Vol. 14(34), pp. 1943-1949, November, 2019
DOI: 10.5897/AJAR2019.14251
Article Number: D2C403162378
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Genotype-by-environment interaction and stability analysis of soybean genotypes for yield and yield components across two locations in Nigeria

Jandong, E. A.[1*], Uguru, M. I.[2] and Okechukwu, E. C.[2]

[1]Department of Agronomy, Faculty of Agriculture, Taraba State University, P. M. B. 1167, Jalingo, Nigeria.
[2]Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria.

Received 17 June, 2019; Accepted 26 August, 2019

A multilocational evaluation of 20 soybean genotypes was conducted in two distinct locations (Nsukka in Derived Savanna agro-ecology and Jalingo in Northern Guinea Savanna) of Nigeria in 2015 and 2016 cropping seasons. The experiments were laid out in an Alpha lattice design and replicated three times in each location. The main objective of the research was to determine the genotype-by-environment interaction (G x E) for specific traits and yield stability. The results revealed highly significant differences among the genotypes and locations for all the traits except for seed yield. Genotype x environmental interaction was not significant for most of the traits except days to 50% flowering indicating relative consistency in time of flowering among the genotypes across the locations and year. The genotype, *Ashuku* produced the highest yield in the two locations. However, the most stable genotypes across the locations were *Dadinkowa* and *Vom* while the ideal environments were Jalingo 2016 (ENV2) and Nsukka 2016 (ENV4) which produced 14.0g and14.5g, respectively. Similarly, Akwanga was discriminated as the overall best genotype across the two locations.

Key words: Genotype, adapted, biplot, environment, yield stability.

INTRODUCTION

The use of stable genotypes over several environments for high yield and quality characteristics is important for many crops. When genotypes are tried in terms of seed yield in multilocational experiments, great differences are commonly observed in yield performance over the environments. This differential yield response of genotypes from one environment to another is called genotype x environment (G x E) interaction (Jose et al., 2017). The G x E interactions is of major importance to the plant breeder in developing improved varieties and the introduction of new cultivar (Yan and Kang, 2003).

The ability of the genotype to demonstrate stability over a wide range of environment and its ability to yield well relative to the productive potential of a test environment is referred to as agronomic stability. Any genotype that demonstrates consistency of performance or slight variation across environment is said to show general adaptation (Ojo et al., 2006). In a breeding programme,

*Corresponding author. E-mail: elias.jandong@gmail.com.

genotype x environment interaction effects is of special interest for identifying adaptation targets, adaptive traits and test sides.

The stability of seed yield in different crops has been statistically evaluated through analysis of G x E interaction in genotype-adaptation trails over several environments. The effective identification of superior genotypes is generally complicated by the presence of G x E interactions whereby genotype relative yields vary across different environments due to different factors. A specific genotype does not always exhibit the same phenotypic characteristics under all environments and different genotypes respond differently to a specific environment.

Soybean (*Glycine max* (L). Merrill) designated as the “miracle bean” has established its potential as an industrially vital and viable oil seed crop in Nigeria. Interest in soybean production in Nigeria has increased considerably as it has the ability to fix high amount of nitrogen, thereby permitting farmers to use less fertilizer and reduce farm cost (IITA, 2014). To satisfy the demand by producers and consumers, soybean production needs to be extended to other parts of the country that were otherwise considered unsuitable or marginal for its production (Aseigbu and Okpara, 2002). This wide agro-ecological variability is the major challenge for field crops resulting in high genotype x environment interaction (GEI) effect. Identification of yield contributing traits and knowledge of GE interactions and yield stability are important for breeding new cultivars with improved adaptation to the environmental constraints prevailing in the target environments. To avoid genetic vulnerability associated with the narrowing of the genetic base of any crop, the GE interactions of the germplasm are important. Therefore, the objectives of this study are to determine the magnitude of G x E interactions and stability of some local cultivars and elite soybean genotypes and thereby identify widely and/or specifically adapted genotypes under Nigerian conditions.

