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Genotype x Environment Interaction and seed yield Stability in Cultivated okra using the Additive Main Effect and Multiplicative Interaction (AMMI) and Genotype and Genotype X Environment interaction (GGE)

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ABSTRACT

Twenty nine okra accessions sourced from different agro-ecological regions in Nigeria were tested for stability and performance in four environments between 2006 and 2008 using Additive main effect and multiplicative interaction (AMMI) and Genotype main effect and Genotype by Environment (GGE) models. The experiment was laid out in a Randomized Complete Block Design (RCBD) with five replications. Both AMMI and GGE biplots identified three common genotypes that were overall best in performance in relation to yield and stability. This suggests that for reliability and optimum result it is better to combine the result of the two analytical tools for yield and stability in the recommendation of genotypes to farmers. Both AMMI and GGE models identified LD88/1-8-5-2(G7), 47-4(G17) and NH88/1-8-16-2(G25) as the best accessions for cultivation across seasons because they combined stability and above average yield. Similarly both AMMI and GGE models identified Abeokuta dry season as more stable and ideal for okra genetic evaluation, while Abeokuta rainy season was the most unstable but gave better mean performance. CCN2005/1 (10.92 g/plant) and Clemson spineless (7.72 g/plant) had the least yield and less stable, hence unsuitable for cultivation across seasons. OSADEP Purple tall and NH99/9 were most adapted to Abeokuta rainy season

Key words: Accessions, Genotype X environment Interaction, stability, Additive main effect, okra, biplot.

Abbreviations used: *AMMI: Additive Main Effect and Multiplicative Interaction, GGE: Genotype and Genotype X Environment Interaction*

INTRODUCTION

Yield data and stability performance of crop varieties across contrasting environments are essential to enable a breeder to select high yielding and constantly performing varieties. Genotype-by-environment interaction (GEI) is a major concern in plant breeding for two main reasons; first, it reduces progress from selection and second, it makes cultivar recommendation difficult because it is statistically impossible to interpret the main effects. GEI occurs in both short-term (3 to 4 years testing at a location) and long-term (several locations crop performance trials).

Various techniques have been employed to analyze GEI [1-10]. Joint regression technique has been extensively used by plant breeders. The regression technique involves the quantification of each environment by the mean of all the genotypes tested, and its environmental conditions. However, several workers have criticized the regression technique as inadequate [11, 6, 12].

Analysis of GEI has shown that it might not always be adequately explained by a linear function of the environment alone but more meaningful when combined with stability variance parameter [13]. Of all the earlier techniques, none could handle both the main effects and interaction quite clearly and effectively in a single model or package at the same time [14].

To this end, the Additive Main Effect and Multiplicative Interaction (AMMI) analysis was proposed by Gauch [15]. It is used in field research where both the main effects and the interaction among effects are considered important. The model partitions the treatment variation (GxE matrix) into a model and a residual. It computes the additive main effects for genotypes and environments, and then analyzed the non-additive residual (namely the interaction) by principal component analysis (PCA). The model provides a biplot using the first interaction principal component axis (IPCA1) and the mean yields. On this biplot, genotypes, locations and environments as well as their interactions are obtained.

Ariyo *et al.* [16], in a study on genotype X environment interaction and stability in cowpea (*Vigna unguiculata (L.)* Walp), compared the effectiveness of AMMI and rank sum methods and observed that both techniques picked the same genotype as the most desirable, but differed on the value of other genotypes. AMMI model is more important in the understanding of GEI. Using GEI analysis, Ariyo and Ayo-Vaughan [13] inferred that it is better to grow okra during the mid- and late-seasons to get the best in yield. Dixon and Nukenin [17] also reported that AMMI model was useful in the diagnosis of GEI pattern in cassava yield and identification of better location for cassava improvement.

A most recent approach for the analysis of GEI is the genotype by genotype by environment (GGE biplot). The biplot method was subsequently expanded by Kempton [18] and Zobal *et al*. [19]. The extensive usefulness of GGE biplot, where G= genotype effect and GE= genotype-by-environment effect, has only recently been elucidated [8] [20] [21]. These aspects make the GGE biplot a more comprehensive tool in quantitative genetics and plant breeding.

The objective of this research is evaluate the efficiency of the combined use of AMMI and GGE technique to study GEI and predict the seed yield stability of twenty nine okra genotypes in four environments for varietal recommendation for specific agro-ecological recommendation.

