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Full Length Research Paper

Genotype x environment interaction for soybean grain yield and other reproductive characters in the forest and savanna agro-ecologies of South-west Nigeria

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Eight soybean varieties were evaluated in 2006 and 2007 at three locations in the forest and savanna agro-ecologies of South west Nigeria for grain yield and other reproductive characters. Data were analyzed using analysis of variance and genotype plus genotype x environment interaction (GGE) biplot analysis. The main effects of year, location, variety and their interactions had significant effects on all the characters except pod length and number of seeds per pod. Among the varieties, number of days to 50% flowering, number of seeds per pod and 100 seed weight had average values of 45.29, 2.31 and 13.07 respectively while that of grain yield was 1027.49 kg/ha. The highest yielding variety across years and locations was TGx 1805-31F while TGx 1485-1D had the lowest value. Grain yields recorded in 2006 and 2007 were 1059.94 and 995.04 kg/ha. Ballah (southern guinea savanna) produced the highest grain yield while Ilora (derived savanna) had the least. GGE biplot analysis showed that genotype, location and genotype x location interaction were responsible for 21.66, 37.63 and 40.71% of their total variations respectively. The variety TGx 1922-1F was found to be high yielding and stable. Suitable varieties were also identified for the three locations under evaluation.

Key words: Soybean, genotype, environment, grain yield, adaptation.

INTRODUCTION

Soybean (*Glycine max* (L.) Merill) utilization is gaining popularity in Nigeria because of its numerous potentials that rank it even better than cowpea in the supply of high quality protein. There is therefore, an increasing cultiva-tion of the crop in the cropping systems of the different agro- ecologies of the country. Although, most of the soy-bean produced in Nigeria come from the Southern guinea savanna, production has however extended to the Northern guinea savanna and the forest environments (Okpara and Ibiam, 2000; Chiezey et al., 2001). Ogoke et al. (2004) also reported an increasing cultivation of soy-bean in the West African moist savanna. Soybean perfor-mance, like any crop however, vary with the environment (Tekrony et al., 1987; Ojo and Amanze, 2001; Aremu and Ojo, 2005), several varieties have to be evaluated in mul-tiple environments for the identification of suitable geno-type for a specific environment.

Differential genotypic responses of crop varieties to variable environmental conditions especially those asso-ciated with changes in ranks of genotypes limit accurate yield estimates and identification of high yielding stable genotypes. In order to identify stable genotypes, the ge-notype x environment interaction (G x E) must be parti-tioned into stability statistics that are assignable to each genotype evaluated across a range of environments (Fer-nandez, 1991). Stability indices have allowed researchers to identify widely adapted genotypes to use in breeding programmes and have helped to improve recommenda-tions to growers (Yayeh and Bosland, 2000). Many met-hods have been used to identify and to compare patterns of performance among crop genotypes across environ-ments with the aim of describing genotypic responses from multi- environment trials (Westcotte, 1986; Byth, 1981). One of such methods of G x E analysis used in re-cent time is GGE biplot analysis. The GGE (Genotype plus genotype x environment interaction) analysis parti-tions G + GE into principal components through singular value decomposition of environmentally centred yield data

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Table 1. Rainfall pattern, longitudes and latitudes of the three locations where 8 soybean varieties were evaluated in Nigeria in 2006 and 2007.

Month	Ibadan		Ilora		Ballah	
	2006	2007	2006	2007	2006	2007
July	169.8	184.7	61.1	217.4	184.6	193.1
Aug	176	111.4	152.6	239.1	74.7	125.8
Sept	375.5	245.8	335.2	112.2	349.1	352.4
Oct	206.1	256.6	70.3	63.5	246.6	275.6
Total rainfall (Growth period)	927.4	798.5	619.2	842.7	855	946.9
Total annual rainfall	1526.	1224.1	1081	1363.3	1209	1625.6
Latitude	7°22' N		7°45 N		8°30 N	
Longitude	3°55 E		3°55 E		4°33 E	
Agro-ecology	Forest		Derived savanna		Southern guinea savanna	

(Yan et al., 2000). GGE has been shown to be effect-tive in understanding G x E interactions (Yan et al., 2000; Yan and Hunt, 2001; Casanoves et al., 2005). The GGE biplot graphically displays the two way data and allows visualization on the interrelationships among each of varieties, environments and their interaction. It therefore enables the breeder to know the performance of genotypes in specific environment. It is simple and easy-to-do procedure, which has gained acceptability and is being used in the analysis of data from multi-environment trials (Otoo and Asiedu, 2008). Hence the aim of this study was to compare the yield performance and other repro-ductive characters of eight soybean varieties at three lo-cations in the forest, derived savanna and Southern gui-nea savanna agro-ecologies of Nigeria and to compare their adaptability using GGE biplot analysis for grain yield.