MATERIALS AND METHODS

The multilocational evaluation trail was carried out in 2015 and 2016 cropping seasons in two different locations: The Teaching and Research Farm, Department of Crop Science, University of Nigeria, Nsukka (Lat.06o 521N and Long.07o 241E) and the Teaching and Research Farm, Department of Agronomy, Taraba State University, Jalingo (Lat.08o 541N and Long. 11o 221E). Twenty (20) soybean genotypes comprising of fifteen (15) farmers' cultivars and five (5) improved varieties were obtained from farmers in some soybean growing states of Nigeria and the International Institute for Tropical Agriculture (IITA), Ibadan, respectively for the research.

Experimental design

The experimental design was Alpha lattice design (Patterson and Williams, 1976), which was used for the multi-location experiment. There were 10 columns and two rows per super block replicated three times and the 20 soybean genotypes were randomly assigned to each super block. Each plot or column measured 1.5 × 1 m and seeds were sown at the spacing of 15 cm between stands and 30 cm between rows, resulting in 7 plants per row and 35 plants per plot (column). Five plants were randomly selected from the two middle rows for data collection at the maturity stage on the agronomic and yield characters.

Statistical analysis

Analysis of variance (ANOVA) statistics using general linear model (GLM G x E) of SAS version 9.5 with 5% level of significance were used. The data collected were subjected to analysis of variance and GE biplot methodology as prescribed by Marjanovic-Jeromela et al. (2011). This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the sources of variation in GEI analysis of yield data.

RESULTS

The experimental sites differed in altitude; rainfall, mean temperature, relative humidity and soil texture (Table 1). Nsukka is located in the southeastern part of Nigeria while Jalingo is in northeastern part. The amounts of rainfall in 2016 in both locations were higher than those of 2015. In 2016, Nsukka had a mean rainfall of 152.98 mm against 141.04 mm in 2015. Similarly, in 2016, Jalingo had a mean rainfall of 153.94 mm against 149.14 mm in 2015. During the growing seasons, mean monthly temperature was higher in Jalingo when compared to that of Nsukka; however, relative humidity was higher in 2015 than 2016 in both locations. Meanwhile, in 2016, relative humidity was higher in Jalingo (66.41%) than Nsukka (61.76%). Also, the two locations varied in soil type with the soil of Nsukka being sandy clay loam while that of Jalingo is sandy loam.

The combined analysis of variance was performed to determine the effects of year (Y), location (L) and genotype (G) as presented in Table 2. Variance due to genotypes (G) were highly significant ($p<0.01$) for all the traits studied, except for pod weight that was significantly ($p<0.05$) different and seed yield that was not significant. Similarly, location (L) was highly significant ($p<0.01$) for all the traits, except seed yield that was significantly ($p<0.05$) different. However, year (Y) effect was highly significant for all the traits with the exception of days to 50% flowering that was not significant. The Y x L interaction was highly significant ($p<0.01$) for all the traits except days to 50% flowering. The G x Y interaction on the other hand was not significant for most of the traits except for days to 50% flowering which was significant at 5% level of probability. Similarly, the interaction between genotype and location (G x L) affected only days to 50% flowering leaving the rest of the traits unaffected. Also, triple interaction (G x Y x L) was found not significant for all the traits except days to 50% flowering.

Mean quantitative characters of the 20 soybean genotypes across the two locations for the two cropping

Table 1. Agro-ecological characteristics of the experimental sites**.**

Location	Nsukka	Jalingo
Latitude	06°52[1]N	08°54[1]N
Longitude	07°24[1]E	11°22[1]E
Attitude (mas)	447.26	349
Agro-ecozone	Derived savannah	Northern Guinea savannah
Soil texture	Sandy clay loam	Sandy loam
Total rainfall (mm/year)	1393.6	1137.8
Average mean temperature	26.0	28.0
Average RH (%)	66.6	67.6

MASI = meters above sea level; RH = relative humidity.

Table 2. Combined analysis of variance for seed yield and yield components in two years and two locations.

