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Genotypic variation for acid stress tolerance in soybean in the humid rain forest acid soil of south Eastern Nigeria

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ABSTRACT
Objective: To identify acid tolerant genotypes of soybean adapted to acid soils of Nigeria.
Methodology and results: A field experiment was conducted on the acid soil of the National Root Crops Research Institute, Umudike, Nigeria, in 2003 and 2004. The experimental design was a randomized complete block (with 55 soybean genotypes as treatments) and 3 replications. Data were combined before analysis due to non-significant genotype x year effect for all the traits. Highly significant differences in genotypic effects were observed for all the traits (days to 50% flowering, plant height at maturity, number of pods/plant, 100-seed weight and grain yield).
Conclusion and application of findings: The result identified eight acid tolerant varieties (Conqvista, TGX 1896-3F, TGX 1897-17F, TGX 1866-7F, TGX 1805-31F, Milena, Doko and TGX 1844-18E) with a higher grain yield of >1.80tons/ha compared to <1.45tons/ha in the previously recommended varieties (TGX 1485-1D and TGX 1440-1E). The result also showed the potential of the EMBRAPA genotypes in upgrading the TGX varieties for higher productivity. The eight identified acid tolerant varieties could therefore be explored in the development of improved high yielding soybean genotypes for production on acid soils of Nigeria.
Key words: Acid stress tolerance, soybean, genotypes, adaptation.

INTRODUCTION
Soybean is one of the most important crops in the world and has higher protein content than any other pulse (Giller and Dashiell, 2007). It therefore serves as an appropriate source of plant protein for complementing the animal protein in meeting the World Health Organization recommendation of 70g protein per person per day in poor countries (WHO, 1985). The crop can be easily produced without much fertilizer inputs. Hence, it is extensively produced in temperate, tropical and subtropical regions of the world. Unfortunately, over 50% of the world's potential arable land surface is composed of acid soils mostly distributed in developing countries (von Uexküll and Mutert, 1995; Kochian *et al.,* 2005). This restricts the production of soybeans and other legumes due to their sensitivity to acid soil infertility. The growth of leguminous crops and development of symbiosis on acid soils are generally affected by deficiencies of Ca, K, P, Mg, S, Zn and Mo and/or toxicities of Al, Mn and Fe (Foy *et al*., 1978; Sanchez and Salina, 1981; Foy, 1984; Clark *et al*., 1988).
In Nigeria, poor and inconsistent grain yield of soybeans have been observed in the South-East and the South-South regions of the country due to

aluminium/acid stress (Okpara and Ibiam, 2000; Yusuf and Idowu, 2001; Okpara *et al.,* 2002; Osedeke and Ojeniyi, 2003). Wide variations in pH (4.0 – 5.87), exchangeable acidity (0.4 – 3.04) and other chemical properties of the soil have been observed (Shomkegh, 2004; Osedeke and Ojeniyi, 2003; Osedeke and Ojeniyi, 2005), with its attendant consequences on the poor performance of soybeans in the South-East and the South-South regions of the country. Liming has been used to ameliorate the problem of aluminium toxicity and low pH in soils. Liming the top soil, however, remains a temporary solution due to subsoil acidity. Restriction in root growth due to subsoil acidity reduces plant nutrient acquisition and access to subsoil water which culminates in the reduction of crop yield (Ferrufino *et al*., 2000). Moreover, the cost of liming particularly in developing countries is prohibitive and does not justify such huge investment given the return on investment from grain yield of soybeans. The input cost of the recommended quantity of 0.5 to 1.00 tons/ha of liming material (Yusuf and Idowu, 2001), is about the expected total revenue from the current average yield of 0.7 tons/ha in the South-East and South-South regions of Nigeria. The identification of acid stress tolerant cultivars of soybeans, therefore, remains a viable alternative.

There has been no concerted effort to evaluate soybean for acid stress tolerance in Nigeria, beyond the scanty, and highly contradictory information on adaptive soil studies in the South-East and the South-South regions of the country (Okpara and Ibiam, 2000; Yusuf and Idowu, 2001; Okpara *et al.,* 2002; Osedeke and Ojeniyi, 2003; 2005). The dearth of such information necessitated this research. The objective of the research, therefore, was to identify acid tolerant genotypes of soybean, with a view to designing an appropriate breeding programme that would enhance its improvement for production on acid soils of Nigeria.