MATERIALS AND METHODS

Twenty-nine okra accessions sourced from five teaching and research institutes (Table 1) were planted in the teaching and research farms of the University of Agriculture Abeokuta (Derived savannah) and Babcock University Ilishan Remo (Rain forest). The study was conducted in four environments, (two seasons in two locations) between 2006 and 2008 cropping seasons (Tables 2).

Table 1: Accessions and their sources

Serial Number	Accession Name	Source
1	Lady's Finger	UNAAB
2	OLA KA-1-6-05	NIHORT
3	OLA V1	NIHORT
4	OLA K2005	NIHORT
5	NIHORT Ilagidi	UNAAB
6	LD88/1-8-11-1	NIHORT
7	LD88/1-8-5-2	NIHORT
8	Short Mouth Ibarapa	UNAAB
9	Clemson spineless	NACGRAB
10	V45-2	NIHORT
11	NH99/DA	NIHORT
12	LD88/1-8-16-2	NIHORT
13	OLA 99/13	NIHORT
14	OSADEP Purple Tall	UNAAB
15	47-4-5	NIHORT
16	ENUGU-1	NACGRAB
17	47-4	NIHORT
18	V2-OYO	UNAAB
19	V-35	IAR&T
20	OLA 3 LOCAL	NIHORT
21	OK 20	NIHORT
22	NH99/28	NIHORT
23	Dajofolowo 1	BU
24	CCN2005/2	BU
25	NH88/1-8-16-2	NIHORT
26	NH88/82	NIHORT
27	NH99/9	NIHORT
28	Jokoso 2	BU
29	CCN2005/1	BU

NIHORT: National Horticultural Research Institute,Ibadan, UNAAB: University of Agriculture, Abeokuta, BU: Babcock University Ilishan-Remo, NACGRAB: National Centre for Genetic Resources and Biotechnology, IAR&T: Institute of Agricultural Research and Training, Ibadan.

Table 2: Experimental site, designation, planting date and seasons

Experimental site	Designation	Planting Date	Seasons
Ilishan 1	E1(Environment 1)	8th October, 2006	Dry season 1
Ilishan 2	E2 (Environment 2)	5th June, 2007	Rainy season 2
Abeokuta 1	E3 (Environment 3)	18th October 2007	Dry season 3
Abeokuta 2	E4 (Environment 4)	8th June, 2008	Rainy season 4

Each experiment was laid out in a Randomized Complete Block Design (RCBD) with five replications in each of the seasons per location. Each replication consisted of 29 single rows of each accession. Each row was 8 meters long with intra-row spacing 30 cm and inter-row spacing of 60 cm. Each row contained twenty five plants.

Data collection

For each of the environments, agronomic and yield data were collected on the following characters:

Days to flowering
Plant Height at Maturity
Fresh pod width
Mature pod width
Fresh pod length
Mature pod length
Seeds per pod
Number of pods per plant
Pod weight per plant
Seed weight per plant
Peduncle length and
100 seed weight

Data analysis

The plot means for each character in each environment and seed yield were subjected to analysis of variance using the method of Steel and Torrie [22].

The seed yield in each environment from the twenty nine accessions were subjected to Additive main effect and multiplicative interaction (AMMI) analysis [19] using the MATMODEL [14] and the Genotype main effects and Genotype X Environment interaction effect (GGE) model [20].The least square fit to AMMI was obtained using two approaches: the main effect is the additive part of the model and was analyzed by ordinary analysis of variance (ANOVA) leaving the non-additive residual, (G X E interaction which is multiplicative part of the model) analyzed by principle component analysis (PCA). For any particular genotype-environment, the main effect equals the accession mean plus the environment mean minus the grand mean. The interaction is the accession PCA scores multiplied by the environment score. When an accession and the environment have the same sign on their respective first PCA axes their interaction is positive; if different, then their interaction is negative.

RESULTS

Analysis of variance of seed and yield related characters of 29 accessions of okra

The combined analysis of variance for 18 yield related characters in 29 Okra accessions in the four environments is presented in (Table 3). There were significant environmental effects for all characters evaluated. Similarly, there were significant varietal effects on all the characters studied except for mature pod width. However, there were significant block effects in all the characters studied except in branches per plant, plant height at flowering, mature pod width, 100 seed weight and seeds per ridge. The combined analysis of variance further indicates that there were significant varietal x environmental interaction effects on all the characters except for mature pod width (Table 3).