SV	DF	DF1	PH (cm)	NP	PW (g)	SY (g)
Year (Y)	1	39.20	999.36**	63583.17**	9208.25**	4064.80**
Location (L)	1	413.44**	752.11**	7811.29**	686.14**	156.33*
Y x L	1	63.04	1365.84**	2426.98*	516.85**	278.00**
REP (Y,L)	8	11.97	58.16*	747.42*	117.19*	65.47*
Genotype (G)	19	63.54**	240.60**	815.80**	65.73*	29.52
G x Y	19	29.04*	23.37	239.11	23.47	14.09
G x L	19	45.69*	15.61	150.84	36.79	18.62
G x Y x L	19	48.10*	31.66	279.33	37.89	17.13
Error	140	4.17	4.45	15.67	5.67	3.89

*,** = significant at 5 and 1%, respectively, SV = source of variation, DF = degree of freedom, DF1 = days to 50% flowering, pH = plant height, NP = number of pods, PW = pod weight, SY = seed yield, Y = year, L = location, G = genotype.

seasons are presented in Table 3. In this study, some genotypes showed significant ($p<0.05$) variations across the locations. It was observed that days to 50% flowering significantly varied across the locations in genotypes such as Kafanchan, Langtang, TGX1448-2E and TGX1835-10E. Similarly, the genotype, Mararaba varied significantly in height across the locations whereas pod weight and seed yield of TGX1448-2E were significantly ($p<0.05$) different across the locations recording 12.81 ± 22.35 and 8.13 ± 14.59, respectively. However, all the genotypes either demonstrated small variation or consistency in number of pods and 100 seed weight per genotype.

The mean seed yield value of genotypes averaged over environments (Table 4) indicated that the genotypes "*Ashuku*" and "*Akwanga*" had the highest and lowest seed yield of 13.0 and 8.5 g, respectively. The environments mean seed yield ranged from 4.1 g (ENV3) to 14.5 g (ENV4) and averaged seed yield over environments and genotypes is 10.1 g. ENV 4 and ENV2 showed the most favorable performance for seed yield (14.5 and 14.0 g, respectively) and are rich environments. ENV3 and ENV1 were unfavorable since they presented the lowest mean for seed yield (4.1 and 7.9 g, respectively).

For easy understanding, a biplot was drawn (Figure 1) where aspect of both genotypes and environments were plotted on the axis so that the inter relationship can be visualized. The vertical line in the middle of the biplot represents the grand mean. Genotypes and environments on the right side of this line has higher yield than those of left hand side. Consequently, TGX1987-10F, Akwanga, Kafanchan, Lau, TGX1448-2E, Andaha, TGX1987-62F, Tiv local, Mararaba and Kagoro by being on the right side of the biplot, constitute the most to least yield mean, respectively. However, Akwanga, Lau and Kagoro generally exhibited high yield with high mean (additive) genotype, Akwanga being the overall best. Other genotypes showed below average yield. Agbonkagoro was moderately stable across the environments but below average yield.

DISCUSSION

The result showed that, both the genotypes and the environmental conditions had significant influence on the yield and yield components performance of the soybean.

Table 3. Mean quantities characters of 20 soybean genotypes from two locations.