MATERIALS AND METHODS

Study site: The National Root Crops Research Institute (NRCRI), Umudike, Nigeria, was selected as an acid soil field site in the rain forest zone of the South-East Nigeria. Umudike is situated on Latitude 5^{o} 29'N and Longitude 7^{o} 32'E at an altitude of 122m above sea level.

Soybean genotypes: Fifty-five varieties of soybean (Table 1) were planted out in a randomized complete block design with three replications on 8th July, 2003 and 1st July, 2004. The 55 genotypes of soybean included 49 IITA-released varieties (the TGX series) and six aluminium-tolerant genotypes obtained from the Brazilian Agricultural Research Cooperation (EMBRAPA), Brazil. The six genotypes (BR IAC-21, Conqvista, Cristalina, Doko, Milena, and Savanna) from Brazil are acid/aluminium tolerant, having been developed for the acid soils of Cerados, Brazil. These six genotypes were included for the purpose of validating the acid tolerance rating of the TGX varieties.

Experimental layout: The size of each plot was 15m^2. Each plot consisted of 3 ridges of 5m length, spaced 1m apart. Seeds were drilled into the ridges and later thinned down to 26 plants per meter after emergence. The field was sprayed with a pre-emergence herbicide immediately after planting and manually weeded at five weeks after planting (5 WAP). Fertilizer was applied at the rate of 10kg N/ha, 36kg P_2O_5/ha and 20kg K_2O/ha within the first two weeks after planting (2 WAP).

Data recording and analysis: Harvesting was carried out in November of the same year and data were taken from the centre row of each plot on:

1. Days to 50% flowering
2. Plant height at maturity from the mean of ten randomly selected plants in each plot.
3. Number of pods per plant, determined from the mean of five randomly selected plants in each plot.
4. 100-seed weight, determined from the mean of duplicate 100 seed-weights taken from seed lot of each plot.
5. Grain yield, in tons/ha estimated from grain yield per plot.

The data was subjected to Analysis of Variance according to Gomez and Gomez (1984). Means were separated using LSD as presented by Obi (1986). The coefficients of variation (CV) were determined.

Table 1: Name and maturity periods of genotypes used in the experiment.

Early maturity genotypes	Medium maturity genotypes		Late maturity genotypes
TGX 1740-2E	TGX 1805-31F	TGX 1893-10F	TGX 1895-35F
TGX 1897-17F	TGX 1895-50F	TGX 1842-1E	TGX 923-2E
TGX 1485-1D	TGX 1888-15F	TGX 1838-5E	
TGX 1805-8F	TGX 1873-16E	TGX 1893-6F	
TGX 1830-20E	TGX 1802-3F	TGX 1896-3F	
TGX 1835-10E	TGX 1878-7E	TGX 1869-13E	
TGX 1876-4E	TGX 1893-7F	TGX 1844-18E	
TGX 1895-33F	TGX 1894-3F	TGX 1886-38F	
TGX 1831-32E	TGX 1882-2F	TGX 1440-1E	
TGX 1871-12E	TGX 1019-2EN	TGX 1844-4E	
TGX 1895-23F	TGX 1890-7F	TGX 1448-2E	
TGX 1892 -10F	TGX 1802-1F	TGX 1864-17F	
TGX 1895-19F	TGX 1886-33F	TGX 1889-12F	
TGX 1895-49F	TGX 1869-31E	TGX 1866-7F	
TGX 1895-22F	TGX 1880-3E	TGX 1846-10E	
BR IAC -21*	TGX 1891-3F	TGX 1866-12F	
CONQVISTA*	DOKO*	SAVANA*	
CRISTALINA*			
MILENA*			

* Cultivars marked in * are from EMBRAPA: The Brazilian Agricultural Research Cooperation; All other cultivars are from the International Institute for Tropical Agriculture (IITA).

