Genotype by Environment Interaction in Soybeanand itsImplications for Crop Improvement

ABSTRACT

Adequate production of soybean [*Glycine max* (L.) Merr.]in Nigeria depends on selection of varieties combining high grain yield with stability. Soybean farmers are recurrently faced with the limitation of selecting the best genotypefor available environments at their disposal for the production of this crop.Soybean genotypes (23) and two landraces weretherefore evaluated in three environments: Abeokuta, Ibadan upland and Ibadan in-land valley in 2017to select genotype that combines high yield and stability. The experiment in each environmentwas arranged ina randomized complete block design with three replicates. Data were collected on grain yield and yield component characters. The grain yield data were analyzed using genotype + genotype x environment interaction (GGE) biplot to select desirable genotypes for grain yield and stability; the yield component data were also analyzed using analysis of variance (ANOVA). The variation attributable to G by E interaction was significant except number of branches per plant.Abeokuta was identified as the most representative environment for soybean production. Thegenotypes TGX 2007-4F, TGX 2016-2E and TGX 2007-1F were the best yielding genotypes in the most discriminating environment – Ibadan upland, thus highly recommended for that specific location.Genotype TGX 2027-7E (G25) was the most stable genotype but was low yielding. Genotypes TGX 2027-3E, TGX 2016-2E, TGX 2007-4F, TGX 2009-1F and TGX 2027-4E, which combined high yield and stability, can be recommended to growers in these three (or similar) environments.

Keywords: environment; genotype; grain yield;soybean; stability.

1. INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a legume that grows in tropical, subtropical and in temperate climates. It belongs to the subfamilyPapilionoideae in theFabaceae family, which is the third largest family of flowering plants.Soybean can adapt to a wide range of soils and climates. It is a good rotational crop for use with high nitrogen-consuming crops such as maize and rice [1].

The growing demand of soybean is as a result of its consumption as human meal supplement, poultry feed and usage of its oil in industries.The combination of level of consumption per year and the increasing population in Nigeria triggers the increased domestic soybean demand and so far is unable to be fully met by domestic production. However, the production and supply still do not meet the demand in Nigeria. The low yield of one ton/hectare [2]recorded in theSouth-western part of Nigeria was largely due to limited use of improved varieties and poor adaptation to the agro-climate of the region.

Soybean grain yield being a quantitative character is associated with some yield components and is influenced by environmental fluctuations [3].Genotypic responses in trials involving many environments are crucial in cultivar evaluation and recommendation [4], because crop grain yield is not determined by genotype and management practices alone but also by environment and Genotype-by-Environment Interaction (GEI).Therefore, to select superior genotype, the investigation of GEI in Multi-Environment Trials (MET) is inevitable [5]. A mega environment can be defined as a group of locations that consistently share bestculivar(s) [6].

Genotype-by-Environment Interaction simply refers to inconsistent phenotypic performance of genotypes across environments. It potentially presents limitations on selection and recommendation of varieties for target set of environments when it is associated with a significant genotypic rank change over environments [7]. The multivariate approaches for the analysis of GEI are numerous; some of the current ones are: Joint Regression [8,9], Kang Modified Rank Sum [10] and the Additive Main effects and Multiplicative Interaction (AMMI) analysis, the AMMI Stability Value (ASV) [11] the Genotype Selection Index(GSi) and Genotype main effect plus Genotype by Environment (GGE) biplot[12].

The GGE model reveals not just stable and adaptable genotypes but also desirable genotypes (combining high yield and stability), discriminating environment suitable for soybean grain yield selection and representative environmentwhere high soybean yield could be obtained. Farmers in Nigeria are faced with problem of low grain yield in soybean despite good agronomic practices employed in its production. Many ofthe soybean genotypes currently planted by the growers are not adaptable to some of the climatic conditions. Hence, there is need to use GGE model for efficient and effective selection of soybean for the farmers. The objectives of the study were to (i)determinethepresence of soybean production mega environmentsand (ii) select desirable genotypes for grain yield and stability.

2. MATERIALS AND METHODS

Twenty-three soybean genotypes and two landraces used for the study were obtained from International Institute of Tropical Agriculture (IITA) and National Centre for Genetic Resources and Biotechnology (NACGRAB) both in Ibadan, Oyo State, respectively (Table 1). The experiments were conducted in three environments:

Environment 1: - Teaching and Research Farm of Federal University of Agriculture Abeokuta (FUNAAB), Ogun state in the Derived Forest ecology of Nigeria (7° 14ˈ 12.9ʺ N and 3° 26ˈ 35.2ʺ E),wet season 2017.

