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Research Article

Genotype by Environment Interaction of Some Soybeans Genotypes (*Glycine max* L. Merr.) Grown Across Three Environments in Southern Guinea Savannah Zone of Nigeria Using GGE Biplot

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Abstract

Soybean is the most important oil crop in Nigeria and the world. It is the leading source of oil and protein. Genotype × environment interaction affect plant breeders in selection of a stable genotype. Ten soybean genotypes were evaluated across three location Ilorin, Ibadan and Minna in Southern Guinea savannah agro-ecological zone in Nigeria to determine the effect of genotype × environment interaction. The experiment was conducted during 2021 rainy season across the three locations. Data were collected focusing on both growth and yield parameters. The data were analyzed using GGE biplot method. GGE biplot revealed that interaction principal component axis 1 accounted for 85.6% while the interaction principal component axis 2 accounted for 9.4% of the total variation explained. Genotype G9 was the most stable genotype across all the locations and also the ideal genotype. Minna location was the ideal location. Positive correlation was observed between Ibadan and Minna while Negative correlation was observed between Ilorin and Ibadan and between Ilorin and Minna.

Keywords: Soybean; Genotype; Environment; GGE Biplot; Stability

Introduction

Soybean (*Glycine max* L merr.) is a world leading source of oil and protein contributing in Nigeria and in the world contributing 20% and 40%, respectively [1]. Nigeria ranks second highest producer of soybeans in sub-sahara Africa [2]. Nigeria recorded 679,000 metric tons of soybeans in year 2023. Soybean is grown by both small scale and large scale farmers in Nigeria. It is grown basically for food for human consumption and also for feed. The interaction between Genotype and environment poses a great challenge to soybeans breeders in development of a stable genotypes. Genotype × environment interaction is the modification of the genetic factor of a genotype by environmental factors and to the role of genetic factors in determining the performance of a genotypes. It's the ranking of genotypes performance from one environment to another.

G×E can occur for quantitative traits of economic importance and is often studied in plant and animal breeding, genetic epidemiology, pharmacogenomics and conservational biology research. Genotype × environment reduces the predictability of the performance of genotypes in target environments based on genotype performance in a test environment. Several statistical methods had been used for analyzing stability, these methods includes both univariate and multivariate method. This paper focuses on the use of Genotype by Genotype and Environment (GGE) model. The aim of the study was to identify high yielding soybeans varieties that are stable in performance across the test environments.

Materials and Methods

Study location

The study was conducted during the 2021 rainy season at three experimental sites across theSouthern Guinea Savanna of Nigeria. The experimental sites were as follows:

- Ayédè village, Pake Jeba Expressway in Ilorin, Nigeria, (9°23'46"N and 3°35'28"E) with an average temperature of 26.7°C(80.06°F), and mean annual rainfall 852 mm.
- National Cereals Research Institute (NCRI) outstation Apata, Ibadan, Oyo state, Nigeria, (7°23'46"N 3°50'26"E) with an average temperature of 25.9°C (78.62°F), andannual rainfall 1470 mm.
- Department of Crop Production Teaching and Research field Federal University of Technology Minna, Gidan Kwano, Minna, Niger State, Nigeria positioned at (9°35'00"N and 6°32'46"E) with an average temperature of 27.9°C (82.22°F), and mean annual rainfall 1161 mm.

Planting materials

Ten soybean genotypes were sourced from the genebank of National cereals research institute Badeggi soybean program.

Treatment and experimental design

The experimental treatments were the ten soybean genotypes and the three locations in southern guinea savannah arranged in a randomized complete block design.

Agronomics practice

The experimental field was plowed and then ridged with the assistance of a tractor. Pre emergence herbicides was applied after forming ridges were made to kill the remaining weeds and the weed seeds. All agronomic practices were carried out following method described by [6]. Seeds of each genotype were sown at the rate of two seeds per stand at an intra-row spacing of 5 cm and inter-row spacing of 60 cm. The seedlings were later thinned to one plant per stand. Seeds were sown on June, July and August for Ilorin, Ibadan and Minna respectively. Weed was control using Penimethalin 500 as pre emergency herbicides and supplementary hand weeding was done at five weeks after planting. Fertilizer application was done at recommended rate of 15 kg N and 40 kg P_2O_5 per hectare at two weeks after planting. Harvesting was done at physiological maturity when 95% of the leaves and pods had turned brown. Harvesting was done on plot bases, where the net plot was harvested and the numbers of plant stand harvested was taken and recorded. The harvested soybeans plant were carefully thrashed and the harvested grain were bagged in paper bags and properly labeled.

