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EVALUATION OF SOME COWPEA (*VIGNA UNGUICULATA* L. [WALP]) GENOTYPES FOR STABILITY OF PERFORMANCE OVER 4 YEARS

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ABSTRACT

Genotype × environment interaction (GEI) plays a significant role in determining the desirability or superiority of a genotype, hence the need to evaluate genotypes over wide range of environment. Seven improved cowpea genotypes were evaluated in four environments (years); the late seasons of 2009, 2010. 2011 and 2012 to determine their desirability based on mean grain yield and stability in Abeokuta South-western Nigeria using the Genotype+Genotype×environment (GGE) biplot. IT98K-573-2-1 had the highest mean grain yield while IFE-98-12 had the lowest. There was highly significant Genotype × Environment Interaction on seed yield (p<0.001) indicating the need for GEI analysis. The GGE biplot identified three mega-environments viz AB10 and AB11 as mega-environment 1, AB09 as the mega-environment 2 and AB12 as the third. IT98K-573-2-1, IT04K-333-2 and IT04K-227-4 were the most responsive genotypes in mega-environments 1, 2 and 3 respectively. IT04K-227-4, IT04K-333-2, IT98K-573-1-1and IT98K-573-2-1 were identified to have performed above average while IT99K-1060, LDP10-OBR1 and IFE-98-12 yielded below average. LDP10-OBR1 was the most stable genotype but was low yielding. IT98K-573-2-1 was selected as the best combiner of high yield and stability and the most desirable for Abeokuta South-western Nigeria. AB10 was identified as the best among the test environments.

Keywords: Genotype × environment interaction, Desirability, Environment, Grain yield, Abeokuta, Stability, Cowpea genotypes.

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Contribution/ Originality

This study documents the responses of improved cowpea genotypes to different environments. Genotype by environment interaction continues to have high implications in plant breeding. *IT98K-573-2-1* was identified as a well buffered genotype and therefore desirable for selection for further improvement.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* L. [Walp]) is a highly nutritious grain legume belonging to the family Fabaceae. It ranks next to soybean in plant protein content and therefore serves as a cheap source of protein in human diet and livestock feed formulations [1]. Soils grown to cowpea do have significant increase in available nitrogen for the next cropping season. In Nigeria, cowpea is consumed solely when boiled or along with garri (cassava grains), bread, yam, plantain or rice. It can also be processed and eaten as fried or boiled cakes. There is an urgent need to increase cowpea yields by developing superior genotypes in Nigeria, the largest producer, importer and consumer of the grains in the world [2]. Identification and release of superior varieties in any crop is hindered notoriously by Genotype × Environment Interaction (GEI). GEI refers to the differential response of genotypes in different environments (location, year, season, etc.). Consequently, performance ranking becomes difficult as a desirable genotype in an environment may be poor in another [3]. However, the knowledge of GEI gained through the several techniques has positive implication on the development of superior crop types [4, 5]. Kang and Magari [6] and Olayiwola and Ariyo [7] reported the consequence of selecting a high yielding but unstable genotypes in breeding program or commercial farms. According to Yan and Kang [8], to statistically detect GEI, it is required that at least two genotypes are evaluated in at least two different locations. Various techniques have been employed in GEI studies but GGE (Genotype + Genotype × Environment) biplot by Yan [9] is the most recent, sophisticated and efficient [7, 8, 10, 11]. GEI analysis shows genotype adaptation and gives useful information for location-specific breeding. A genotype that consistently gives good performance over years in multi-environment trials (METS) can be said to well adapt to the test environments and breeders do consider such genotype for varietal release. Though much works have been reported on stability in Nigeria [11]; those on cowpea are rather few. Genetic studies aimed at evaluating cowpea genotypes for consistent good performance in different environment becomes important. Information obtained from the study could be helpful in the development of high yielding and stable genotypes to meet the growing demand of the locals in Nigeria. The aim of the study was therefore to evaluate promising cowpea genotypes for stability of performance at different environments (years) in South-western Nigeria.

2. MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm of the Federal University of Agriculture Abeokuta (7°38'N, 3°88'E, 450m above sea level), South-western Nigeria in four environments (years): late seasons of 2009 (AB09), 2010(AB10), 2011(AB11) and 2012(AB12). The weather data for the years is presented in Table 1. Abeokuta is a transition between rainforest and derived savannah agro-ecology with a humid tropical climate and a mean annual rainfall of 1200mm.The soil of the experimental area was described as loamy sand and was classified as Arenic Plinthic Kandindalf [12]. Seven improved cowpea genotypes obtained from the Grain Legume Improvement Program (GLIP) of International Institute of Tropical Agriculture (IITA), Ibadan were used in the study.

Table-1. Weather Data for the Experimental Sites in 2009 – 2012

Months	**Mean temperature (°c)**				**Rainfall (mm)**				**Relative humidity (%)**				**Sunshine duration (hours)**			
	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012
January	26.3	28.1	27.2	27.0	0.0	4.4	0.0	0.0	59.9	80.9	65.9	75.2	3.8	5.3	6.2	4.2
February	26.0	30.7	28.9	28.8	0.0	41.2	139.8	67.2	67.1	78.3	78.7	70.5	3.9	6.4	6.2	4.5
March	26.7	29.4	29.2	29.1	96.0	58.9	23.9	67.7	64.0	78.8	80.0	79.3	4.0	3.9	6.5	5.1
April	26.3	28.5	29.2	28.5	101.0	112.7	74.5	80.1	53.0	78.8	76.4	79.5	3.9	7.0	6.5	5.7
May	26.1	28.0	28.0	27.7	124.0	169.6	73.7	115.3	73.0	80.5	78.9	77.3	3.2	7.2	6.6	4.8
June	26.3	27.4	26.9	26.9	140.0	98.3	84.5	225.1	72.0	85.4	82.2	78.7	3.1	7.1	5.7	3.9
July	26.7	25.9	24.5	26.0	160.0	322.9	349.5	155.4	77.2	87.7	84.6	80.9	3.6	5.5	3.8	4.0
August	26.5	26.1	25.3	25.5	162.1	266.6	88.7	36.3	80.7	85.9	84.7	82.6	3.3	4.5	3.1	2.7
September	29.5	26.7	26.6	26.2	151.6	257.6	204.1	181.4	78.1	85.9	84.1	76.0	3.7	5.3	5.5	4.0
October	26.7	27.3	26.9	27.2	180.1	172.3	288.1	184.7	74.7	81.7	79.5	77.5	3.1	6.2	5.0	5.7
November	26.0	27.1	27.9	28.2	64.6	94.7	3.6	49.6	68.0	86.0	82.0	81.9	3.2	6.4	6.4	5.4
December	26.1	27.2	27.1	28.8	10.4	0.0	0.0	1.3	63.7	81.1	67.7	78.5	3.7	7.2	6.4	6.1

Source: Dept. of Water and Agro-meteorology, Federal University of Agriculture Abeokuta

The genotypes include IFE-98-12 (entry 1), IT04K-227-4 (entry 2), IT04K-333-2 (entry 3), IT98K-573-1-1 (entry 4), IT98K-573-2-1 (entry 5), IT99K-1060 (entry 6), and LDP10-OBR1 (entry 7). In each year, the land was cleared, ploughed and harrowed. In all the environments (years), genotypes were evaluated on a single row plot laid out in randomized complete blocked design, replicated three times. Each row was 4 m long, **0.60 m** apart with **0.30** m as within row distance. Two seeds were sown per hill and thinned to one at ten days after sowing (DAS).Karate 2.5 EC was applied at the rate of 80 ml/15L of water at two weeks interval to check insect pest and weeds were controlled manually as and when due.