Environment 2: - Ibadan upland,in the Rainforest ecology of Nigeria (7° 22ˈ26.1ʺ N and 3° 50ˈ41.1ʺ E), wet season 2017.

Environment 3: - Ibadan in- land valley, in the Rainforest ecology of Nigeria(7° 22ˈ40.9ʺN and 3° 50ˈ41.1ʺE)dry season 2017.

Theagrometeorological data of the environments are presented in Table 2.

The trial sites were manually cleared, stumped and pulverized. Seeds were sown in single - row plots, each1-m long in a randomized complete block design with three replications. The plant-to-plant spacing was 5cm while row-to-row was 60cm at a depth of 2 – 3 cm. Each block was divided into 25 single - row plots. Manual weeding was carried out at three weeks interval, starting from two weeks after planting till maturity.Insect pests were controlled chemically using 40 ml of Cypermethrin in 15 Liters of water, three weeks after planting, and subsequently after two weekly intervals,till physiological maturity was reached.

Table 1: List of 25 soybean genotypes used in the study

No.	Genotype	Status	Source
1	TGX 1988- 5F	Improved variety	IITA
2	TGX 2025- 19E	Improved variety	IITA
3	TGX 2004- 13F	Improved variety	IITA
4	TGX 2004- 9F	Improved variety	IITA
5	TGX 2004- 7F	Improved variety	IITA
6	TGX 2007- 1F	Improved variety	IITA
7	TGX 2016- 2E	Improved variety	IITA
8	TGX 2007- 4F	Improved variety	IITA
9	TGX 2013- 2F	Improved variety	IITA
10	TGX 2023- 4E	Improved variety	IITA
11	TGX 2007- 3F	Improved variety	IITA
12	TGX 2025- 16E	Improved variety	IITA
13	TGX 2018- 5E	Improved variety	IITA
14	TGX 2027- 3E	Improved variety	IITA
15	TGX 2009- 14F	Improved variety	IITA
16	TGX 2010- 5F	Improved variety	IITA
17	TGX 2010- 14F	Improved variety	IITA
18	TGX 2027- 2E	Improved variety	IITA
19	TGX 2023- 1E	Improved variety	IITA

20	TGX 2027- 8E	Improved variety	IITA
21	TGX 2009- 1F	Improved variety	IITA
22	TGX 2027- 4E	Improved variety	IITA
23	TGX 2027- 7E	Improved variety	IITA
24	NG/SA/07/150	Local landrace – check	NACGRAB
25	NG/AA/09/166	Local landrace – check	NACGRAB

IITA - International Institute of Tropical Agriculture, Ibadan

NACGRAB - National Centre for Genetic Resources and Biotechnology, Ibadan

Table 2: Agrometeorological data of the trial environments

Month	**Mean temperature (°C)**	**Total Rainfall (mm)**	**Relative Humidity (%)**	**Month**	**Mean temperature (°C)**	**Total Rainfall (mm)**	**Relative Humidity (%)**
	Abeokuta 2017				Ibadan 2017		
Jan.	28	16	61	Jan.	27	5	69
Feb.	30	0	89	Feb.	29	15	48
March	30	34	59	March	28	44	74
April	29	113	63	April	27	144	79
May	28	146	69	May	27	150	64
June	28	111	74	June	26	180	79
July	26	156	75	July	25.5	154	74
August	26	91	77	August	26	126	64
Sept.	25	50	69	Sept.	25	174	89
Oct.	28	92	73	Oct.	26	148	55
Nov.	29	46	66	Nov.	28	19	39
Dec.	29	0	69	Dec.	27	2	56

Source: Department of agro-meteorology and water resources management, FUNAAB, Ogun State. Location (Long: Lat) 03.22: 07.14;

Source: Department of agro-meteorology and water resources management, IART Ibadan. Location (Long: Lat) 03.90: 07.43

Observations were made in the three environments on the following agronomic and yield related characters from ten (10) randomly selected plants in each plot.