Genotype	DF (50%)	PH (cm)	NP	PW (g)	SY (g)	100 seed weigh (g)
	NSK/JAL	NSK/JAL	NSK/JAL	NSK/JAL	NSK/JAL	NSK/JAL
Agbon kagoro	43.17±45.67	25.42±29.84	35.66±37.29	12.33±12.33	8.10±7.08	12.50±14.00
Akwanga	42.14±44.64	29.10±33.21	54.69±63.55	20.09±25.02	12.44±16.58	14.00±13.50
Andaha	44.90±46.90	29.79±32.12	44.67±53.87	14.84±21.34	8.57±13.65	12.00±12.00
Ashuku	43.97±44.81	32.65±39.25	63.99±79.92	22.09±27.89	14.21±18.88	13.00±13.50
Dadinkowa	45.28±46.28	29.63±31.87	38.43±40.36	12.13±16.03	8.07±10.32	14.00±13.00
Garkawa	42.00±45.00	33.32±37.06	48.29±59.06	15.93±19.70	10.78±13.50	14.00±13.00
Gwantu	43.97±44.47	30.10±34.56	46.09±56.22	16.22±20.72	10.98±13.61	12.00±13.00
Kafanchan	42.48*±48.32*	30.18±31.76	43.62±54.18	14.24±21.54	9.37±14.56	13.50±12.00
Kagoro	43.44±44.61	31.67±37.63	52.70±57.76	15.56±19.46	11.43±13.59	9.50±14.50
Langtang	46.44*±50.28*	29.13±32.30	50.43±55.96	21.90±24.46	14.50±16.48	11.50±12.50
Lau	50.51±52.01	30.56±37.03	57.20±74.84	20.57±25.37	12.54±16.89	10.50±13.00
Mangu	42.47±44.64	34.18±38.35	60.45±67.42	22.62±25.46	14.20±16.85	14.50±14.00
Mararaba	45.44±46.61	30.27*±38.00*	49.16±59.96	14.56±18.86	9.70±13.45	13.50±13.00
TGX1485-ID	38.73±40.37	31.82±30.32	53.07±51.43	19.68±20.54	12.21±12.95	14.00±14.00
TGX1448-2E	40.37*±44.37*	34.94±38.67	47.28±72.08	12.81*±22.35*	8.13*±14.59*	14.50±13.50
TGX1987-10F	41.57±43.71	31.52±34.35	38.83±54.20	17.98±23.11	10.51±15.41	15.50±15.00
TGX1835-10E	39.21*±43.71*	31.44±33.01	41.68±47.28	14.88±17.41	10.80±11.59	13.00±14.50
TGX1987-62F	47.87±48.64	35.94±41.83	42.44±65.65	13.45±21.74	8.50±14.97	12.00±13.00
Tiv local	41.23±42.73	33.29±36.22	50.77±68.30	18.18±24.78	11.44±16.65	15.00±13.00
Vom	56.07±54.73	49.85±53.35	76.20±86.77	21.98±23.18	12.47±14.68	9.50±11.00
LSD(0.05)	3.83	6.69	24.90	9.27	6.35	5.70

DF = days to 50% flowering, PH = plant height, NP = number of pods, PW = pod weight, SY = seed yield, NSK = Nsukka, JAL= Jalingo.

Table 4. Mean soybean seed yield evaluated in four environments.

	Environment				
Genotype	ENV 1	ENV 2	ENV 3	ENV 4	Mean
ANDAHA	5.5	11.5	2.4	5.0	6.1
AGBON KAGORO	**11.9**	13.4	3.4	**19.6**	12.1
AKWANGA	5.1	10.5	3.9	14.5	8.5
ASHUKU	9.8	19.0	4.4	18.6	13.0
DADINKOWA	6.9	10.9	4.2	12.3	8.6
GARKAWA	4.9	17.4	3.5	10.9	9.2
GWANTU	6.5	14.9	3.7	12.1	9.3
KAFACHAN	7.3	11.9	3.2	17.7	10.0
KAGORO	10.5	14.0	4.6	15.7	11.2
LANGTANG	7.3	**23.3**	4.3	12.2	11.8
LAU	10.7	13.6	4.1	18.0	11.6
MANGU	**11.9**	16.9	4.4	16.7	12.5
MARARABA	7.3	13.7	4.1	15.7	10.2
TGX1485-1D	3.4	12.5	5.1	17.0	9.5
TGX1835-10E	10.9	11.9	4.0	11.7	9.6
TGX1987 -10F	7.2	14.0	3.9	9.5	8.7
TGX1448-2E	6.8	12.6	4.9	15.9	10.1
TGX1987-62F	5.8	10.8	4.7	17.4	9.7
TIV LOCAL	7.1	14.1	**6.1**	16.8	11.0
VOM	10.8	12.5	3.5	12.9	10.0
Mean	7.9	14.0	4.1	14.5	10.1

ENV1 = Jalingo 2015, ENV2 = Jalingo 2015, ENV3 = Nsukka 2016, ENV4 = Nsukka 20.