Data collection

Data were collected on both growth and yield.

Growth data

The following growth data were collected.

Percentage of germination (%)

Calculated using the formula below

Plant height

This was measured for the plants in the middle rows at 12 weeks after planting (WAP) using the tape. It was measured from the ground to the last leaf of the main shoot. The average height of the selected plants was computed and recorded.

- **Number of leaves:** Was done by counting the visible leaves on the plants in the middle rows and the average number were taken and recorded.
- **Branches per plant:** This was done by counting the number of branches of the plants in the middle rows, their average computed and recorded.
- **Days to 50% flowering:** Were recorded when half of the plants in a net plot flowered.

This was done through visual observation.

- **Days to maturity:** This was calculated from the sowing date to the date when 95% of the plants in the net plot reached maturity.

Yield data

- **Pods per plant:** Were counted manually from the plants in the middle rows during harvestand recorded.
- **Above-ground biomass (kg/plot):** Were taken by weighing the above-ground part of all the plants in a net plot during harvest, using a weighing balance and recorded.
- **Seed yield (kg/plot):** The weight of seeds harvested per net plot were measured using a weighing balance and recorded.
- **100-seed weight (g):** One hundred (100) seeds of each genotype were randomly taken and their weight measured using a digital (sensitive) weighing balance in the laboratory and the values recorded.

Data analysis

Analysis of variance

Data collected were subjected to Analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of STAR Statistical tools for Agricultural Research Version 2.0.1. Means were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability. The GGE analysis was done using GGE biplot [8].

Results

Means Square values for some growth and yield parameters of soybeans is shown in Table 1. There were significant differences at P ≤ 0.05 among the traits measured for genotype, location and genotype x location interactions except for days to 50% flowering.

Sources of variation	Df	%GEM	Numbers of leaves	Numbers of branches	Plant height	Numbers of pod per plant
Rep	2	0.2841	37.4274	0.1314	2.8195	4.933
Genotype	9	261.3768 **	741.0265**	29.3898**	122.2197**	23143.0481**
Location	2	5204.5381**	3155.8388**	3162.6481**	1486.0357**	92055.0333**
Genotype by location	18	172.0491**	938.2795**	33.9486**	132.1191**	10521.3296**
Error	58	4.9658	15.9918	1.7465	2.7163	95.4966
Total	89					
Sources of variation	**Df**	**Days to 50% flw**	**Days to 80% maturity**	**Biomass**	**Seed weight**	**Seed yield**
Rep	2	4.6778	1.0111	0.0212	0.700	0.002
Genotype	9	31.9556	40.449**	0.1041**	4.8654**	0.0802**
Location	2	0.0778	113.3778**	9.62**	46.800**	1.1641**
Genotype by location	18	1.0037	10.7975**	1.2081**	1.9358**	0.0595**
Error	58	1.2295	1.1950	0.0570	0.8149	0.0008
Total	89					

Table 1: Means Square values for some soybeans genotypes traits grown across different locations.

The GGE biplot in Figure (1) Indicates that the Interaction Principal Component 1 (IPCA1) accounted for 85.6% of the variation, while the Interaction Principal Component 2 accounted for 9.4%. The analysis reveals that genotypes G1, G8, and G10 are classified as stable genotypes.

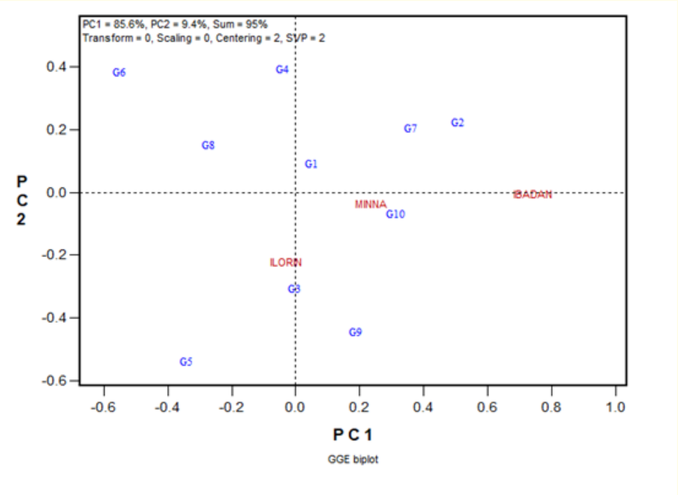

Figure 1: GGE biplot of soybeans genotypes grown across three environments.