- Plant height at harvest (PLH; cm) was measured from the ground level to the tip of the plant recorded at harvest
- Number of branches per plant (NB/P**;** number**)** was taken as the average number of branches from selected plants counted per plot
- Number of pods per plant (NP/P; number) was counted as the average number of pods from selected plants per plot at the time of harvest
- Days to 50% flowering (DF; days) was taken as the number of days from the date of seed sowing to when 50% of the plants in the plot had flowered
- Days to maturity (DTM; days) was determined when 95% of the plants in the plot were physiologically mature as judged from the yellowish coloration of leaves and pods
- Harvest index (HI; %) was calculated by dividing grain yield per plot by biomass then multiplying by 100
- Hundred seed weight (HSW; g) was recorded as the mean weight of three sets of 100 seeds from each plot (at 13% moisture content) using analytical scale
- Grain yield per plot (GY/P; g)was recorded as the total weight of mature shelled seeds on a plot using analytical scale.

Data collected were subjected to Analysis of Variance using statistical analysis software [13] to determine effect of genotype (G), environment (E) and their interactions (GEI). Means were separated using Least Significant Difference (LSD) at 5% probability.

The Genotype plus Genotype x Environment Interaction (GGE) biplots were used to decompose the Genotype by Environment Interactions (GEI) by its visuals and for identifying mega-environments and their best performers. Mean performance and stability of genotypes were determined and the discriminatory ability andrepresentativeness of the test environment were revealed [12].

The liner model for GGEbiplot is:

$$Y_{ij} - \mu - \beta_j = \lambda_1 \xi_{i1}\, \eta_{j1} + \lambda_2 \xi_{i2}\, \eta_{j2} + \epsilon_{ij}$$

where Yij is the measured mean of genotype i(=1,2,….,n) in environment j(=1,2…,m), μ is the grand mean,

βj is the main effect of environment j,

μ + βj being the mean yield across all genotypes in environment j,

λ1 and λ2 are the singular values (SV) for the first and second principal component (PC1and PC2), respectively,

ξi1 and ξi2 are eigenvectors of genotype I for PC1 and PC2, respectively,

ŋ1jand ŋ2j are eigen vectors of environment j for PC1 and PC2, respectively,

εij is the residual associated with genotype i in environment j.

3. RESULTS ANDDISCUSSION

Analysisof variance for eight agronomic characters evaluated on 25 genotypes of soybean across three environments are presented in Table 3. There were significant differences among the genotypes with respect to all the evaluated characters except for days to 95% maturity, number of pods per plant, number of branches per plant and plant height.

The variation attributable to G by E interaction was significant except number of branches per plant.Partitioning of mean squares into its components showed that environments differed significantly and were quite diverse with respect to their effects on the performance of genotypes for seed yield and yield components.These results were in agreement with the earlier findings ofThangwana and Ogola [14] who investigated the yield and yield components of chickpea (Cicerarietinum) as a response to genotype and sowing environment within the Venda Experimental Farm in Thohoyandou. They reported a significant difference in the yield of this crop as a function of the growth region investigated in their study. Jai Dev [15],also investigated effects of GEIon soybean where he observed highly significant differences between genotypes, environments and G x E interaction.A large grain yield variation, explained by environment was diverse and major part of variation in grain yield can be a result of changes in environment. This observation is consistent with the findings of Ojo*et al*. [16] on soybean grain yield at different locations at the Teaching and Research Farm of the University of Agriculture Makurdi, within the Southern Guinea Savanna Agro-ecological zone of Nigeria.

Table 3: Analysis of variance for agronomic and yield - related characters evaluated in 25 genotypes of soybean in Abeokuta, Ibadan upland and Ibadan in-land valley.

		Mean Square							
Source of	Df	D50F	DTM	NP/P	NB/P	PLH	HI	HSW	GY/P

variation									
Block	2	8.41*	0.72	163.21*	18.32**	54.46	57.77	25.32	240.94**
Gen.	24	29.02**	14.43	42.55	2.21	101.39	550.44**	47.85**	163.33**
Envir.	2	1956.21**	6027.2**	382.98**	18.26**	5779.04**	4787.79**	593.71**	2809.10**
GEI	48	1956.21**	19.21**	54.56*	1.8	1084.74*	326.68**	33.87**	192.27**
Error	148	2.07	9.65	36.69	1.43	70.96	142.53	14.42	14.84

***, * significant at P < 0.01 and 0.05 level of probability respectively*
Gen. = Genotype, Envir. =Environment, GEI = Genotype by Environment interaction, Df = Degree of freedom, D50F = Days to 50% flowering, DTM = Days to 95% maturity, NP/P = Number of pods per plant, NB/P = No of branches per plant, PLH = Plant height, HSW = Hundred seed weight, HI = Harvest index, GY/P = Grain yield per plot.