In each year data were collected on seed yield and these were subjected to combined analysis of variance and means were separated using the Duncan Multiple Range Test (DMRT) of the Statistical Analysis Software (SAS) Institute Inc [13]. The data were further subjected to GEI analysis using the GGE biplot to determine the responses of genotypes to the different environments (years).

3. RESULTS

The combined analysis of variance for grain yield of the genotypes evaluated over years (Table 2) shows that effects due to genotype, year and Genotype x Environment Interaction were highly significant. IT98K-573-2-1(5) had the highest overall mean grain yield while IFE-98-12(1) had the lowest grain yield (Table 3). Grain yield ranged from 435.7kg/ha to 1761.2kg/ha in 2009, 370.7kg/ha to 1807.7kg/ha in 2010, 710.7kg/ha to 1365.7kg/ha in 2011 and 761.7kg/ha to 2453.2kg/ha in 2012 (Table 3). The rankings of the genotype based on grain yield differed from year to year (Table 3). IT99K-1060 (6) was the best genotype in terms of yield in 2009 and 2011 but was the fifth and sixth in 2010 and 2012 respectively. IT98K-573-1-1(4) had the highest yield in 2010 but was 4th in 2009 and 3rd in the other two years (2011 and 2012). IT04K-227-4(2) was the top performer in 2012, whereas it was 7^{th}, 4^{th} and 2^{nd} in 2009, 2010 and 2011 respectively.

Table-2. Analysis of variance of mean square for grain yield of evaluated cowpea genotypes

Source	df	Grain yield
Genotype	6	173071***
Year	3	352392***
Genotype × year	18	89711**
Error	54	33074

**= Significant at p< 0.01, *** =p< 0.001.

Table-3. Grain yield (kg/ha) of genotypes in each year showing performance ranking in parenthesis

Entry	Genotype	2009	2010	2011	2012	Mean
1	IFE-98-12	966.0c(6)	370.7c(7)	710.5b(7)	761.7d(7)	701.7c
2	IT04K-227-4	435.7d(7)	1463.5a(4)	1049.2ab(2)	2453.2a(1)	1350.0a
3	IT04K-333-2	1714.5a(2)	1543.0a(3)	802.5b(6)	1684.2c(5)	1436.2a
4	IT98K-573-1-1	1100.2bc(4)	1807.7a(1)	951.7b(3)	1997.0b(3)	1464.2a
5	IT98K-573-2-1	1510.7ab(3)	1735.0a(2)	948.2b(4)	2192.5a(2)	1596.5a
6	IT99K-1060	1761.2a(1)	812.2bc(5)	1365.7a(1)	1315.7c(6)	1313.7a
7	LDP10-OBR1	1034.5c(5)	639.0c(6)	911.2b(5)	1710.2c(4)	1074.2b

Means with similar alphabets on the same column are not significantly different using DMRT at p<0.01

The GEI analysis based on GGE biplot shows that the first and second principal components (PC1 and PC2) accounted for 91.5% of the total variation (Fig 1). The test environments (years) fell into three of the five sectors outlined on the polygon view, thus, the mega-environments were identified. AB10 and AB11 were in the same sector to form mega-environment 1. AB09 and AB12 occupied a sector each to form mega-environment 2 and 3 respectively. IT98K-573-2-1(5) and IT98K-573-1-1(4) were associated with mega-environment 1 with IT98K-573-2-1(5) being the vertex genotype. IT04K-333-2(3) was the vertex genotype in mega-environment 2 while IT04K-227-4(2) was at the vertex of the polygon in mega-environment 3. Four genotypes, IT99K-1060(6), LDP10-OBR1 (7) and IFE-98-12(1) fell into sectors containing none of the test environments.