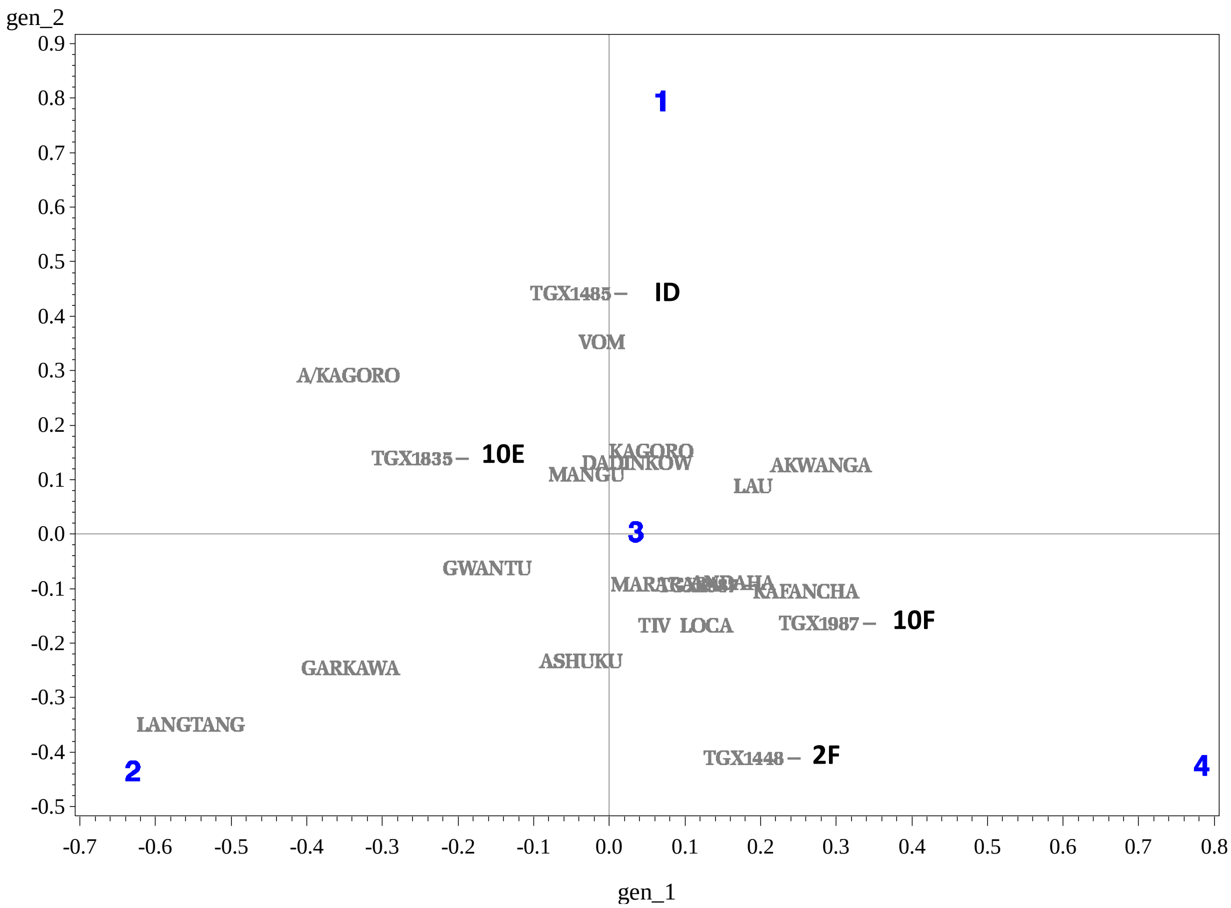

Figure 1. Biplot of G*E interaction: seed yield.