Table 3: Mean squares of combined analysis of variance of seed and yield related characters of twenty-nine okra accessions evaluated in four environments

Source of variation	Df	Days to flowering	Plant height at bud initiation	Plant height at maturity	Plant height at flowering	Branches per plant	Fresh pod length	Mature pod length	Fresh pod width	Mature pod width	Ridge per pod	100-seed weight	Peduncle length	Pods per main stem	Seed per ridge	Seeds per pod	Pods per plant	Pod weight per plant	Seed weight per plant
Block	4	139.0**	232.2*	2286.9**	313.6	1.0	2.2*	1.9*	0.2*	0.7	2.2*	0.4	1.7**	8.6**	0.2	424.6**	23.5**	579.7**	206.2**
Varieties	28	352.9**	947.2**	10341.0**	4708.9**	5.33**	68.5**	114.7**	0.68**	1.1	68.51**	3.4**	4.4**	4.5**	2.2**	1339.84**	7.07**	586.1**	202.0**
Environment	3	47930.6**	8898.3**	191481.8**	62690.8**	101.7**	44.1**	122.2**	9.2**	13.2**	44.1**	17.5**	32.2**	64.4**	14.5**	19381.6**	227.6**	37202**	13150**
Variety x Environment	84	93.6**	135.0**	1385.35**	842.91**	2.85**	1.76**	2.19**	0.16**	1.20	1.76**	0.74**	0.43**	1.69**	0.64**	334.47**	2.19**	419.5**	125.9**
Error	460	12.84	79.19	380.91	207.17	0.98	0.80	0.76	0.07	1.13	0.35	0.17	0.25	0.89	3.27	174.45	2.21	223.04	71.30
CV%		6.93	26.40	21.25	24.08	37.67	11.89	9.52	10.29	32.61	7.55	7.82	19.07	25.97	14.72	14.51	36.27	47.14	46.81

* *Significant at 5% ($p \leq 0.05$) level of probability*
** *Significant at 1% ($p \leq 0.01$) level of probability*

Table 4 shows the additive main effect and multiplicative interaction(AMMI) model analysis of variance for seed yield per plant in twenty-nine accessions tested across 4 environments (2-locations by 2- seasons). The result showed a strong evidence that, environment (E), genotype(G) and genotype-by-environment(G x E) interaction were highly significant at ($p < 0.01$) and respectively accounted for 70.8,10.2 and 19.0% of the total variation. The total sum of squares due to G x E interaction was mainly explained by the first principal component axis (IPCA1), which was significant and accounted for 76.5% of the sum of squares. The IPCA1 mean square was almost four times larger than the error mean square. The IPCA 2 and IPCA3 were not significant and accounted for the 17.0% and 6.5% of the G x E interactive sum of squares respectively

The genotype and environment mean yields of 29 okra accessions as well as their first principal axes scores (interaction) from the AMMI analysis is presented in Table 5.

Seed yield per plant ranged from 6.58 g for Clemson spineless to 19.57 g for V45-2, in dry season Ilishan (Environment 1). In the rainy season Ilishan (environment 2) seed yield per plant was highest in Jokoso 2 (29.63 g) and was closely followed by LD88/1-8-11-1 (28.92 g). The least in seed yield per plant was also Clemson Spineless (4.76 g). In the dry season Abeokuta (environment 3), seed yield per plant ranged between 7.08 g for Clemson spineless and 16.13 g for LD88/1-8-11-1, whereas in the rainy season Abeokuta (environment 4) average seed yield per plant ranged between 9.23 g for CCN2005/1 and 48.10 g for OSADEP Purple tall.

The result clearly indicates that the environment had a significant effect on the seed yield in the various accessions. All the accessions reacted differently in the four environments, with regards to seed yield per plant. Clemson Spineless exhibited a consistent low yield across the four environments with an average yield of (7.74 g). The highest average seed yield across the environment was recorded in OSADEP Purple tall (22.17 g), followed by LD88/1-8-5-2 (21.64 g). (environment 4) average seed yield per plant ranged between 9.23 g for CCN2005/1 and 48.10 g for OSADEP Purple tall.