MATERIALS AND METHODS

Eight soybean varieties were planted at three locations for two years (2006 and 2007). The three locations are Ibadan, Ilora and Ballah. Ibadan is in the rain forest agro-ecology of South-west Nigeria; Ilora falls within the derived savanna while Ballah is in the southern guinea savanna agro-ecology of the country. The latitudes, longitudes and total annual rainfall for 2006 and 2007 at each of the three locations are presented in Table 1. Seeds of the soybean varieties were supplied by the International Institute of Tropical Agriculture (IITA).

The plantings were done in mid July of each year using a randomized complete block design with three replicates. Each plot consisted of four rows of 5 m long, with 50 cm between and 5 cm within row spacing. Two seeds were initially planted per hole but later thinned to one three weeks after seedling emergence. No fertilizer was applied and manual weeding was done as at when due.

At maturity, data were taken from the two middle rows of each plot to reduce border effect. Data recorded include number of days to 50% flowering, pod length, number of seeds per pod, 100 seed weight and grain yield per plot from which grain yield per hectare was calculated at 15% moisture content. Data collected were subjected to analysis of variance using general linear model (GLM) procedure of SAS (SAS, 1997). Significant mean differences were determined with Duncan Multiple Range Test. GGE (genotype plus genotype by environment interaction) biplot analysis was used to show the distribution of the soybean genotypes among the locations according to Yan et al. (2000).

RESULTS AND DISCUSSION

Mean values of the characters of the eight soybean varieties evaluated across locations and years are shown in Table 2. The soybean varieties differed significantly for these characters. Number of days to 50% flowering varied from 42.38 in TGx 1485- 1D to 47.50 days in TGx 1990-1F. Number of seeds per pod had an average value of 2.31. The variety TGx 1448-2E had the highest 100 seed weight of 13.07 while TGx 1485-1D had the least. Grain yield ranged from 891.87 to 1137.84 kg/ha. The highest yielding variety across years and locations was TGx 1805-31F while TGx 1485-1D had the lowest value. Mean grain yields ranging between 521 and 1538 kg/ha was reported by Nassiuma and Wasike (2002) for soybean varieties evaluated in Kenya.

Significant effect of year was observed on the characters evaluated except for pod length which could be due to changes in environmental conditions which vary from one year to the other. The varieties took longer period to flower in 2007 with an average value of 47.63 compared with 42.96 days in 2006. Bigger seeds were however produced in 2006 with a mean 100 seed weight of 12.95 g instead of 12.16 g in 2007. Higher grain yields were also recorded in 2006 than 2007 with mean values of 1059.00 and 995.09 kg/ha respectively. The best yielding variety in 2006 across locations was TGx 1805-31F while TGx 1922-1F had the best grain yield in 2007 (data not shown).

The performance of the soybean varieties in each of the three locations across years are shown in Table 3. The eight varieties took longer period to flower at Ilora with an average number of days to 50% flowering of 48.77, while they flowered early at Ibadan (40.33 days). Longer pods were also produced at Ibadan and there were no significant differences among the locations for number of seeds per pod. The highest 100 seed weight was recorded at Ilora (13.11 g) while Ballah produce the

Table 2. Average values for grain yield and other reproductive characters of eight soybean varieties evaluated in three locations in Nigeria for two years.

Varieties	50% flowering	Pod length (cm)	Seeds/pod	100 seed weight (g)	Grain yield (kg/ha.)
1. TGx 1485-1D	42.38d	3.17bc	2.25b	11.83e	897.87c
2. TGx 1922-1F	45.50b	3.51a	2.67a	12.94abc	1090.20ab
3. TGx 1903-7F	44.00c	3.04bc	2.21b	12.43cd	1047.65bc
4. TGx 1448-2E	46.78a	3.14bc	2.33b	13.07ab	1018.23bc
5. TGx 1903-4F	44.11c	2.97bc	2.11b	12.22de	1087.20ab
6. TGx 1805-31F	46.72a	3.06bc	2.23b	12.55bcd	1137.84a
7. TGx 1019-2ED	45.33b	3.19bc	2.31b	12.95abc	913.02c
8. TGx 1920-1F	47.50a	3.31ab	2.39b	13.24a	1027.90bc
Mean	45.29	3.17	2.31	12.65	1027.49
SEM	0.53	0.04	0.04	0.09	22.33

Means on the column followed by different letter(s) are significantly different at 0.05 probability level

Table 3. Average values for seed yield and other reproductive characters of eight soybean varieties evaluated at Ibadan, Ilora and Ballah, Nigeria for 2 years.