3.1 Genotype - by - Environment Interaction and Stability Performance of Soybean

The “which-won-where” grain yield performance of 25 soybean genotypes across test environments was presented in Figure 1. This explicitly displays the which-won-where pattern of genotypes. Each of the environment is located one of the five sectors found in the biplot. The genotype(s) vertex in these sectors may have higher or the highest yield compared to other parts in all environments.The longest vector of the polygon on the sector 1 and is also the closest to Abeokuta (E1) was TGX 2023-1E (G17), suggesting that it was high – yielding and welladaptable to Abeokuta (E1).The vertex genotype for Ibadan upland (E2) sector was TGX 2007-4F (G9) suggesting it was the most adaptablegenotype in thisenvironment while the vertex genotype for the fifth sector, Ibadan in-land valley (E3), wasNG/AA/09/166 (G24). The genotype in each sector is also adaptable for environment whose marker fell into corresponding sector so that environments within the same sector share the same winning genotype. No environment fell into the sector withTGX 2004-9F (G5) and TGX 2023-4E (G10), which indicates they were the poorest genotypes in some or all of the environments.

Figure 2 presents the mean performance and stability of 25 soybean genotypes across the test environments. The dispersion of genotypes markers ontothe Average Environment Axis approximates the mean yield of genotypes. The highest yielding genotype was TGX 2023-1E(G17), the next high yielding ranked was TGX 2007-4F (G9) while the least yielding genotype was NG/AA/09/166 (G24). A double arrowed line also divided the biplot into two, separating genotypes that performed above average (genotypes on the right) from the below average (genotypes on the left). Thus, the abscissa arrow points in the direction of increasing yield performance. The projections on to the ordinate are measure of instability of the genotypes.

The AEA approximate the GEI associated with genotype and this is a measure of variability or instability of the genotypes.The longer the vector of the graph is, the more unstable the associated genotypes irrespective of the direction. Therefore, TGX 2023-1E(G17), TGX 2007-1F (G7), TGX 2013-2F (G10) and TGX 2023-4E (G11) were more variable and very unstable. The short vector implies high stability [14].NG/SA/07/150 (G1), TGX1988 -5F (G2), TGX 2025-19E (G3), TGX 2004-13F (G4), TGX 2007-3F (G12), TGX 2025-16E (G13), TGX 2018-5E (14), TGX 2027-3E (15), TGX 2009-14F (G16), TGX 2010-14F (G18), TGX 2023-1E (G20), TGX 2027-8E (G21) andTGX 2027-7E (25)were fairly stable genotypes. Genotype TGX 2027-3E (15) was desirable as it combined stability with high yield (37.70 g) while TGX 2027-7E (25) was stable but it performed below average (34.58 g) in the test environments.

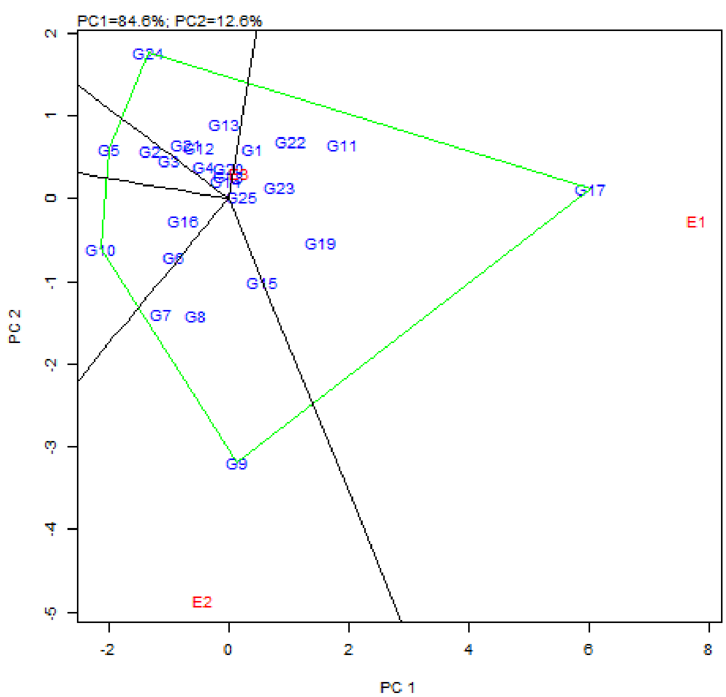

Figure 1. The polygon view of the GGE biplot of grain yield for the "which-won-where" pattern for genotypes and environment

Code	Environments
E1	Abeokuta
E2	Ibadan upland
E3	Ibadan in-land valley
	Genotypes