Table 4: AMMI analysis of variance of seed yield in 29 okra accession grown across 4 Environment

Source	Df	Sum of squares	Mean square	Percentage total sum of squares	Percentage treatment	Percentage G x E
Total	579	90925.27	157.04			
Treatment	115	55682.98	484.20**	61.2		
Genotype	28	5656.85	202.03**		10.2	
Environment	3	39451.34	13150.45**		70.8	
G x E	84	10574.79	125.89**		19.0	
IPCA1	30	8087.49	269.58**			76.5
IPCA2	28	1798.38	64.23			17.0
IPCA3	26	688.93	26.50			6.5
Error	464	35242.29	75.95	38.8		

**, **, significant at 5%, and 1% respectively*

Table 5: Mean seed yield of twenty-nine accessions of okra in each of four environments, and across environments, first PCA scores for genotypes and environments

SN	Accession	Environment 1 Dry season Ilishan	Environment 2 Rainy season Ilishan	Environment 3 Dry season Abeokuta	Environment 4 Rainy season Abeokuta	Mean	First PCA Score
G1	Lady's Finger	13.57	21.71	11.81	30.52	19.42	-0.500
G2	OLA kg 1-6-05	14.84	16.76	12.42	21.27	16.33	-1.469
G3	OLAV1	11.72	13.67	14.15	38.24	19.46	1.056
G4	OLA K2005	7.43	21.13	9.72	32.05	17.58	0.015
G5	Ila Gidi	11.74	11.20	10.86	30.80	16.15	0.340
G6	LD88/1-8-11-1	10.54	28.92	16.13	29.43	21.26	-1.187
G7	LD88/1-8-5-2	14.74	21.22	15.64	34.96	21.64	-0.039
G8	Short Mouth Ibarapa	13.71	14.60	10.43	31.31	17.51	0.134
G9	Clemson Spineless	6.58	4.76	7.08	12.52	7.74	-1.386
G10	V45-2	19.57	15,20	12.16	38.06	21.25	0.754
G11	NH99/DA	11.56	16.61	11.72	36.65	19.14	0.737
G12	LD88/1-8-16-2	13.56	20.35	10.58	26.26	17.69	0.933
G13	OLA99/13	10.73	20.75	9.98	41.76	20.81	1.234
G14	OSADEP Purple Tall	12.15	15.79	12.66	48.10	22.17	2.279
G15	47-4-5	11.07	18.29	9.64	33.84	18.21	0.336
G16	Enugu-1	12.92	13.92	9.19	35.88	17.98	0.863
G17	47-4	10.51	22.08	13.32	33.52	19.87	-0.076
G18	V_2-OYO	6.75	14.26	10.36	28.27	14.91	-0.032
G19	V-35	9.35	15.07	8.27	30.42	15.78	0.195
G20	OLA 3 Local	7.53	13.73	7.85	35.33	16.11	1.018
G21	OK 20	7.67	15.33	15.71	24.55	15.82	-0.823
G22	NH99/28	14.03	20.06	13.59	30.90	19.65	-0.413
G23	Dajofolowo 1	11.86	17.84	12.21	34.66	19.14	0.360
G24	CCN2005/2	8.10	22.04	14.26	18.63	15.76	-2.032
G25	NH88/1-8-16-2	9.72	20.03	13.93	37.39	20.32	0-.572
G26	NH88/82	11.13	16.62	12.14	40.55	20.11	1.260
G27	NH99/9	9.13	14.90	12.87	46.43	20.69	2.224
G28	Jokoso 2	13.70	29.63	10.64	25.05	19.76	-1.727
G29	CCN2005/1	9.31	17.01	8.04	9.23	10.92	-2.764
	Mean	11.22	17.72	11.61	31.61	18.04	
	First PCA	-1.266	-2.707	-1.434	5.407		

Generally, the rainy season at Abeokuta recorded the highest mean yield per plant (31.64 g) relative to other environments. This was followed by mean seed yield in the rainy season at

Ilishan with value of 17.72 g. The two dry seasons both at Ilishan and Abeokuta recorded the least mean seed yields, which were 11.22 g and 11.61 g, respectively. Genotypes (29) had the largest interaction (-2.764) and was obviously the most dynamic whereas genotype 4 has the least interaction (0.015) and thus, the most stable across the four environments. Environment 4 with largest PCA score (5.407) was the most unstable, while environment 1 with PCA score of (1.266) appeared to be the most stable.