RESULTS

Significant differences in years were observed for plant height, number of pods per plant and grain yield (Table 2). The data were however combined for analysis due to non significance of genotype x year interaction for all the traits. Highly significant differences in the genotypes were observed for all the traits considered (days to 50% flowering, plant height, number of pods per plant, 100 seed weight and grain yield). Number of days to 50% flowering ranged from 35.17 for TGX 1892-10F to 53.50 for TGX 1895-35F with a mean of 43.76 and coefficient of variation (C.V.) of 2.4% (Table 3). Mean plant height was 38.78cm with TGX 1871-12F (an early maturing variety) maintaining the shortest height of 23.95cm and TGX 923-2E (a late maturing variety) maintaining the tallest height of 50cm. A low C.V. of 9.7% was observed for plant height. A wide range in the number of pods/plant was observed, with TGX 1891-3F and TGX 1805–31F producing the least (17.83) and the highest (89.00) number of pods/plant, respectively (Table 4). Number of pods/plant were also high for Conqvista, TGX 1844-18E, Milena, TGX 1866-7F and TGX 1896-3F with 84.00, 82.42, 77.33, 76.33 and 72.85, respectively. Mean number of pods/plant of 40.33 and a C.V. of 32% were observed.

Mean 100-seed weight of 13.63g was observed, with TGX 1893-7F and TGX 1864-17F having the least weight of 9.97g. Ten genotypes had 100-seed weight significantly different from the population mean. The six genotypes obtained from Brazil, namely, Conqvista, Cristalina, BR IAC-21, Doko, Milena and Savanna maintained the highest weights of 22.50g, 20.33g, 19.67g, 19.0g, 18.50g and 18.33g respectively, indicating they were best adapted. The C.V. for 100 seed weight was however low (7.3%).

Only eight genotypes, namely Conqvista (2.21t/ha), TGX 1896-3F (2.19 t/ha), TGX 1897-17F (2.07 t/ha) TGX 1866-7F (2.01 t/ha), TGX 1805-31F (1.96 t/ha), Milena (1.93 t/ha), Doko (1.92 t/ha) and TGX 1844-18E (1.83 t/ha), had grain yield significantly different from the population mean. Seven varieties, namely, TGX 1893-6F, TGX 1891-3F, TGX 1802-1F, TGX 1888-15F, TGX 1895-50F, TGX 1892-10F and TGX 1876-4E yielded below 0.8t/ha and were significantly lower than the population mean. Mean grain yield was 1.3139 tons/ha and C.V. 24.4%.

TABLE 2: Mean squares for grain yield and other quantitative traits in 55 diverse soybean genotypes evaluated in 2003 and 2004 in the acid soil rain forest ecology of Nigeria

Source of Variation	Df	Days to 50% Flowering	Plant Height (cm)	Number of Pods per Plant	100-Seed Weight (g)	Grain Yield (tons/ha)
Years	1	40.7757	86.3774*	879.7134*	0.2087	0.6068*
Reps (Years)	4	0.5318	7.0982	96.7930	1.1951	0.0158
Genotypes	54	71.7512**	271.9426**	1820.0122**	40.0836**	0.9140**
Genotypes X Years	54	0.6091	4.7788	106.1670	0.6806	0.0349
Pooled Error	216	1.0797	14.1308	166.2176	0.9952	0.1028

*, **: Significant at P<0.05 and P<0.01 respectively

DISCUSSION

The non-significance of the genotype x year interaction for all the traits is an indication of consistent relative performance of the genotypes across the years. The pattern of days to 50% flowering observed in the current work is consistent with the maturity groupings of the genotypes used. The range in values for the days to 50% flowering, plant height and number of pods per plant, observed for the TGX varieties in the current work, are consistent with the range previously reported by Okpara and Ibiam (2000). The 100-seed weight and the grain yield observed in the current work however, exceeded the upper limit reported by Okpara and Ibiam (2000), indicating the superiority of the investigated genotypes (in the current work) in filling up the pods set with grains. The high 100-seed weight (18.33 – 22.50g) observed for the 6 acid/aluminium tolerant genotypes from Brazil, indicates the potential to use these genotypes in upgrading the seed weight of adapted acid tolerant varieties on acid soils of Nigeria. The grain yield of a few TGX varieties compared favorably with the best acid/aluminium tolerant genotype (Conqvista), indicating that such TGX genotypes could be selected for production on acid soils of Nigeria.