The performance of genotypes in specific environments is illustrated in Figure (2). Genotypes located at the vertices of the polygon are considered the best performing genotypes in those particular environments. Genotype G2 is identified as the top-performing genotype in Ibadan and Minna, whereas genotype G9 excels as the best performer in Ilorin.

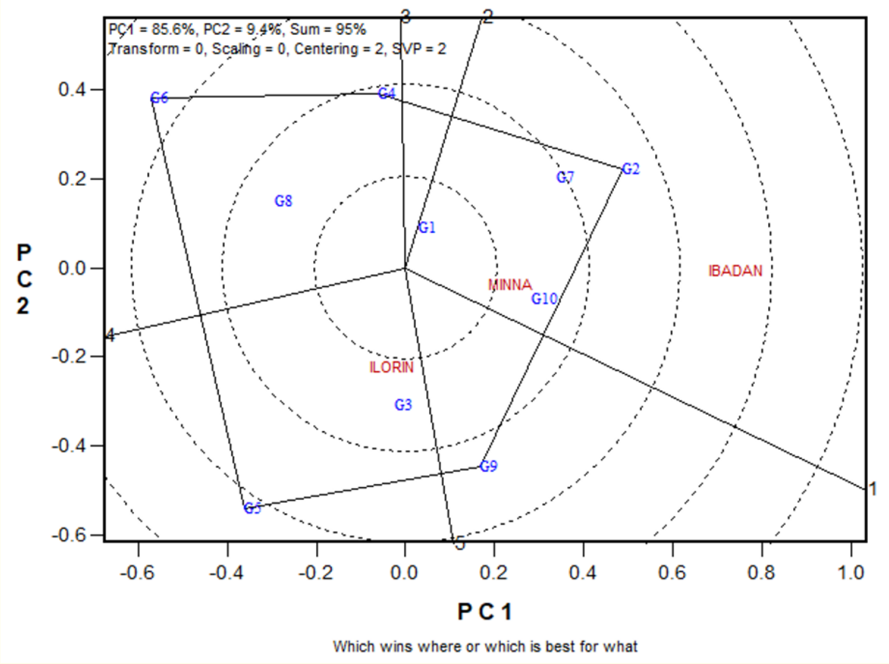

Figure 2

The mean verse stability biplot is shown in Figure (3). The red line with a single arrowhead represents the mean grain yield, while the blue line with a double arrowhead signifies the degree of stability. The length of the blue double-arrow line indicates the level of stability, where genotypes with shorter lines are more stable compared to those with longer lines. Notably, genotypes G4, G3, G9, and G10 are stable genotypes, with genotype G9 standing out as the most stable.

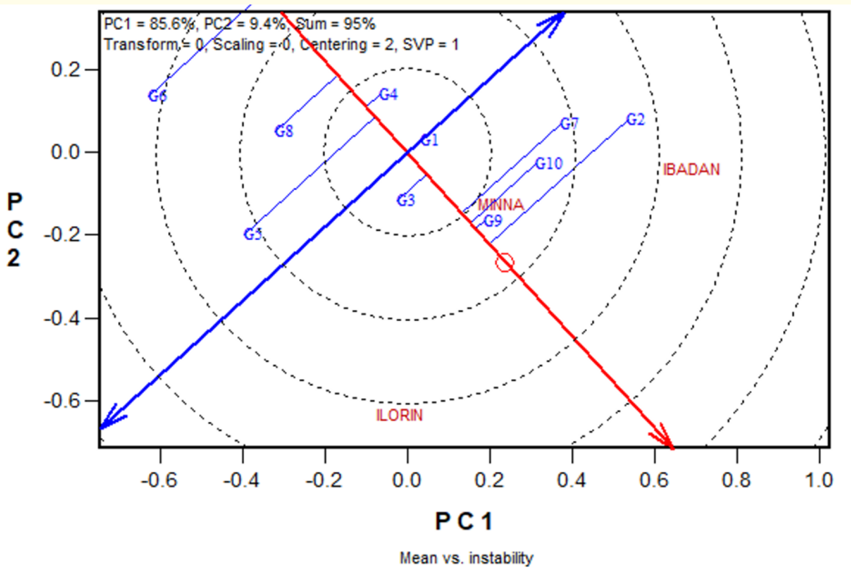

Figure 3: Mean vs. Stability Analysis.