Figure 1 represents the biplot of AMMI result. The y-axis represents the IPCA1 scores, while the x-axis represents the seed yield per plant (main effect) of the accessions. Accessions LD88/1-8-5-2 (G7) was the overall best of them all combining relative stability and high yield. Accessions V45-2 (G10), 47-4 (G17), and NH88/1-8-16-2 (G25), NH99/28 (G11) were above average in yield and stable, while OSADEP Purple tall (G14) was above average in yield but relatively unstable. OLA K2005 (G4), Short Mouth Ibarapa (G8), V2-OYO (G18) and 47-4-5 (G15) had below average yield but stable. The poorest of the accessions due to instability and lowest yield were Clemson spineless

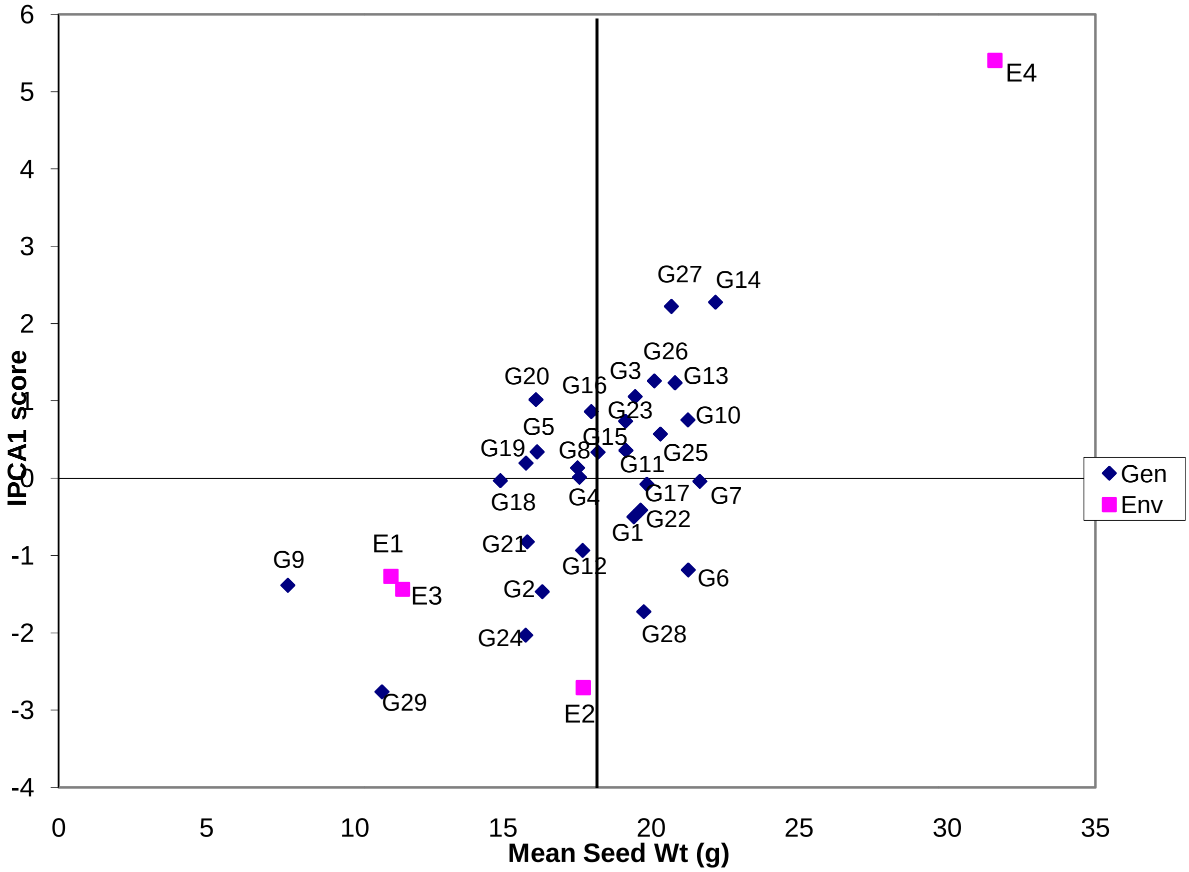

Figure 1: Biplot of AMMI for 29 okra accessions grown in four environments (2-location by 2-seasons)

(G9), and CCN2005/1 (G29). Ilishan-Remo dry season (E1), Ilishan-Remo rainy season (E2), Abeokuta dry season (E3), had below average seed yield, while Abeokuta rainy season had above average yield. The dry seasons at both Ilishan-Remo (E1) and Abeokuta (E3) were most stable, whereas the rainy seasons at Ilishan-Remo (E2) and Abeokuta (E4) were most unstable producing higher interaction.