The low grain yields observed for some genotypes in the current work have also been observed in adaptability studies from parts of the South-East and South-South Nigeria (Okpara and Ibiam, 2000; Yusuf and Idowu, 2001; Osedeke and Ojeniyi, 2003; 2005). For example varieties TGX 1802-1F and TGX 923-2F recorded grain yield of less than 1 ton/ha in both previous and present work.

However, a wider range in genotypic means was observed for grain yield (0.69 – 2.21 tons/ha) and yield components in this study. A higher grain yield was also observed for some genotypes in the current work compared to the two varieties (TGX 1485-1D and TGX 1440-1E) previously recommended for the acid soils of Nigeria by Okpara and Ibiam (2000). The high C.V. of 32% observed for number of pods/plant in the current work is a reflection of the sensitivity of this trait to spatial variability in exchangeable acidity of the soil. According to Urrea-Gomez *et al.* (1996), field evaluations for acid stress tolerance is frequently affected by large coefficients of variation due to spatial variability. The higher C.V. observed for grain yield and number of pods/plant compared to other traits, indicates that concentrating on the grain yield and number of pods/plant in a selection work on acid soils might likely achieve the objective of identifying acid tolerant genotypes with reasonable grain yield. Acid soils of Nigeria are highly weathered and changes in the chemistry of such soils resulting from weathering translate into serious impact in the performance of crops, particularly soybean (Ojo, 2010). The identification of some genotypes with grain yield of >1.80t/ha adds to knowledge regarding the potential ability of the tropically adapted varieties of soybean to yield optimally on acid soils of Nigeria.The eight varieties (Conqvista, TGX 1896-3F, TGX 1897-17F, TGX 1866-7F, TGX 1805-31F, Milena, Doko and TGX 1844-18E) with grain yield of >1.80tons/ha, should be explored further in the development of improved soybean genotypes for production on acid soils of Nigeria.

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TABLE 3: Character means and coefficients of variation for days to 50% flowering and plant height in 55 diverse soybean genotypes evaluated in 2003 and 2004 in the acid soil rain forest ecology of Nigeria

GENOTYPE	DAYS TO 50% FLOWERING	PLANT HEIGHT AT MATURITY (cm)	GENOTYPE	DAYS TO 50% FLOWERING	PLANT HEIGHT AT MATURITY (cm)
TGX 1740-2E	39.50	30.73	TGX 1869-31E	46.00	42.30
TGX 1897-17F	37.33	28.48	TGX 1880-3E	44.00	42.50
TGX 1485-1D	39.00	24.47	TGX 1891-3F	45.33	42.35
TGX 1805-8F	37.00	27.88	TGX 1893-10F	46.33	40.50
TGX 1830-20E	39.500	28.95	TGX 1842-1E	46.83	42.63
TGX 1835-10E	41.00	30.22	TGX 1838-5E	48.83	42.18
TGX 1876-4E	40.00	34.28	TGX 1893-6F	46.00	41.53
TGX 1895-33F	41.00	31.12	TGX 1896-3F	47.00	43.33
TGX 1831-32E	39.67	25.93	TGX 1869-13E	46.00	43.70
TGX 1871-12E	38.50	23.95	TGX 1844-18E	44.83	43.55
TGX 1895-23F	41.00	28.27	TGX 1886-38F	45.17	43.67
TGX 1892 -10F	35.17	30.22	TGX 1440-1E	44.83	43.07
TGX 1895-19F	41.00	33.27	TGX 1844-4E	45.50	43.67
TGX 1895-49F	40.50	26.40	TGX 1448-2E	45.50	44.88
TGX 1895-22F	41.00	29.12	TGX 1864-17F	49.50	44.27
TGX 1805-31F	45.83	35.47	TGX 1889-12F	46.67	45.47
TGX 1895-50F	44.00	36.17	TGX 1866-7F	45.00	43.05
TGX 1888-15F	44.00	38.45	TGX 1846-10E	46.83	44.37
TGX 1873-16E	45.17	37.12	TGX 1866-12F	46.00	43.70
TGX 1802-3F	45.00	40.65	TGX 1895-35F	53.50	48.20
TGX 1878-7E	46.17	43.53	TGX 923-2E	53.00	50.00
TGX 1893-7F	45.00	40.43	BR IAC -21	41.00	38.82
TGX 1894-3F	44.67	40.97	CONQVISTA	41.00	45.85
TGX 1882-2F	44.50	42.97	CRISTALINA	40.83	46.00
TGX 1019-2EN	45.67	41.67	DOKO	44.33	47.42
TGX 1890-7F	44.00	43.22	MILENA	38.50	38.75
TGX 1802-1F	44.83	40.48	SAVANA	45.17	44.50
TGX 1886-33F	44.00	43.67			
GRAND MEAN				**43.76**	**38.78**
LSD .05				**1.66**	**6.02**
C.V. (%)				**2.4**	**9.7**