G1	NG/SA/07/150
G2	TGX 1988- 5F
G3	TGX 2025- 19E
G4	TGX 2004- 13F
G5	TGX 2004- 9F
G6	TGX 2004- 7F
G7	TGX 2007- 1F
G8	TGX 2016- 2E
G9	TGX 2007- 4F
G10	TGX 2013- 2F
G11	TGX 2023- 4E
G12	TGX 2007- 3F
G13	TGX 2025- 16E
G14	TGX 2018- 5E
G15	TGX 2027- 3E
G16	TGX 2009- 14F
G17	TGX 2010- 5F
G18	TGX 2010- 14F
G19	TGX 2027- 2E
G20	TGX 2023- 1E
G21	TGX 2027- 8E
G22	TGX 2009- 1F
G23	TGX 2027- 4E
G24	NG/AA/09/166
G25	TGX 2027- 7E

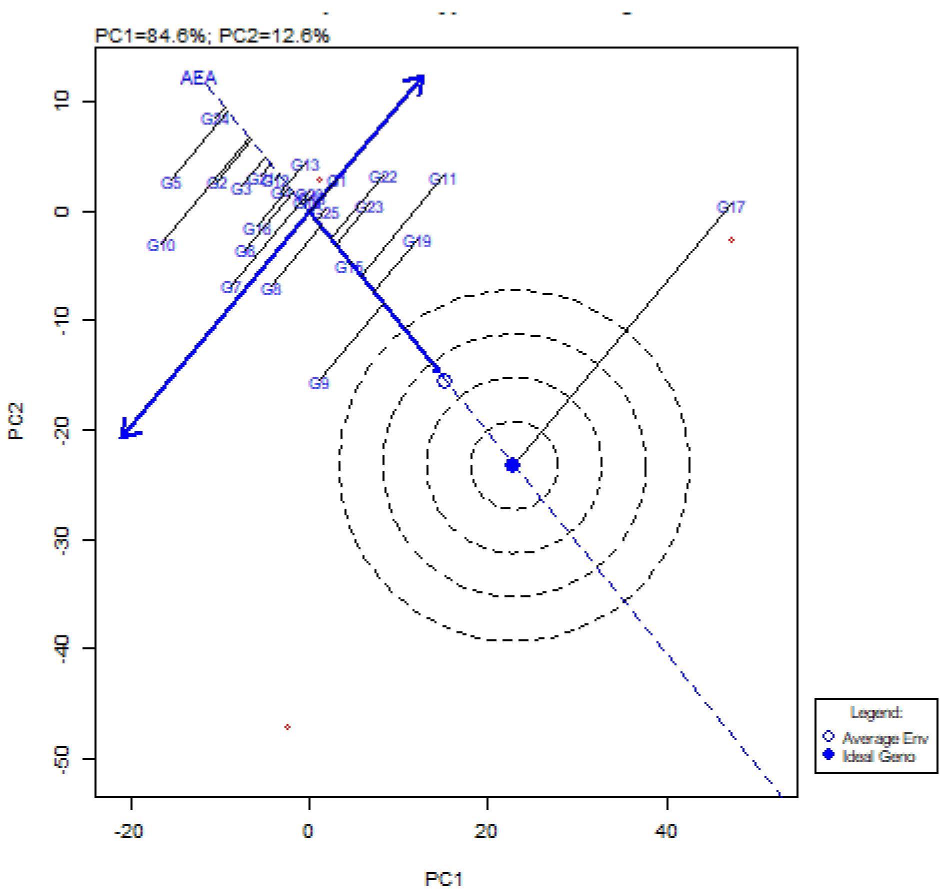

Figure 2. The mean performance and stability of 25 soybean genotypes across the test environments

Figure 3 shows representativeness and discriminatory ability of the test environments. From the vector view of the biplot, the length of the environment vectors approximates the standard deviation within each environment [17]. Thecentre of concentric circlesis where an ideal environment should be located, thus, Ibadan upland was most discriminatory. The biplot way of measuringrepresentativeness of an average environment is to define an average environment and use it as reference or benchmark [17]. The line that passes through the biplot origin and the average environment is the Average Environment Axis (AEA). The angle between the vector of an environment and the AEA is measure of representativeness of the environment. Abeokuta (E1) is the most representative environment since it has the smallest angle to AEA while Ibadan upland is the least representative.

Table 4 presents grain yield of 25 soybean genotypes in each environment.The grain yield across three environments ranged from as low as 28.22 g in Ibadan upland to 38.66 g in Abeokuta environment. Suggesting that there was 10.44 g difference between these two environments.