Table 6 shows the GGE analysis of variance for seed yield per plant in 29 okra accessions tested across four environments (2-location by 2-seasons). The result showed that Environment (E), Genotype (G) and Genotype-by-Environment (G x E) interaction were highly significant at ($p \leq 0.01$) and accounted for 43.4%, 6.2% and 11.6% of the total percentage sum squares respectively. The environmental sum of square is seven times larger than genotype sum of squares and about four times larger than the GEI sum of square.

Figure 2 shows the GGE biplot analysis of seed yield per plant in twenty nine okra accession evaluated in four environments (2-locations by 2-seasons). The GGE biplot accounted for 90 % of the total variation consisting of 63.3 % and 26.7% of variance attributable to the first two principal components (PC1 and PC2) respectively. The biplot also revealed the genotypes that performed best in each environment and the relationship between the environments. The biplot revealed a close relationship between the dry season Ilishan (Environment E 1), dry season Abeokuta (Environment E3) and rainy season Ilishan (Environment E2) environments. This is explained by smaller angle between these environments, whereas there was a wider variation between the rainy season Abeokuta (environment E4) and the rest. Dry season Abeokuta (E3) is the most ideal as most of the accessions particularly OLA K2005 (G4), NH99/28 (G22), LD88/1-8-5-2 (G7), 47-4 (G17) and NH88/1-8-16-2 (G25), 47-4-5 (G15) and NH99/DA (G11) performed well in this environment.

This was followed by the dry season Ilishan (E1) in which OLA99/13 (G13), Lady's finger (G1), Dajofolowo-1(G23) and LD88/1-8-5-2(G7) specifically did very well. In the rainy season Ilishan (E2) Jokoso-2 (G28) yielded below average, while in the rainy season Abeokuta (E4) the closest accessions that yielded best in this environment were NH99/9 (G27) and OSADEP Purple Tall (G14). The rainy season Ilishan (E2) was the least ideal environment. Clemson spineless (G9), CCN2005/1 (G29), Ila gidi (G5), CCN2005/2 (G24), OLA-KG-1-6-05 (G2), OK 20 (G21) and V_2-OYO (G18) performed poorly in all the 4 environments.

Figure 3 represents the ranking of accessions based on mean yield and stability of performance. It is a biplot of the 'ideal genotype' concept. It indicates desirability in terms of both crop stability and mean performance. The average environments coordinate (AEC), which is the single arrowed line that passes through the biplot origin is the abscissa. The AEC and the average environment represented by the small circle represent the mean yield of genotypes. However, the AEC-ordinate, which is the double arrowed line that passes through the biplot origin and perpendicular to the abscissa represents the GE interaction or stability/instability of the genotypes.

Table 6: GGE biplot analysis of variance of seed yield in 29 okra accession grown across 4 environments

Source	Df	SS	MS	% Total SS
Total	579	90925.31		
Genotype	28	5656.88	202.03**	6.2
Environment	3	39451.37	13150.46*	43.4
G x E	84	10574.76	125.89**	11.6
Block	16	3298.52	206.16**	
Error	448	31943.78	71.30	
Std Error	8.44			
LSD (5%)	10.70			