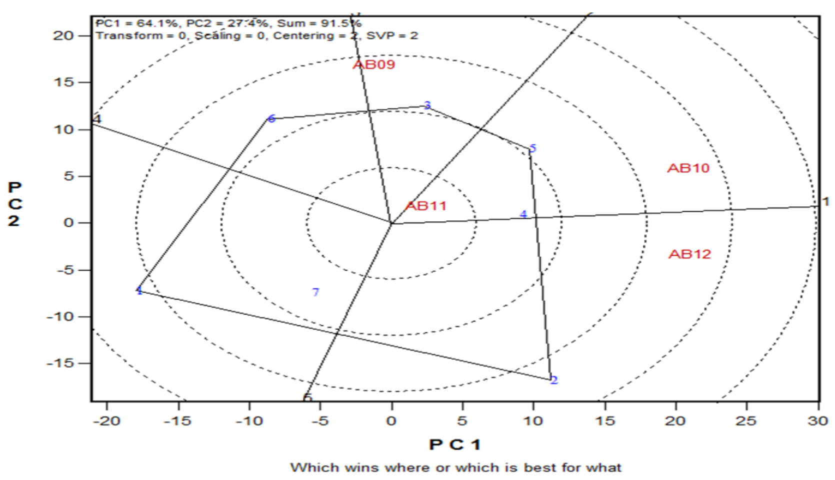

Figure-1. Biplot of Mega-environment and "Which-Won-Where"

Fig 2 shows the mean vs. stability of the genotypes evaluated. The abscissa (single – arrowed) and the ordinate (double-arrowed) of the Average Environment Coordinate (AEC) are the two lines passing through the origin of the biplot. The small circle on the abscissa delineates the AEC which is the environment PC1 and PC2 mean scores [8]. The ordinate divides the genotypes into two; those that yielded above and below average. Entries on the right [IT04K-227-4(2), IT04K-333-2(3), IT98K-573-1-1(4) and IT98K-573-2-1(5)] all yielded above average while those on the left [IT99K-1060(6), LDP10-OBR1 (7) and IFE-98-12(1)] fell below average performance. The abscissa therefore points towards increased order of genotype performance based on yield. IT98K-573-2-1(5) was on the

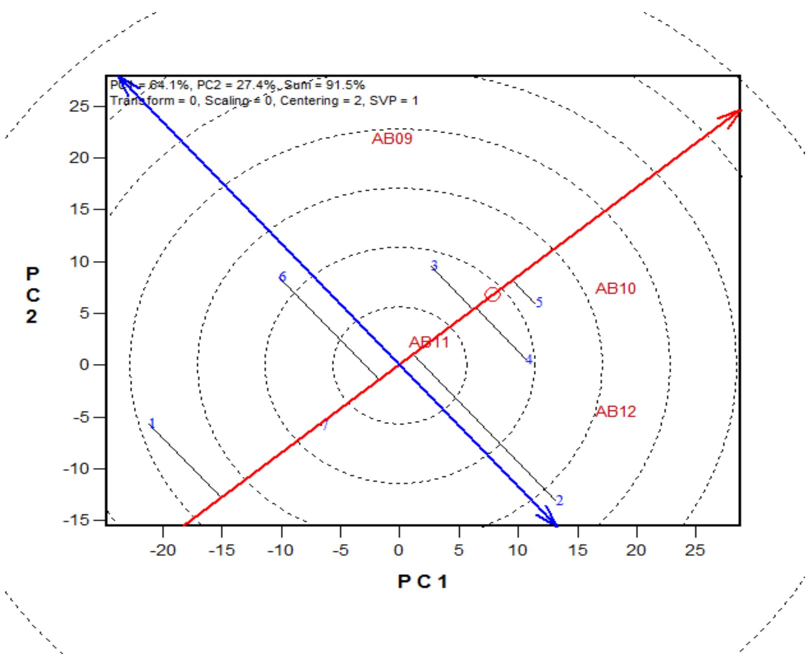

Figure-2. Biplot of Mean vs. Stability of Evaluated Genotypes extreme right while IFE-98-12(1) was on the extreme left. The projection on the abscissa towards the ordinate of the AEC is a measure of stability. LDP10-OBR1 (7) had the shortest projection, followed by IT98K-573-2-1(5), while IT04K-227-4(2) had the longest. The biplot also showed that IT98K-573-2-1(5) was the closest to the small circle (AEC). The discriminatory ability and representativeness of the environments (years) were presented in Fig 3. The vector length for each environment reveals the discriminatory ability of the environment while the angle formed by each vector with the abscissa implies representativeness. AB10 formed the shortest angle with the abscissa while AB09 had the largest. AB10 also had the longest vector from the origin while AB11 had the shortest. The biplot identified AB10 has the environment closest to the AEC.

