means	=	NS	NS

Lime alone had no effects on soybean growth. However, the combined effects of lime and variety were such that crop growth was increased at the lower lime rates of 0.5 to 1.0 t/ha in TGX 1485-1D, TGX 1799-8F and TGX 1440-1E but reduced in the TGX 1485-1D at the highest lime rate of 2.0 t/ha. This may probably be due to the nutrient imbalance induced at high lime rates. The findings confirm the report of Turan *et al.* (2002) which showed that dry matter content of spinach increased to a peak in 100% lime dose followed by a decrease in dry matter content with further lime additions. While Onunka and Ugbaja (1995) found adverse effects on soybean crop nutrient uptake by liming at 2.0 t/ha. Enwezor *et al.* (1989) reported that excess liming inhibits the absorption of micro-elements and affects crop performance.

Table 9: Effect of lime application on grain yield (t/ha) of four varieties of soybean in 2003 and 2004

Variety	Lime rates (t/ha)					
	0	0.5	1.0	1.5	2.0	Mean
			2003 cropping season			
TGX 1485-1D	2.85	2.77	2.29	2.06	1.87	2.37
TGX 1799-8F	1.30	2.42	1.77	1.63	1.37	1.70
TGX 1805-8F	1.71	1.40	1.41	2.70	1.38	1.72
TGX 1440-1E	1.08	2.58	1.15	2.11	1.23	1.63
Mean	1.74	2.29	1.66	2.13	1.45	
			2004 cropping season			
TGX 1485-1D	2.58	4.43	4.40	4.96	5.28	4.33
TGX 1799-8F	2.85	4.12	5.60	5.91	3.65	4.43
TGX 1805-8F	3.14	4.35	5.96	4.24	4.57	4.45
TGX 1440-1E	3.23	6.29	8.46	7.99	6.59	6.51
Mean	2.95	4.80	6.10	5.77	5.02	

		2003	2004
$LSD_{(0.05)}$ for lime (L) means	=	NS	1.01
$LSD_{(0.05)}$ for variety (V) means	=	0.52	0.90
$LSD_{(0.05)}$ for LXV means	=	NS	NS

Table 10: Effect of lime application on mean grain yield (t/ha) of four soybean varieties for 2003 and 2004.

Variety	Lime rate (t/ha)					
	0	0.5	1.0	1.5	2.0	Mean
TGX 1485-1D	2.71	3.60	3.35	3.51	3.58	3.35
TGX 1799-8F	2.07	3.27	3.69	3.77	2.51	3.06
TGX 1805-8F	2.43	2.88	3.69	3.47	2.98	3.09
TGX 1440-1E	2.16	4.44	4.80	5.05	3.91	4.07
Mean	2.34	3.55	3.88	3.95	3.24	

$LSD_{(0.05)}$ for lime (L) means = 0.54
$LSD_{(0.05)}$ for variety (V) means = 0.48
$LSD_{(0.05)}$ for LXV means = NS

In the soil used for this investigation, lime [$Ca(OH)_2$] application at 1.0 t/ha was on the average, found optimal for soybean production as no yield improvements occurred beyond that level. Higher rates of lime, especially at 2.0 t/ha, seemed unnecessary since the liming efficiency dropped markedly after the first level of lime application and since more lime will tend to be leached away because of the sandy nature of the soil and the humid environment. Liming, however, makes phosphorus available in the soil and phosphorus promotes root development, carbohydrate and nitrogen metabolism in plants, initiation of generative organs and grain forming (Yagodin, 1984). Generally, over liming depresses not only crop growth and yield but also uptake of nutrients especially P, K, Zn and Cu (Gupta and Sharma, 1985). Edward and Kang (1978) obtained a similar response pattern in cassava, and they attributed the decrease in yield at higher lime rates to induced Zn deficiency. Asiegbu (1989) had recommended low dosages but more frequent application of lime to onion in a similar sandy loam soil at Nsukka.

Grain yield of the soybean varieties TGX 1440-1E and TGX 1485-1D across the lime rates used in the current study was not consistent from year to year. However, on the average TGX 1440-1E clearly out-yielded other varieties. The superior grain yield obtained with TGX 1440-1E over TGX 1485-1D in 2004 indicates greater yield improvements in the former due to liming. On the other hand, the lower yield obtained with TGX 1440-1E compared with TGX 1485-1D in 2003, may have been due to rodent attack which occurred in some plots. In previous studies involving no lime application, TGX 1485-1D consistently gave higher yields than TGX 1440-1E (Okpara and Ibiam, 2000; Okpara *et al.*, 2005). In this study, the modifying effect of liming on TGX 1440-1E was such that the variety not only produced higher grain yield but also higher number of leaves and nodules while taking the longer period to flower than other varieties. The average grain yield of 4.80 t/ha obtained for the TGX 1440-1E variety at 1.0 t/ha lime rate was satisfactory when compared to the lower average yield of 1.15 t/ha obtained at the same lime rate by Onunka and Ugbaja (1995) for TGX 536-02D at Umudike.

The study generally showed that lime alone at the rate of 1.0 t/ha was effective in increasing grain yield in soybean in southeastern Nigeria. On the average, grain yield was increased by 66% over no lime application under the conditions of this study. Grain yields were generally higher by 166% in 2004 (4.93 t/ha) than in 2003 (1.86 t/ha), probably due to the considerably higher nitrogen content of the soil in the former. Okpara *et al.* (2002) reported yield increases in soybean at higher nitrogen rates in a similar soil.

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