Adugna and Labuschgne (2003) also reported significant variations among locations for days to 50% flowering in linseed. The non-significant variation of GxY,GxL andGxYxL for almost all the traits with the exception of days to 50% flowering implies that in any of the two locations, the same genotype will have the same plant height, number of pods, pod weight and seed yield. The findings are in agreement with the report of Ojo et al. (2010) who recorded non-significance of genotype x year interaction in plant height, number of pods and seed yield in soybean. Highly significant variations were observed for most of the parameters studied among the genotypes across the environments indicating the existence of variability among the soybean genotypes.

The low yield observed in Nsukka location may be as a result of the soil fertility variation indicating that Jalingo is a more potential site for soybean production. This observation is in agreement with the results of previous researchers (Okpara and Ibiam, 2000; Osedeke and Ojeuiyi, 2005) who also reported low grain yield in some soybean genotypes in southeastern Nigeria. Genotypes produced low yield in areas where soil fertility is a limiting factor especially in Nsukka (southeastern Nigeria) which is in humid tropics as compared to Jalingo in northern Guinea savanna. The significant variation in mean pod weight and seed yield demonstrated by TGX1448-2E suggested that the four environments represented sufficient diversity to allow assessment of GE interaction and stability of performance of these traits. However, any genotype that demonstrated consistency in yield or little variation across the environments is said to be generally adapted. In this study, all the genotypes demonstrated little variation in yield and other traits across the two locations with the exception of TGX1448-2E which differed significantly in pod weight and seed yield (Table 3). This consistency or little variation in yield of most of the genotypes across the environments showed general adaptation as observed by Adeseye et al. (2018). Similar findings were obtained by Yan and Tinker (2006); Jose et al. (2017) who reported small variation between two locations in respect to days to flowering in cowpea. The purpose of stability analysis is to identify soybean genotypes with wide geographic adaptation, high agronomic performance and high seed yield (preferably above the overall mean of 10.1g) as observed in this study in heterogeneous environments. The identification