Variety	Days to 50% Flowering			Pod length (cm)			Number of seeds per pod		
	Ballah	Ilora	Ibadan	Ballah	Ilora	Ibadan	Ballah	Ilora	Ibadan
TGx 1485-1D	44.33c	43.17e	39.07bc	2.73ab	3.28bc	3.48ab	2.00b	2.25ab	2.50
TGx 1922-1F	47.33ab	49.33bc	39.83abc	3.10a	3.55ab	3.88a	3.00a	2.33a	2.67
TGx 1903-7F	44.83c	48.17cd	39.00c	2.67ab	3.03c	3.42ab	2.00b	2.12bc	2.50
TGx 1448-2E	48.83a	50.50ab	41.00ab	3.02ab	3.33bc	3.08b	2.50ab	2.33a	2.17
TGx 1903-4F	46.00bc	46.67d	39.67bc	2.78ab	2.96c	3.17b	2.17b	2.00c	2.17
TGx 1805-31F	48.00ab	58.67ab	41.50ab	2.87ab	3.40ab	2.90b	2.33b	2.20ab	2.17
TGx 1019-2ED	46.00bc	49.67bc	40.33abc	2.95ab	3.28bc	3.33ab	2.33b	2.25ab	2.33
TGx 1920-1F	48.83a	52.00a	41.67a	2.80ab	3.81a	3.33ab	2.50ab	2.33a	2.33^{ns}
Mean	46.77b	48.77a	40.33c	2.87b	3.33a	3.33a	2.35	2.23^{ns}	2.35^{ns}
SEM	0.67	1.03	0.51	0.04	0.09	0.07	0.07	0.04	0.07

Table 3. Continued.

Variety	100 seed weight (g)			Grain yield (kg/ha)		
	Ballah	Ilora	Ibadan	Ballah	Ilora	Ibadan
TGx 1485-1D	11.57d	12.05d	11.85cd	925.00c	741.67d	1026.95b
TGx 1922-1F	12.13bcd	13.86a	12.82ab	1076.39bc	1136.26a	1057.96ab
TGx 1903-7F	12.63ab	12.39cd	12.27bcd	1366.56a	752.78d	1023.61b
TGx 1448-2E	11.70cd	13.53ab	13.98a	1139.22b	1058.80ab	856.67c
TGx 1903-4F	11.54d	12.82bcd	12.31bcd	1277.78ab	927.00c	1056.83ab
TGx 1805-31F	12.76ab	13.25ab	11.62d	1249.99ab	990.74bc	1172.80a
TGx 1019-2ED	12.51abc	13.23ab	13.11ab	1187.67ab	763.89d	787.50c
TGx 1920-1F	13.10a	11.47ab	12.85abc	1157.61cde	1084.43ab	841.67c
Mean	12.24	13.11	12.60	1172.53	931.95	977.99
SEM	0.12	0.30	0.09	36.86	37.72	32.80

smallest seeds (12.24 g). Ballah (Southern guinea savanna) had the highest grain yield of 1172.53 kg/ha followed by Ibadan (forest) (977.99 kg/ha), while Ilora (derived savanna) had the least value of 931.95 kg/ha. Mean grain yields ranging from 1017.24 to 2133.01 kg/ha was observed for 26 soybean varieties evaluated at Ballah for two years (Akande et al., 2007).

Aremu and Ojo (2005) also reported grain yields of between 768.15 and 1060.52 kg/ha for soybean evaluated in the forest environment of Southwest Nigeria, while va-

Table 4. Number of days to 50% flowering and grain yield (kg/ha) of 8 soybean varieties evaluated in 2006 and 2007 at Ballah, Ilora and Ibadan in Nigeria.