TABLE 4: Character means and coefficients of variation for number of pods per plant, 100-seed weight and grain yield in 55 diverse soybean genotypes evaluated in 2003 and 2004 in the acid soil rain forest ecology of Nigeria

GENOTYPE	NUMBER OF PODS PER PLANT	100-SEED WEIGHT (G)	GRAIN YIELD (Tons/Ha)	GENOTYPE	NUMBER OF PODS PER PLANT	100-SEED WEIGHT (G)	GRAIN YIELD (Tons/Ha)
TGX 1740-2E	40.52	12.48	1.42	TGX 1869-31E	40.50	11.27	0.96
TGX 1897-17F	61.87	13.93	2.07	TGX 1880-3E	22.50	11.42	0.86
TGX 1485-1D	41.02	15.55	1.42	TGX 1891-3F	17.83	10.92	0.79
TGX 1805-8F	30.33	14.32	1.22	TGX 1893-10F	37.83	10.42	1.39
TGX 1830-20E	32.03	13.10	1.24	TGX 1842-1E	50.83	11.32	1.71
TGX 1835-10E	33.67	13.20	1.28	TGX 1838-5E	31.33	12.65	0.93
TGX 1876-4E	22.27	12.03	0.76	TGX 1893-6F	35.00	13.03	0.74
TGX 1895-33F	50.93	15.98	1.64	TGX 1896-3F	72.85	15.10	2.19
TGX 1831-32E	28.38	13.28	1.29	TGX 1869-13E	29.67	12.75	1.16
TGX 1871-12E	22.70	12.48	0,86	TGX 1844-18E	82.42	12.12	1.83
TGX 1895-23F	29.67	14.07	1.22	TGX 1886-38F	33.33	12.92	1.26
TGX 1892 -10F	22.40	12.43	0.79	TGX 1440-1E	40.67	12.70	1.39
TGX 1895-19F	25.00	14.08	1.13	TGX 1844-4E	28.67	12.03	1.15
TGX 1895-49F	22.57	15.62	0.85	TGX 1448-2E	40.67	13.78	1.48
TGX 1895-22F	32.20	14.73	1.26	TGX 1864-17F	31.50	9.97	1.18
TGX 1805-31F	89.00	12.55	1.96	TGX 1889-12F	31.83	12.38	1.23
TGX 1895-50F	18.83	12.95	0.78	TGX 1866-7F	76.33	13.53	2.01
TGX 1888-15F	39.52	11.12	0.69	TGX 1846-10E	38.67	14.50	1.40
TGX 1873-16E	25.67	14.22	1.11	TGX 1866-12F	38.17	14.57	1.40
TGX 1802-3F	55.72	12.93	1.77	TGX 1895-35F	43.0	12.83	1.23
TGX 1878-7E	34.23	12.42	1.27	TGX 923-2E	37.67	11.45	0.99
TGX 1893-7F	41.33	9.97	1.24	BR IAC -21	47.83	19.67	1.57
TGX 1894-3F	33.67	14.47	1.26	CONQVISTA	84.00	22.50	2.21
TGX 1882-2F	38.83	12.20	1.39	CRISTALINA	44.83	20.33	1.42
TGX 1019-2EN	26.90	13.23	1.12	DOKO	66.33	19.00	1.92
TGX 1890-7F	37.33	13.87	1.35	MILENA	77.33	18.50	1.93
TGX 1802-1F	24.33	11.87	0.79	SAVANA	49.42	18.33	1.66
TGX 1886-33F	26.50	10.85	1.12				
GRAND MEAN					**40.33**	**13.63**	**1.31**
LSD .05					**20.63**	**1.60**	**0.51**
C.V. (%)					**32.0**	**7.3**	**24.4**