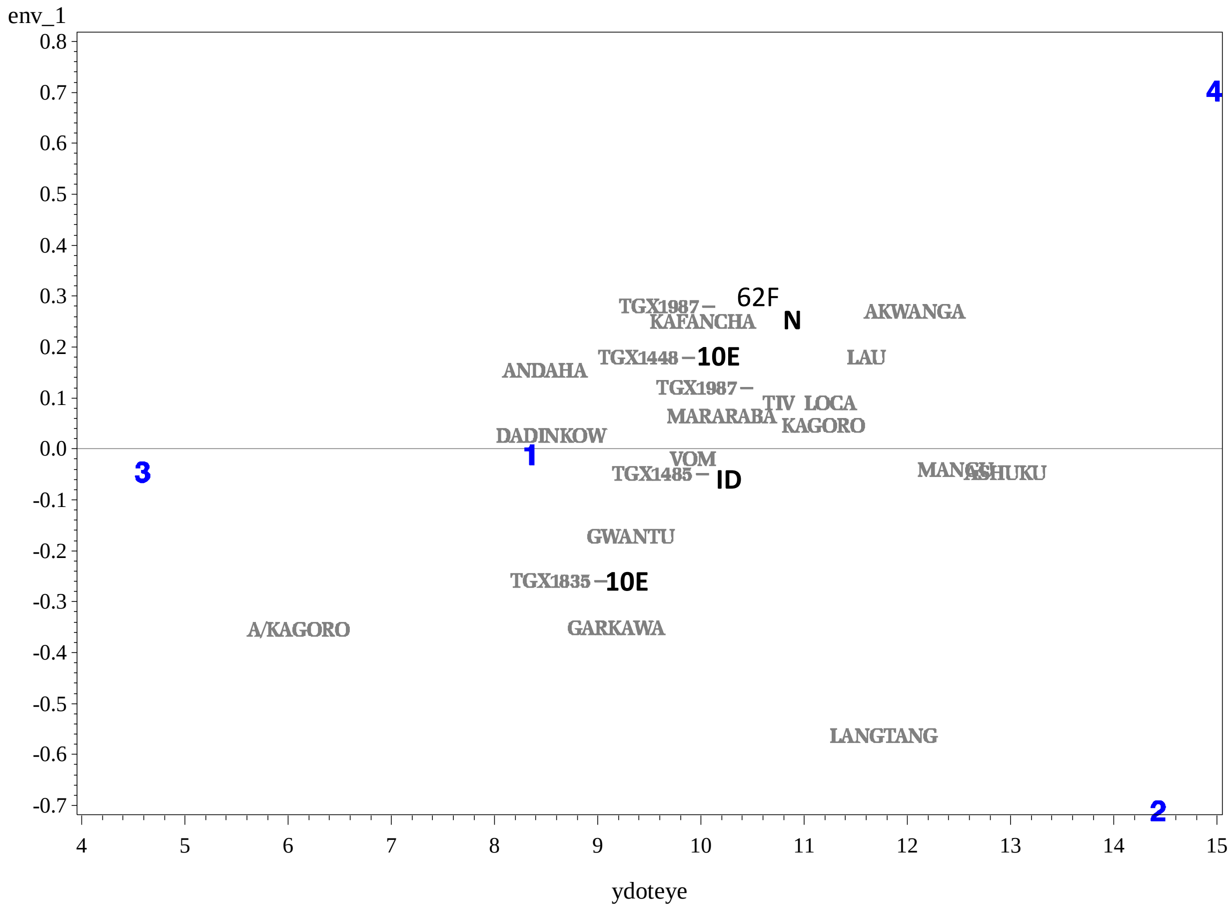

Figure 2. Biplot of first E*Vector vs. Means.

of genotypes with specific adaptations can be extremely useful for more regionalized genotypic recommendations.

The range of values for grain yield suggested that the four environments had different levels of productivity. Based on mean performance of the genotypes, the environments were classified into three mega environments. The first include ENV1 and ENV4 with genotype Akwanga having the highest seed yield and was joined by Mangu only in ENV1. The second mega environment is ENV2 in which Langtang performed the best. The third mega environment is ENV3 with Tiv local as the outstanding genotype. The general mean performance of the genotypes across the two locations revealed that Akwanga is leading by its impressive performance in ENV4 (Table 4) among the environments. The most stable for mean performance of the soybean genotypes in this study is ENV 1 and was closely followed by ENV3. Therefore, the use of GGE in this study have not only identified the most stable genotypes across locations but also is able to identify the locations that optimize the genotypes performance as confirmed by Agyeman et al. (2015).

The differences and genotype distributions in the biplot are a consequence of genotype variations in different environments (Figure 1). This indicates that the two locations and the two seasons had a large impact on yield variation. The clustering of some of the genotypes and their yield average on the biplot also explain their similarities in yield per plant variations (Marjanovic-Jeromela, 2005). In general, environments with scores near zero have little interaction across genotypes and provide low discrimination among the genotypes (Anandan et al., 2009) as seen in ENV 3 in this study. Genotype stability is considered a reaction to changing environmental conditions, which depend on unpredictable variation components (Kang, 2002). In this study, the two agro-ecological zones of the experimental sites were the source of this variation component.

Conclusions and recommendations

Crop yield is a complex trait that is influenced by a number of component characters along with the environment either directly or indirectly. The G x Y, G x L and GxYxL effects were no significant for most of the traits indicating general adaptation of the genotypes across the environments. However, the study is able to identify Akwanga as the highest yielding genotype in ENV1 and ENV4 (Table 4 and Figure 2), stable genotypes and the ideal environments (ENV 2 and ENV 4) across the locations that optimize the genotypes performance.

Conclusion

Crop yield is a complex trait that is influenced by a number of component characters along with the environment either directly or indirectly. The G x Y and G x L effects were no significant for most of the traits indicating general adaptation of the genotypes across the locations. However, the study is able to identify the most stable genotypes and the ideal environments across the locations that optimize the genotypes performance.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

The authors are grateful to Tertiary Education Trust fund (TETfund) for sponsoring this study. The staff of Department of Crop Science, University of Nigeria, Nsukka are deeply acknowledged for their assistance.