Varieties	Days to 50% Flowering						Grain yield (kg/ha)					
	Ballah		Ilora		Ibadan		Ballah		Ilora		Ibadan	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
TGx 1485-1D	38.67e	50.00b	34.00f	52.33b	42.33bc	37.00a	1033.33bc	816.67c	766.67d	716.67ab	780.56c	1273.33a
TGx 1922-1F	44.67ab	50.00b	43.33cd	55.33ab	42.00bc	37.67a	833.33c	1319.44ab	1436.42a	836.11ab	813.67c	1302.26a
TGx 1903-7F	39.67d	50.00b	41.67d	54.67ab	40.67c	37.33a	1422.00a	1311.11ab	805.56d	700.00b	0883.33c	1163.89a
TGx 1448-2E	47.00a	50.67b	46.67ab	54.33ab	45.00ab	37.00a	867.33c	1411.11a	1367.59ab	750.0ab	980.0bc	733.33c
TGx 1903-4F	41.67cde	50.33b	37.67e	55.67ab	42.00bc	37.33a	1477.77a	1077.78bc	983.33c	870.67a	1127.78a	985.89b
TGx 1805-31F	43.00bc	53.00a	45.00bc	56.33a	45.33ab	37.67a	1099.22bc	1402.78a	1223.15b	758.33ab	1417.51a	927.78b
TGx 1019-2ED	41.67bcd	50.33b	44.67bc	54.67ab	43.33ab	37.67a	1250.33ab	1125.00ab	783.33d	744.44ab	813.59c	761.11c
TGx 1920-1F	46.67a	51.0ab	48.33a	55.67ab	46.33a	37.0a	1022.22bc	1293.00ab	1351.85ab	817.0ab	900.0c	783.33c
Mean	42.88	50.67	42.67	54.85	43.33	37.33ns	1125.44	1219.61	1089.74	774.15	964.63	991.37
S E M	0.67	0.29	0.95	0.40	0.51	0.098	55.02	48.30	57.69	17.91	46.47	47.14

lues varying from 919.4 to 2006.90 kg/ha was also reported by Bhatnagar et al. (1994) for soybean varieties evaluated in Central India. Significant location x variety interaction effects were observed for all the characters evaluated except for number of seeds per pod indicating that different varieties were suitable for different locations (Nassiuma and Wasike, 2002). The variety TGx 1485-1D had one of the lowest values for all the characters evaluated at all the three locations although it had the advantage of being early maturing. At Ballah, TGx 1903-7F had the highest grain yield while TGx 1922-1F was the best yielder at Ilora. TGx 1922-1F also had the longest pods at Ballah and Ilora. At Ibadan, the best yielding variety was TGx 1805-31F. TGx 1920-1F had the longest number of days to 50% flowering at all the locations; it also had the longest pods at Ilora and the highest 100 seed weight at Ballah.

Only number of days to 50% flowering and grain yield kg/ha had significant year x location x variety interaction effects (Table 4). The soybean varieties flowered late in 2007 at Ballah and Ilora with average values of 50.67 and 54.85 days respectively instead of 42.88 and 50.67 days recorded in 2006 at the two locations respectively. The opposite was however the case at Ibadan where the varieties flowered earlier in 2007 (37.33) against 43.33 days in 2006. Significantly higher grain yields were recorded at Ballah (Southern guinea savanna) than the other locations in both years. Southern guinea savanna agro-environment was reported to be suitable for soybean production in Nigeria and the bulk of the crop consumed in the country is produced in this environment (Okpara and Ibiam, 2000). Significantly higher grain yields were obtained in 2007 than 2006 at Ballah and Ibadan, while the opposite was the case for Ilora (derived savanna).

The rainfall pattern as shown in Table 1 indicates that more precipitates were received in 2007 at Ballah (Southern guinea savanna) than Ibadan (forest), this is contrary to the previous observations ((Ajibade and Ogunbodede, 2001; Akande, 2007) . This may be due to climate change. It was also observed that greater grain yield was recorded in the year with more rainfall at Ballah (2007) while the opposite was the case for Ibadan which recorded less yield in the year with more rainfall (Tables 1 and 4).

Although past reports had shown that soy-bean performance can be affected by location and seasonal differences and that days to matu-rity and seed weight are affected by moisture availability (Tekrony et al., 1987; Ojo and Amanze, 2001; Aremu and Ojo, 2005), other climatic factors, soil properties and biotic factors may have to be studied to explain the variation in yield among the locations in the three agro- eco-logies. Among the varieties, TGx 1485-1D had the lowest values for number of days to 50% flo-wering in each year at each location. Although TGx 1920-1F was late maturing, TGx 1805-31F had the highest number of days to 50% in 2007 at Ballah and Ibadan. Different varie-ties had the highest grain yield in each year at each location. For instance, while the variety

Table 5. Variance terms for genotype (G), location (L) and G x L interaction from GGE biplot analysis for soybean grain yield at 3 locations.