The discriminating ability of the locations is shown in Figure 4. Positive correlation exist between Minna and Ibadan because the angle between the two environments vector is an acute angle while negative correlation exist between Illorin and Ibadan and between Illorin and Minna because the angle between the environment vectors is an obtuse angle.

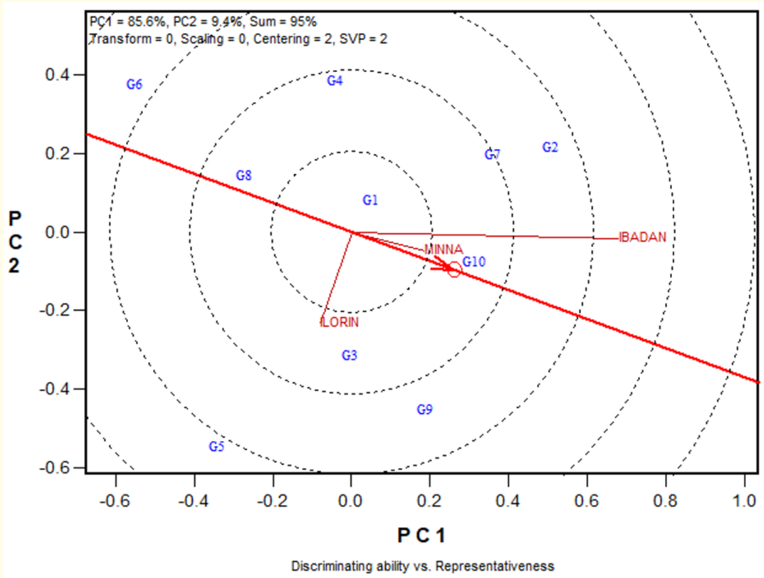

Figure 4: Discriminating ability vs Representativeness ability of the environments.

The ideal genotype bipolt is represented in figure 5, the ideal genotype which is represented by the small red circle within the concentric circle. Genotypes closer to the ideal genotypes are desiring genotypes. Genotype G9 is the closest to the ideal enhance it is the most stable genotype across the locations under evaluation.

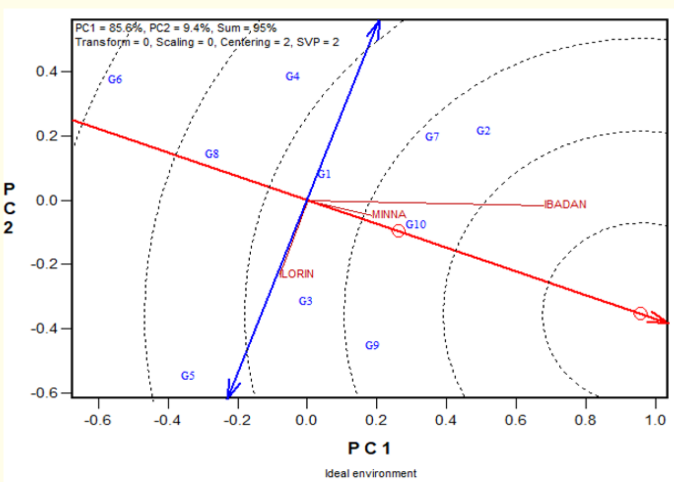

Figure 5

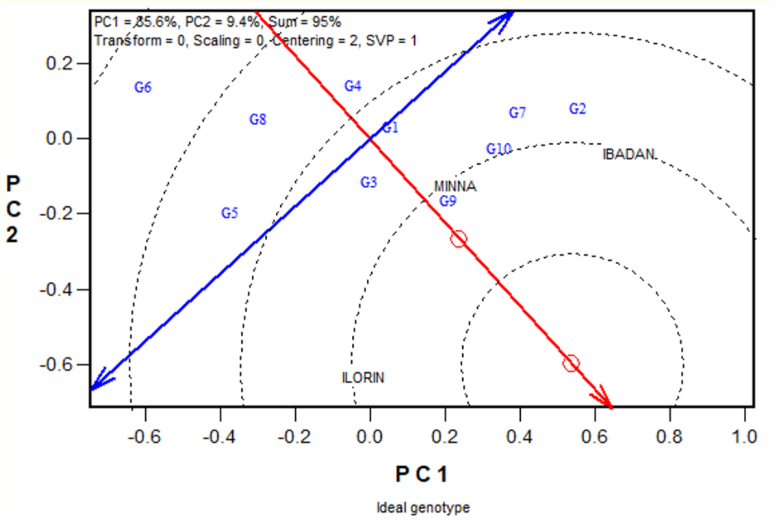

Figure 6: Shows the ideal environment which is represented red circle. Minna is the ideal environment among the three environment under evaluation.