REFERENCES

Adeseye AO, Amusa NA, Ijagbone IF, Aladele SE, Ogunkanri LA (2018). Genotype by environment interactions of twenty accessions of cowpea (*Vigna unguiculata* (L) Walp) across two locations in Nigeria Annals of Agrarian Science 16:481-489.

Adugna W, Labuschagne MT (2003). Parametric and nonparametric measures of phenotypic stability in linseed (*Linum usitatissimum* L.). Euplytica 129:211-218.

Agyeman A, Parkes E, Peprah BB (2015). AMMI and GGE biplot analysis of root yield performance of cassava genotypes in the forest and coastal ecologies. International Journal of Agricultural Economics 3(3):222-232

Anandan A, Sabesan T, Eswaran R, Rajiv G, Muthalagan N, Suresh R, (2009). Appraisal of environmental interaction on quality traits of rice by additive main effects and multiplicative interaction analysis. Cereal Research Communication 37(1):131-140.

Aseigbu JE, Okpara DA (2002). Soybean production in marginal soils of south eastern Nigeria paper presented at 36th Annual conference of the agricultural society of Nigeria held at the Federal University of Technology, Owerri, Nigeria.

International Institute of Tropical Agriculture (IITA) (2011). Genotype x environment interation analysis of IITA mandate crops in Sub-saharan Africa: In J. Indira (Ed), Ekanayake and Rodomiro Ortiz published by IITA, Ibadan, Nigeria.

International Institute of Tropical Agriculture (IITA) (2014). Better soybean for Africa. IITA Annual Report.

Jose TF, Christiane NGO, lindomar MDS, Glauber HDN, Autonio JR, Matheus FN (2017). Genotype by environment interactions in Green Cowpea Analysed via mixed models Rev. Caatinga, Mossoro 30(3):687-697.

Kang MS (2002). Genotype-environment interaction: Progress and prospects. In MS Kang (Ed.) Quantitative genetics, genomics and plant breeding, CAB International: Wallingford: England 221-243.

Marjanovic-Jeromela A (2005) Genetic divergence and variability of seed yield components in winter rapeseed (Brassica napus L.). (in Serbian, with English abstract) 91p. Thesis (Ph.D.)- University of Novi Sad, Serbia.

Marjanovic-Jeromela A, Nevena N, Gvozdanovic-Varga J, Hristov N, Kondic-Spika A, Vasicand M, Marinkovic R (2011). Genotype by environment interaction for seed yield per plant in rapeseed using AMMI model. Pesquisa Agropecuaria rasileira 46(2) Brasilia.

Ojo DK, Odunola MS, Oduwaye OA (2006). Graphical Assessment of yield stability and adaptation in cowpea Nigeria Journal of Genetics 20:22-23.

Ojo GOS, Bello LL, Adeyemo MO (2010). Genotypic variation for acid stress tolerance in soybean in the humid rainforest acid soil of south eastern Nigeria. Journal of Applied Biosciences 36:2360-2366.

Okpara DA, Ibiam B (2000). Evaluation of soybean varieties for adaptability to a humid tropical environment in South Eastern Nigeria. Journal of Sustainable Agricultural Environment 2(1):26-31.

Osedeke VE, Ojeuiyi SO (2005). Evaluation of the forest zone of south east Nigeria for soybean production. Nigeria Journal of Soil Science (3):1-6.

Patterson HO, Williams ER (1976). A new clars of resolable in-complete block design. Biometrika 63:83-90.

Piepho HP (1998). Methods for comparing the yield stability of cropping systems a review. Journal of Agronomy and Crop Science 180:193-213.

Silveira LCJ, Kist V, Paula TOM, Barbosa MHP, Peternelli LA, Dares E (2013). AMMI analysis to evaluate the adaptability and phenotypic stability of sugar cane genotypes. Scientia Agricola 70:27-32.

Yan W, Kang MS (2003). GGE biplot analysis: A graphical tool for breeders, geneticist and agronomists. CRC Press, Boca, Raton, FL, USA.

Yan W, Tinker NA (2006). Biplot analysis of multi-experiment trial data: principles and applications. Canadian Journal of Plant Science 86:623-645.