Source of variation	DF	Sums of squares	%G+L+GL
Genotype	7	901363.65	21.66
Location	2	1565507.89	37.63
Genotype x Location	14	1693917.15	40.71

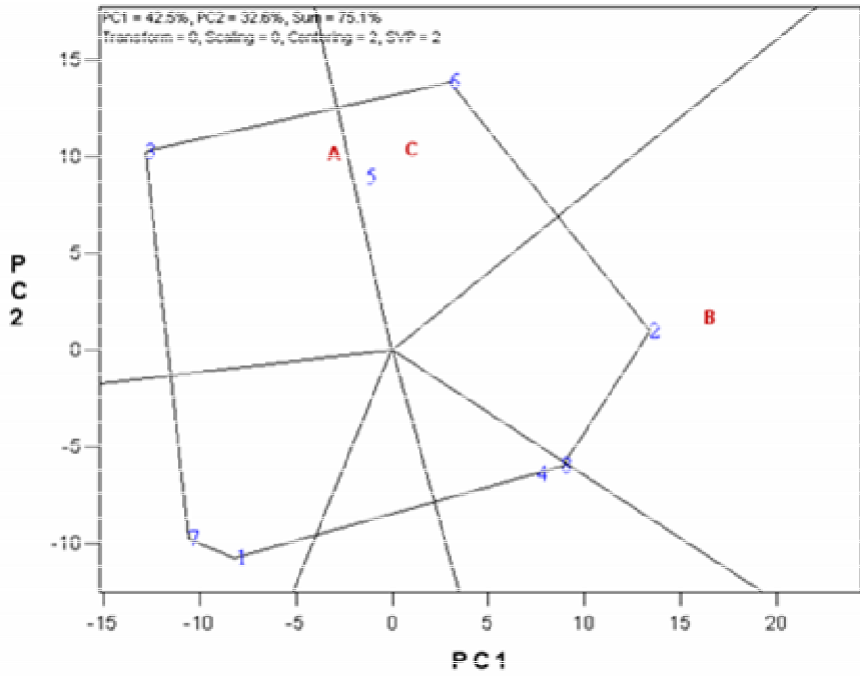

Figure 2. Yield performance of soybean varieties at 3 location in Nigeria.

TGx 1903-4F was the best yielding variety in 2006 at Ballah, TGx 1448-2E was the best at this location in 2007. TGx 1922-1F also had the highest mean values for grain yield at Ilora and Ibadan in 2006 and 2007 respectively (Table 4).

Results from GGE biplot analysis showed that genotype, location and genotype x location interaction were responsible for 21.66, 37.63 and 40.71% of their total variation respectively (Table 5). The first two principal components explained 75.1% of the variation with PC1 and PC2 accounting for 42.5 and 32.6% respectively. The dispersion of the soybean varieties among the three locations are shown in Figure 1. The locations were divided into three main sectors with A (Ballah) and C (Ibadan) having high interaction effects, although the highest mean grain yield was recorded at Ballah (Table 3). Ilora (B) was more distinct with its near zero PC2 value indicating stability for grain production but this environment was however low yielding (Tables 3 and 4). Variety 3 (TGx 1903-7F) was better adapted to Ballah (A) and it was the best yielding variety at this location (Table 3).

Varieties 5 (TGx 1903-4F and 6 (TGx 1805-31F) were suitable for cultivation at Ibadan (C) while variety 2 (TGx 1922-7F) was more appropriate for planting at Ilora (B). Only TGx 1922-1F appeared to be stable as it had high PC1 and near zero PC2 values, it can therefore be planted at any of the locations under evaluation in addition to the identified location specific varieties. This variety was also identified to be one of the best yielding varieties at Ballah by Akande et al., (2007). Four varieties 1, 4, 7 and 8 (TGx 1485-1D, TGx 1448-2E, TGx 1019-2ED and TGx 1920-1F) were found not to be suitable for cultivation at any of the test environments evaluated (Figure 1).

In this study the identified highest yielding variety across years and locations was TGx 1805-31F while the variety TGx1485-1D flowered earlier than the other varieties. Ballah (Southern guinea savanna) had the highest grain yield while Ilora (derived savanna) had the least. GGE bilpot showed that genotype x location interaction was responsible for the highest proportion of variability due to genotype, location and their interaction. It was observed that the variety TGx 1922-1F combined high grain

yield with stability in performance, it could therefore be planted at any of the locations evaluated. Suitable location specific soybean genotypes were also identified. The adoption of the identified high yielding soybean varieties at each of the locations evaluated would significantly improve soybean production in Nigeria.

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