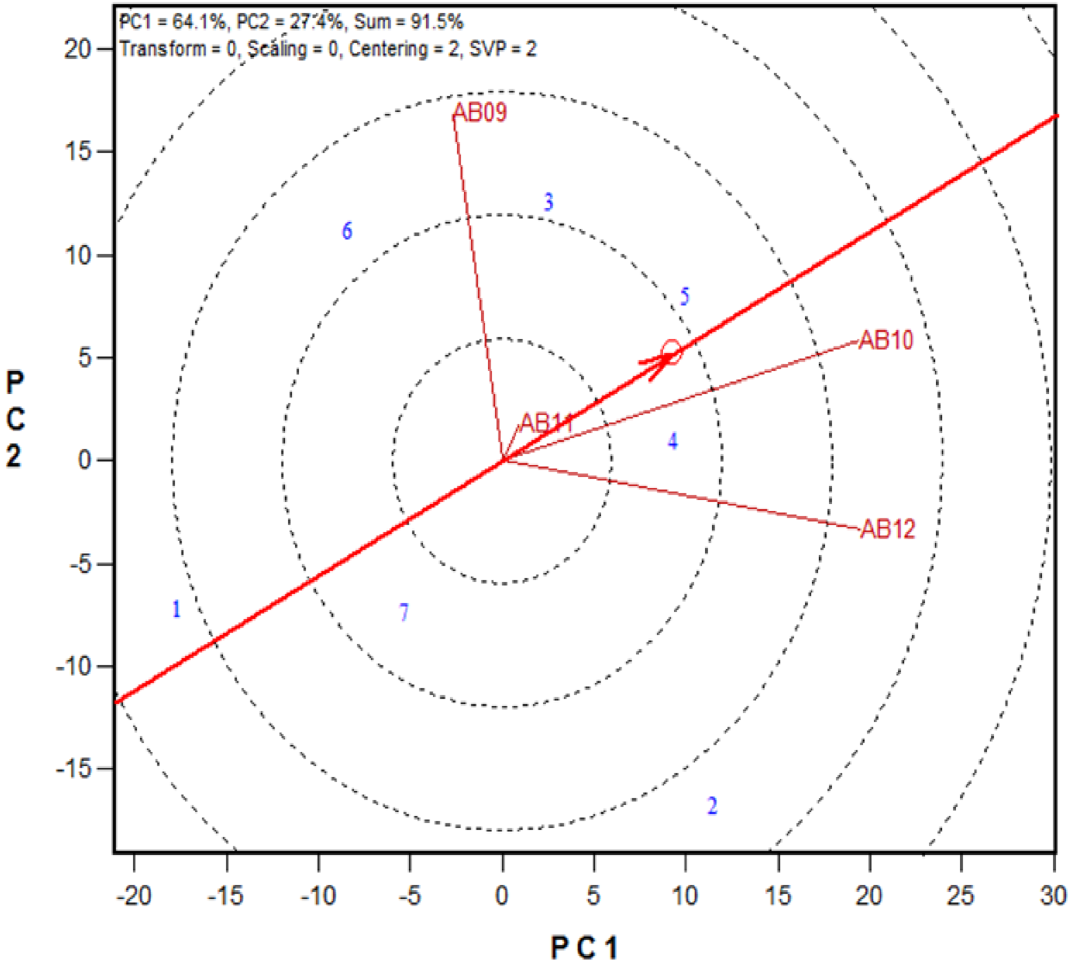

Figure-3. Biplot of Discriminatory Ability vs. Representativeness of the Test Environment

