*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

## Akande, S. R.*, Taiwo, L. B., Adegbite, A. A. and Owolade, O. F.

Institute of Agricultural Research and Training, P. M. B. 5029, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria.

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 cultivation of the crop in the cropping systems of the different agro-ecologies of the country. Although, most of the soybean 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 soybean in the West African moist savanna. Soybean performance, 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 multiple environments for the identification of suitable genotype for a specific environment.

Differential genotypic responses of crop varieties to variable environmental conditions especially those associated with changes in ranks of genotypes limit accurate yield estimates and identification of high yielding stable genotypes. In order to identify stable genotypes, the genotype x environment interaction (G x E) must be partitioned into stability statistics that are assignable to each genotype evaluated across a range of environments (Fernandez, 1991). Stability indices have allowed researchers to identify widely adapted genotypes to use in breeding programmes and have helped to improve recommendations to growers (Yayeh and Bosland, 2000). Many methods have been used to identify and to compare patterns of performance among crop genotypes across environments 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 recent time is GGE biplot analysis. The GGE (Genotype plus genotype x environment interaction) analysis partitions G + GE into principal components through singular value decomposition of environmentally centred yield da-

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*Corresponding author. E-mail: remiajibade2002@yahoo.com.

**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 obser-

ved 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 soybean performance can be affected by location and seasonal differences and that days to maturity 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-ecologies. Among the varieties, TGx 1485-1D had the lowest values for number of days to 50% flowering 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 varieties 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.

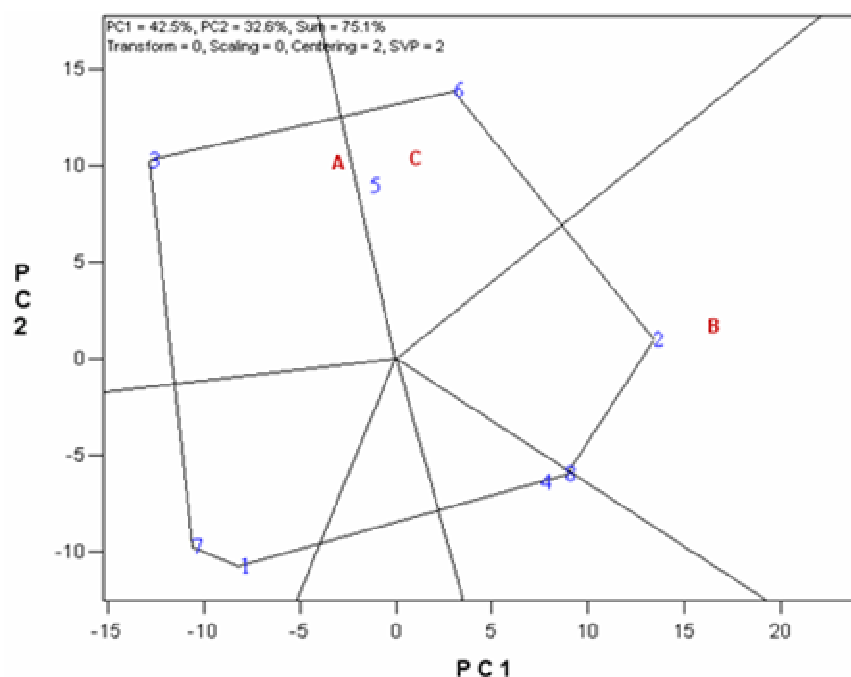| Source of variation | DF | Sums of squares | % G + L + GL |
|---|---|---|---|
| Genotype | 7 | 901363.65 | 21.66 |
| Location | 2 | 1565507.89 | 37.63 |
| Genotype x Location | 14 | 1693917.15 | 40.71 |



**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.

## ACKNOWLEDGEMENTS

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