**, **, significant at 5% and 1% respectively*

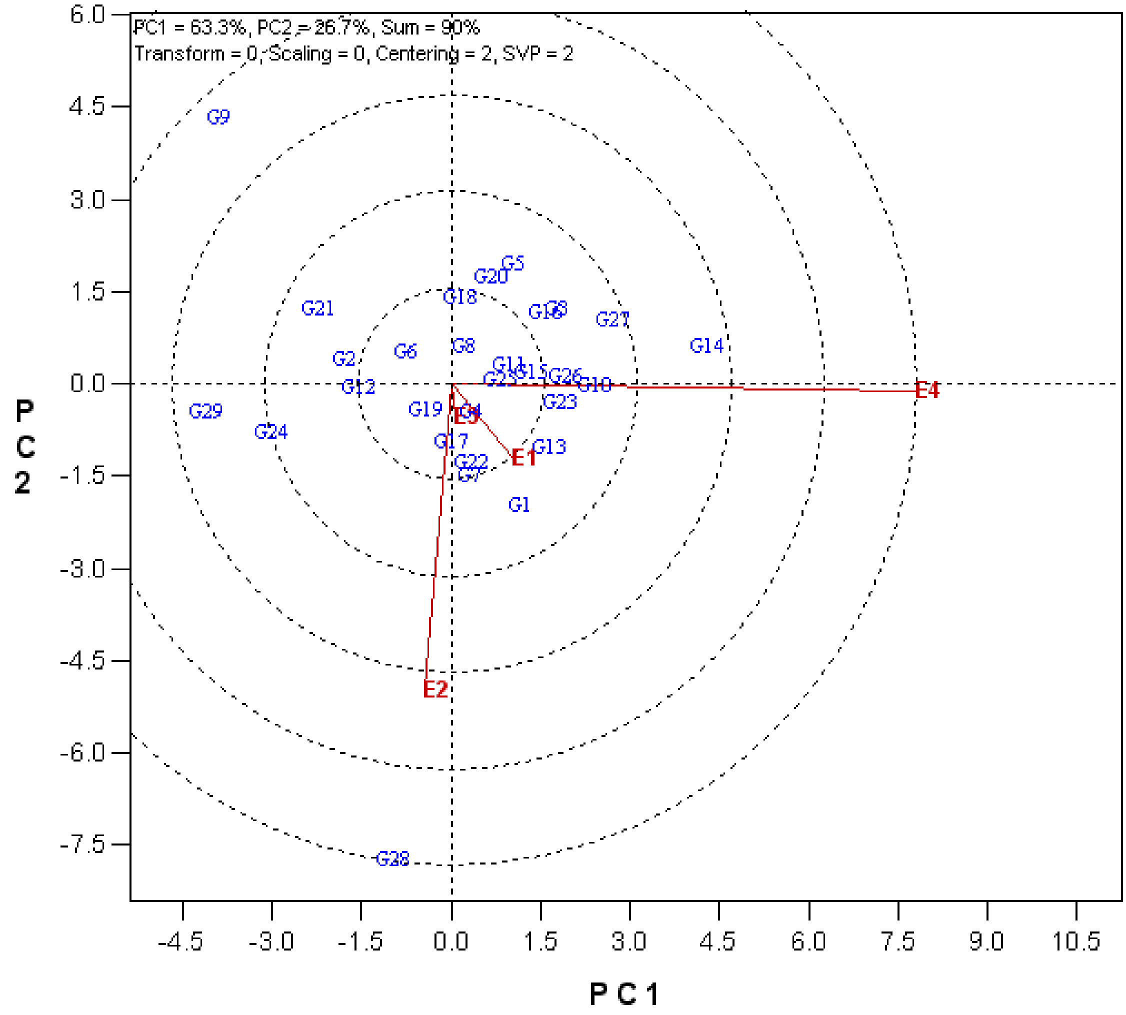

Figure 2: GGE Biplot showing relationship among environments for seed yield of okra twenty-nine accessions

The single arrowed line points towards the direction of increasing mean yield and the two arrows on the AEC- ordinate points to greater GE interaction or lower stability (instability). Thus Ilishan dry season (E1) and dry season Abeokuta (E3) though with reduced yield were more stable and better than Ilishan rainy season (E2) and Abeokuta rainy season (E4) were very unstable but had better mean performance. LD88/1-8-5-2 (G7) and 47-4 (G17), were best-most stable and closest to the ideal genotype. These were followed by OLAK2005 (G4), NH99/28 (G22), Lady's finger (G1), NH88/1-8-16-2 (G25), NH99/DA (G11) and 47-4-5 (G15). NH99/9 (G27), OLA99/13 (G13) and OSADEP Purple tall (G14) had above average mean yield but highly unstable, whereas Clemson spineless (G9) and CCN2005/1 (G29) have no place as far as yield and stability is concerned. OK 20 (G21) performed below average but stable. The biplot of the best genotypes in each of the environments for seed yield is presented in Figure 4. The polygon view of the GGE-biplot explicitly displays 'which-won-where' i.e. (best genotype in each environment) and it is a summary of the GEI pattern of a multi-environment seed yield trial data.