4. DISCUSSION AND CONCLUSION

The highest overall grain yield associated with IT98K-573-2-1 indicates that the genotype is high yielding and could be selected based on yield performance alone for improvement. IFE-98-12 with the lowest yield is however low yielding and **not** desirable based on grain yield performance. However, the significant GEI implies that judgment on genotype performance could not be solely based on yield performance. This is particularly true as the rank of the genotype varied from environment to environment such that each year had different superior genotype, implying crossover type interaction. Ariyo [14] opined that crossover type interaction was due to imperfect correlation between the environment and genotype performance. According to Haldane [15], GEI is present when superior genotype varies with environment. Kang and Magari [6], Waldron, et al. [16] and Olayiwola and Ariyo [7] then concluded that simultaneous selection of genotypes for high yield and stability was more useful in multi-environment trial. The GEI present therefore makes further analysis imperative. The GGE biplot analysis by Yan [9] was employed in this study for the GEI analysis. The method through the biplot identifies mega-environment (environment offering similar conditions to genotypes), best genotype in each mega-environment, the ideal genotype (genotype that best combine high yield with stability) and the ideal environment (the most representative and highest discriminatory power). From the GGE biplot it was shown that the test environments fell into three of the sectors indicating that different genotype was the best in each environment. AB10 and AB11 were grouped together to form mega-environment 1 while IT98K-573-2-1 was the vertex genotype therein. IT98K-573-2-1 was most favoured by that environment and therefore the most responsive genotype in 2010 and 2011 combined. IT04K-333-2and IT04K-227-4that were the vertex genotypes in mega-environment 2 (AB09) and mega-environment 3 (AB10) respectively, equally were the most favoured and outstanding in their respective mega-environments. IT99K-1060, LDP10-OBR1and IFE-98-12 fell into sectors containing none of the test environments, an indication that they were poor yielding in one or more of the test environment [9]. This is true as the mean vs. stability biplot identified the three genotypes to have performed below average over years. IT98K-573-2-1 was again spotted as the most yielding genotype over years. On the mean vs. stability view of the GGE biplot, the projections from the abscissa towards the AEC ordinates are measures of stability. The length of the projection irrespective of direction is inversely proportional to the stability of a genotype Yan and Kang [8]. In this study LDP10-OBR1 had the shortest projection and therefore identified as the most stable. It was closely followed by IT98K-573-2-1, second best in terms of stability rating. IT04K 227-4-2 had the longest projection and therefore identified as the most unstable The GGE biplot decides on the desirability of a genotype based on the average yield and relative stability. The analysis identified IT98K-573-2-1 as a good combiner of high yield and stability; the mean table showed that the genotype was among the top three performers in most of the tested years. This implies that the genotype was well buffered and thus avoided fluctuations in performance across environments [17]. Becker and Leon [5] identified a successful cultivar as one that possesses high and stable yield potential over a wide range of environmental conditions. IT04K 333-2, IT04K 227-4-2 and IT98K 573-1-1 all performed above average but were not stable indicating that they were inconsistent in yearly performance and therefore unpredictable. LDP10-OBR1 was identified as the most stable but low yielding thereby becoming undesirable for selection. IFE-98-12 and IT99K-1060 were worse-off as both were identified to be unstable and yielded below average. The small circle (AEC) on the abscissa of the mean vs. stability biplot represents the 'ideal genotype' [9]. He defined the ideal genotype based on the mean performance and stability. Since this 'ideal' genotype rarely exists in nature, the closest genotype to the AEC is considered the ideal genotype [8]. In this study, IT98K-573-2-1 was the closest to the circle and therefore the ideal or most desirable genotype. The GGE biplot evaluates test environments based on discriminatory power and representativeness. The longer the vector of an environment the higher its power to discriminate among genotypes while the shorter the angle formed with the abscissa the more representative [8-10]. AB10 combined both and was also closest to the AEC ('ideal' environment). The year 2010 was therefore the best year of evaluation among the four years.