Table 5 presentsgrain yield and yield components of the 25 soybean genotypes tested inthree environments. Days to 50% flowering ranged from 46 days for TGX 2009-1F to 52 days for TGX 2025-19E.For Days to 95%maturity it was also observed that genotypes TGX 2004-7F had highest mean value of 89 days while TGX 2009-14F and TGX 2027-4E had same least value of 84.89Harvest index also recorded highest mean value57.68% forTGX 2023-1E while TGX 2010-14F had the least of 18.05%.Genotype TGX 2023-1Eas unstable genotype but highest grain yield (66.20 g) was early maturing comparable tothe two landraces; NG/AA/09/166 and NG/SA/07/150.

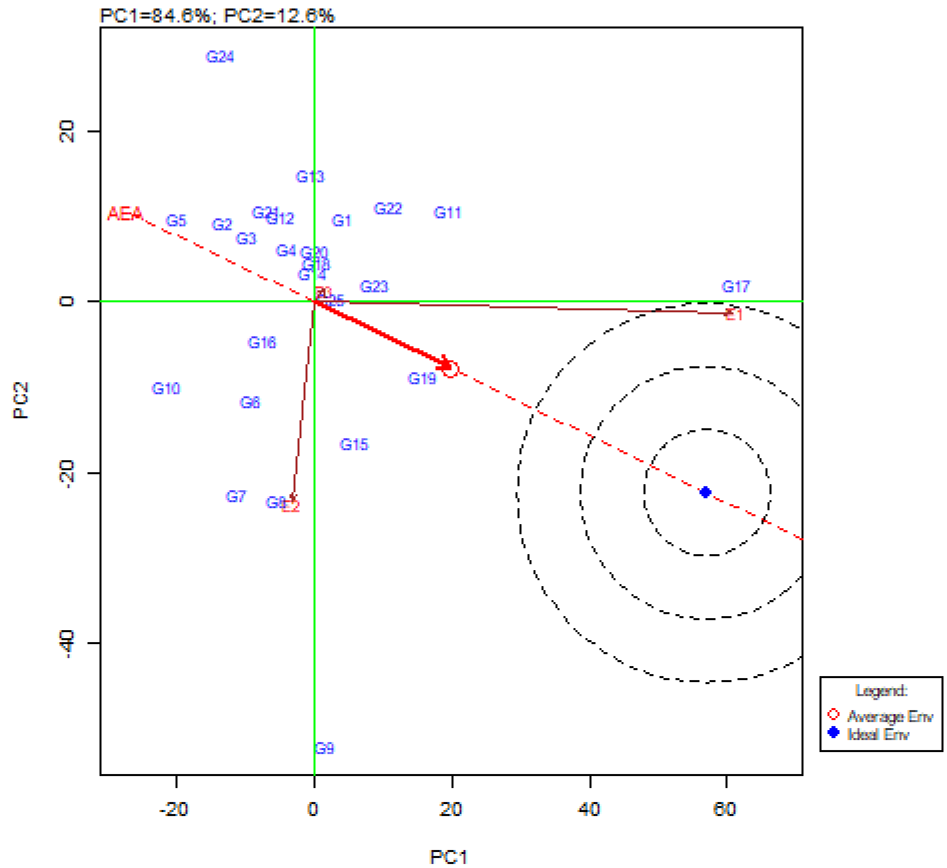

Figure 3. Discriminating ability versus representativeness of the test environments.

Table 4. Mean grain yield of 25 soybean genotypes tested across three environments

Code	Genotype	Abeokuta	Ibadan Upland	Ibadan In-landValley	Mean
G1	TGX 2027-7E	27.82	10	26.99	25.96
G2	TGX1988 -5F	30.87	26.3	26.43	27.05
G3	TGX2025-19E	38.64	26.34	28.21	32.11
G4	TGX 2004-13F	35.37	26.51	28.74	30.9
G5	TGX 2004-9F	31.79	32.01	28.23	31.53
G6	TGX 2004-7F	13.02	26.23	25.75	22.81
G7	TGX 2007-1F	30.26	35.29	27.09	31.84
G8	TGX 2016-2E	43.36	32.82	32.79	40.2
G9	TGX 2007-4F	40.56	43.7	37.02	46.5
G10	TGX 2013-2F	38.37	27.08	27.5	32
G11	TGX 2023-4E	38.72	26.8	23.34	32.6
G12	TGX 2007-3F	34.76	35.4	33.05	37.26
G13	TGX2025-16E	50.72	29.91	30.5	41.42
G14	TGX 2018-5E	32.85	29.99	27.95	32.87