Discussion

Genotype by environment interaction

Genotype by environment interaction was observed among the 10 soybeans genotypes grown across three locations within the Southern Guinea Savannah. Highly significant difference observed for all trait measured except for days to 50% flowering and harvest index for main effect such as genotype, location and genotype by environment interactions indicate indicate distinct characteristics among the genotypes and locations. Highly significant difference observed for genotype by environment interaction confirms the presence of genotype by environment interaction. Similar result pattern was observed by [1] who reported significant difference grain yield of 43 accession grown across three in Nigeria. Additionally [2] reported significant difference at $P \leq 0.05$ for grain yield when 32 soybeans varieties were grown across 8 environment in Ethopia. Furthermore [7] reported highly significant different for genotype, location and genotype by environment interaction when yield stability was carried out for some rust resistant soybean varieties grown in four location in Uganda.

Stability analysis of genotypes across environment

Genotype x Genotype and Environment (GGE) biplot shows that the first two interaction principal component axis was adequate to explain the variation observed genotype by environment sum of square. This finding aligns with the results of [2] who reported that IPCA1 and IPCA2 accounted for 76.26% and 23.74% of the total variation explained by genotype by environment sum of square [3] reported that the first interaction principal component axis and the second interaction principal component axis accounted for 31.80% and 28.9% respectively. Similarly [4] reported that the first and the second interaction principal component axes accounted for 36.36% and 29.79% respectively for variation explained by genotype by environment interaction sum of square for soybean percentage oil content.

Genotypes G1 and G10 had IPCA1 scores closer to zero, and are said to be stable genotypes. Genotypes with IPCA scores are very responsive to change in the environment such genotypes may be classified as unstable and unpredictable hence they are recommended for high yielding environment because they have specific adaptation. Genotype G6, G4, G7 and G2 had specific adaptation. Similar result pattern was reported by [1] Genotypes located at the vertex of the polygon are considered the best performing genotypes in that particular location. Genotypes found on the vertex of the polygon without an environmental association perform poorly in all location, which is consistent with results of the [5] when stability and adaptability studies were conducted for soybean yield in Ethopia. [1] reported that the genotypes at the vertex of the polygon are the best performing genotypes in that particular location. Accession G17 was the most suitable accession at environment E1whereas accession G26, G1, G31 and G34 were the best performing genotypes in environment E3 while G31 performed most suitable in E2 and E3 environments. Ranking of genotype base on yield and stability revealed that genotype G3, G4 and G9 are stable genotypes because these genotypes had short stability vector. However genotype genotype G3 and G9 had high seed yield per plot compare to G4. Genotype G9, being stable with high seed yield per plot and closer to the ideal genotype, is the most desirable. This genotype G9 would perform optimally in all the locations under evaluation. This is in agreement with the report of [5].

Positive correlation was observed between Ibadan location and Minna this is because the angle between this two environmental vectors is less than 90^o this implies that the genotypes would perform similarly in both locations. Conversely, a negative correlation was noted between Ilorin and Ibadan and between Ilorin and Minna because the angle between the environmental vectors is greater than 90^o. This implies that the genotypes under evaluation would performed different across this two environment. Genotypes that performed optimally in one location would not perform optimally in the other location. Similar result pattern was reported by [5] who reported positive correlation between Y2L and Y2L5 and negative correlation between Y2L1 and Y2L6 when stability and adaptability analysis were carried out for soybeans genotypes in Ethopia. An Ideal environment had the longest vector with small IPCA scores which falls into the centre of the concentric circle. Ideal environment is the most powerful in genotype discriminating. Notably, based on the study, the Ibadan location emerges as the Ideal location due to its close proximity to the Ideal environment. Ideal environment is the most representative of all the environments.

Conclusion

The presence of genotype by environment interaction was established among the ten soybeans genotypes across three locations in Southern guinea savannah in Nigeria. Genotype G3, G9 and G10 are stable genotypes while genotype G9 is the most stable across locations under evaluation. The ideal environment is Minna while the ideal genotype is G9. Genotype G9 is recommended for farmers in Southern guinea savannah agro- ecological zone of Nigeria.

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