The influence of GEI on plant breeding necessitated multi-environment trials. The presence of the phenomenon in this study dictated that the decision on genotype desirability could not be based on yield alone but accompanied by stability to avoid substantial commercial losses. IT98K-573-2-1 best combined high yield and stability and therefore was considered the most desirable for Abeokuta, South–western Nigeria.

REFERENCES

[1] IITA, *Cowpea. A publication of the international institute of tropical agriculture*. Nigeria: IITA-Ibadan. ISBN 978-131-332-3, 2007.

[2] J. Lowenberg-DeBoer and G. Ibro, "The potential effect of economic growth and technological innovation on women's role in the Cowpea value chain in Kano State, Nigeria. USAID/NIGERIA: A study of the cowpea value chain in Kano state, Nigeria, from a pro-poor and gender perspective. Greater access to trade expansion (Gate) project under the women in development IQC. CONTRACT NO. GEW-I-00-02-00018-00, task order No. 02. 2008," 2008.

[3] S. Ceccarelli, *Positive interpretation of genotype by environment interaction in relation to sustainability and biodiversity. In: Plant adaptation and crop improvement. (Eds.): Cooper, M. and Hammer, G. L.* Wallingford, UK: CABI, 1996.

[4] S. A. Eberhart and W. A. Russel, "Stability parameters for comparing varieties," *Crop Sci.*, vol. 6, pp. 36-40, 1966.

[5] H. C. Becker and J. Leon, "Stability analysis in plant breeding," *Plant Breeding*, vol. 101, pp. 1-23, 1988.

[6] M. Kang and R. Magari, "STABLE. A basic program for calculating stability and yield stability," *Agron J.*, vol. 87, pp. 276-277, 1995.

[7] M. O. Olayiwola and O. J. Ariyo, "Relative discriminatory ability of GGE biplot and YSi in the analysis of genotype × environment interaction in Okra (Abelmoschus Esculentus)," *International Journal of Plant Breeding and Genetics*, vol. 7, pp. 146-158, 2013.

[8] W. Yan and M. S. Kang, *GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists*. Boca Raton, FL: CRC Press, 2003.

[9] W. Yan, "GGE biplot: A windows application for graphical analysis of multi-environment trial data and other types of two-way data," *Agron. J.*, vol. 93, pp. 1111-1118, 2001.

[10] W. Yan, M. Kang, B. Ma, S. Woods, and P. Cornelius, "GGE biplot vs. AMMI analysis of genotype-by-environment data," *Crop Science*, vol. 47, pp. 643-655, 2007.

[11] A. L. Nassir and O. J. Ariyo, "Genotype × environment interaction and yield-stability analyses of rice grown in tropical inland swamp," *Not Bot Hort Agrobot Cluj.*, vol. 39, pp. 220-225, 2011.

[12] M. A. Busari, "Soil physical quality and isotopic fractionation aftertillage, application of poultry manure and fertilizers in Abeokuta, South-Western Nigeria," Ph.D Thesis, Department of Soil Science and Land Management, University of Agriculture, Abeokuta, Nigeria, 2011.

[13] Statistical Analysis Software (SAS) Institute Inc. Cary, NC: SAS Institute Inc, 2002.

[14] O. J. Ariyo, "Genotype and environment interplay in crop production," presented at the 25th Inaugural Lecture, University of Agriculture Abeokuta, 2009.

[15] J. B. S. Haldane, "The interaction of nature and nuture," *Ann. Eugenics*, vol. 13, pp. 197-205, 1946.

[16] B. L. Waldron, H. Asay Kay, and B. Jensen Kevin, "Stability and yield of cool-season pasture grass species grown at five irrigation levels," *Crop Sci.*, vol. 42, pp. 890–896, 2002.

[17] G. M. Heinrich, C. A. Francis, and J. D. Eastin, "Stability of grain sorghum yield components across diverse environments," *Crop Sci.*, vol. 23, pp. 209-212, 1983.