G15	TGX 2027-3E	46.64	24.49	32.94	37.7
G16	TGX 2009-14F	12.25	31.87	23.29	24.8
G17	TGX 2023-1E	85.7	25.21	53.82	66.2
G18	TGX 2010-14F	34.67	25.39	26.25	28.56
G19	TGX 2027-2E	32.95	25.84	34.94	32.3
G20	TGX 2023-1E	85.70	25.21	53.82	66.20
G21	TGX 2027-8E	40.45	27.91	29.35	34
G22	TGX 2029-1F	53.48	24.21	34.15	41.67
G23	TGX 2027-4E	45.09	27.16	30.85	37.34
G24	NG/AA/09/166	41.53	25.52	39.25	38.83
G25	NG/SA/07/150	28.26	25.89	24	24.41
Mean		38.66	28.22	36.86	34.58

Table 5: Grain yield and agronomic performance means of 25 soybean genotypes tested in three environments

Genotype	D50F	DTM	NP/P	NB/P	PLH	HSW	HI	GY/P
TGX 2027-7E	49.33	85.67	14	2.44	44.06	13.77	26.08	25.9
TGX1988 -5F	51.33	88.33	18.78	3.89	48.63	14.87	29.54	27
TGX2025-19E	52.33	86.78	12.44	3.11	42.68	11.65	39	32.11
TGX 2004-13F	46.89	87.33	16	3.11	50.88	13	28.91	30.91
TGX 2004-9F	47.67	86.11	12.11	3.22	50.82	10.49	34.84	31.5
TGX 2004-7F	47.78	89	11.33	3.11	51.32	9.48	27.33	22.81
TGX 2007-1F	48	84.89	14.11	2.89	46.99	11.25	31.97	31.84
TGX 2016-2E	48.44	88.89	16	3.22	48.89	13.18	35.04	40.2
TGX 2007-4F	46.22	85.78	16.78	4.11	45.24	9.56	36.36	46.5
TGX 2013-2F	47	86.22	13.33	3.33	46.59	12.32	26.44	32.01
TGX 2023-4E	48.33	86.44	15.78	3	48.39	10.2	24.23	32.6
TGX 2007-3F	46.44	87.67	16.22	4.11	46.1	12.48	24.56	37.21
TGX2025-16E	50.11	88.33	13.11	3.56	49.58	11.21	27.07	41.21
TGX 2018-5E	46.67	85.44	14.44	4.11	45.71	9.63	45.64	32.2
TGX 2027-3E	46.22	86	13.67	2.89	48.01	14.29	37.95	37.71

TGX 2009-14F	48.67	84.89	10.78	2.89	43.66	9.43	18.27	24.8
TGX 2023-1E	51	85.11	15.11	3.89	46.36	15.1	57.68	66.2
TGX 2010-14F	48.78	86.56	17.56	4.33	56.44	9.47	18.05	28.6
TGX 2027-2E	49.11	86.44	13.11	3.67	47.57	16.41	43.36	32.3
TGX 2010-5F	51.56	87.44	13	3.67	46.23	11.55	24.25	30.5
TGX 2027-8E	48.11	85.56	15.11	3.33	45.01	11	23.4	34
TGX 2009-1F	46.11	86.11	15.11	3.22	40.9	12.99	43.64	41.7
TGX 2027-4E	47.11	84.89	17.22	4.11	49.19	18.46	28.57	37.4
NG/AA/09/166	47.89	87.88	13.78	3	43.97	13.24	46.21	38.8
NG/SA/07/150	46.56	87.78	17.78	3.33	43.32	11.44	21.68	24.41
L. S. D. (0.05)	1.33	2.87	5.6	1.11	7.78	3.51	11.03	3.56

D50F = Days to 50% flowering, DTM = Days to 95% maturity, NP/P = Number of pods per plant, NB/P = No of branches per plant, PLH = Plant height, HSW = Hundred seed weight, HI = Harvest index, GY/P = Grain yield per plot.

Significant variation attributable to Genotype-by-Environment Interaction was observed for all the characters except number of branches per plant,this could suggest that the soybean genotypes respond differently in each of the tested environments [18,19,20,21].Genotype TGX 2004-7F (G6) with lowest grain yield is a poor genotype and therefore not desirable in the trial environments. The characters, such as: number of pods per plant, number of branches per plant and plant height with no significant difference across the genotypes indicated little prospect in selecting them for soybean improvement.

An ideal genotype is expectedto be adapted to a broad range of environmental conditions to produce consistent yields everywhere[17]. The vertex genotype for Ibadan in-land valley (E3) sector was the landrace NG/AA/09/166 (G24) while the vertex genotype for Ibadan upland (E2) was genotype TGX 2007-4F (G9) suggesting them as most outstanding genotype for each of the two separate environments. Genotype TGX 2023-1E (G17) was the highest yielder at Abeokuta (E1). No environment fell into sector where TGX 2004-9F (G5) and TGX 2023-4E (G10) were present, indicating that they were the poorest genotypes in some or all of the test environments.The study revealed there were no consistent relationships among test environments.

The GGE model precisely selected genotypes that combined high yield and stability. This is in accordance with Yan *et al.*[22], who compared the effectiveness of the available techniques and concluded that GGE biplot is more comprehensive and its visual effects are unparalleled. The GGE biplots distinctly and figuratively placed genotypes into environment of the adaptation, and also identified the stable genotypes and representative environment.

GGE biplots displayed ideal genotypes and discriminatory environments. Based on the mean performance of grain yield and stability of 25 soybean genotypes across the test environments, TGX

2023-1E (G17) was observed to be highest grain yielder but very unstable. Discriminating ability versus representativeness of the test environments graph revealed Abeokuta (E1) as the most representative environment. Ibadan upland (E2) was identified as the less representative. The GGE biplot identified TGX 2010-14F (G18), TGX 2027-3E (G15), TGX 2027-4E (G23) and TGX 2027-7E (G25) as fairly stable genotypes having short vector to the AEA.

Genotype TGX 2027-3E (G15) and TGX 2027 -7E (G25)were established in this study to have the most stable performance across the trial environments. The GGE models clearly identified TGX 2027-3E (15), TGX 2016-2E (G8), TGX 2007-4F (G9), TGX 2009-1F (G22) and TGX 2027-4E (23) as desirable genotypes that combined high yield and stability in the test environments.This was similar to the findings of Sunil*et al.* [23] who found one desirable Soybeancultivarat the experimental Farm of Kisan (PG) collegeSimbhaoli India where they observed that the cultivar was high yielding and stable for seed yieldover the tested environments. Genotype TGX 2027-7E (G25) was identified as most stable in performance but low yielding across the environments. Therefore it is regarded not desirable for soybean growers in the environments.

The GGE biplot is found to be a crucial stability model, as the most discriminatory for selection of desirable genotypes in soybean. Therefore, it is being recommended, for researchers, either singly or in addition with other models, for crop selection and improvement purposes. The following genotypes TGX 2027-3E (15), TGX 2016-2E (G8), TGX 2007-4F (G9), TGX 2009-1F (G22) and TGX 2027-4E (23) found to bedesirable for grain yield and could be recommended for growers in similar environments.

4.CONCLUSION

This research study investigated the superior soybean genotype that combines high yield and stability in three tested environment in southwest Nigeria (Abeokuta, Ibadan upland and Ibadan in-land valley). It was observed that yield performance of soybean genotypes were highly influenced by GEI effects. Consequently, mega environment does not exist in the selected soybean growing environments. Among the 25 tested genotypes, 5 genotypes [TGX 2027-3E (15), TGX 2016-2E (G8), TGX 2007-4F (G9), TGX 2009-1F (G22) and TGX 2027-4E (23)] demonstrated high yield and relatively stable performance across the environments. Genotype TGX 2004-7F (G6) showed the poorest and unstable yield performance.

5. RECOMMENDATION

Genotypes TGX 2027-3E (15), TGX 2016-2E (G8), TGX 2007-4F (G9), TGX 2009-1F (G22) and TGX 2027-4E (23) could be recommended to be released as new soybean varieties in the three growing (or similar) environments.

COMPETINGINTERESTS

Authors have declared that no competinginterests exists.

Authors' contributions

Ayo-Vaughan, M. A. and Ariyo, O. J. contributed to the conceptualization and the initial design of the research work. Sakariyawo, O. S. and Aremu, C. O. contributed to overseeing the research execution (methodology) and manuscript review. Adediran, B. O. contributed to the execution of Genotype by Environment Interaction in Soybean [Glycine max (L.)*Merr.]and the development of the first draft of manuscript. Ibitoye, D. O. reviewed and edited the manuscript. All authors contributed the drafting, revision, and final approval of the submitted manuscript.*

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