The polygon is formed by connecting the genotypes that are further away from the biplot origin such that all other genotypes are contained within the polygon. To each side of the polygon, a perpendicular line, starting from the origin is drawn and extended beyond the polygon so that the biplot is divided into several sectors, and the different environment were separated into different sectors. There were six sectors. The genotype at the vertices of each sector is the best performer at environments included in that sector, provided that GGE is sufficiently approximated by PC1 and PC2. Hence, though there were six sectors in all, two mega environments were identified. Rainy season Abeokuta (E4) was one mega environment with NH99/9 (G27) and OSADEP Purple Tall (G14) as winning or the best genotypes in this environment. The winning (best) genotype for the second mega-environment consisting of dry season Ilishan (E1), rainy season Ilishan (E2) and dry season Abeokuta (E3) were LD88/1-8-5-2 (G7) and 47-4 (G17).

However, E2 within the second mega environment is highly unstable. The remaining sectors have no environment within them and contain the following genotypes on their vertices Clemson spineless (G9), CCN2005/1(G29), Jokoso-2 (G28) and LD88/1-8-11-1 (G6). These vertices genotypes without environment in the sectors were not the highest yielding genotypes at any environment. Moreover, they were poorest at all or some sites. However, genotypes within the polygon, particularly those located near the plot origin, were less responsive than the vertex genotypes.

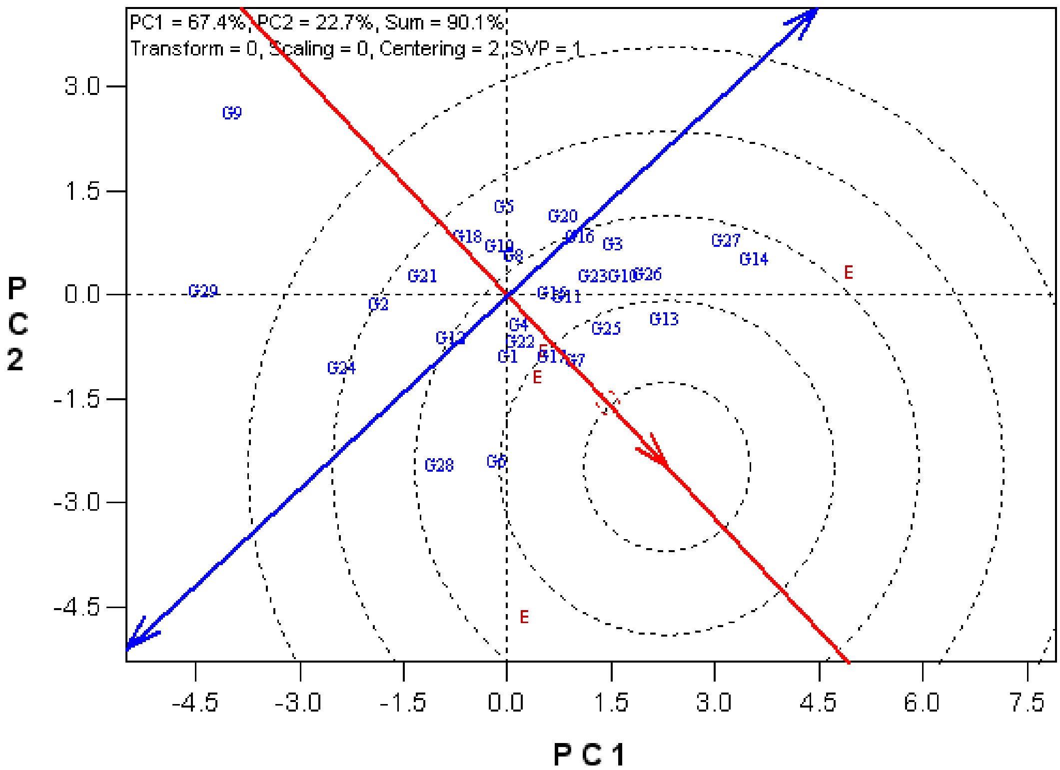

Figure 3: Biplot showing ranking of accessions based on both mean yield and stability of Performance of twenty-nine okra accessions

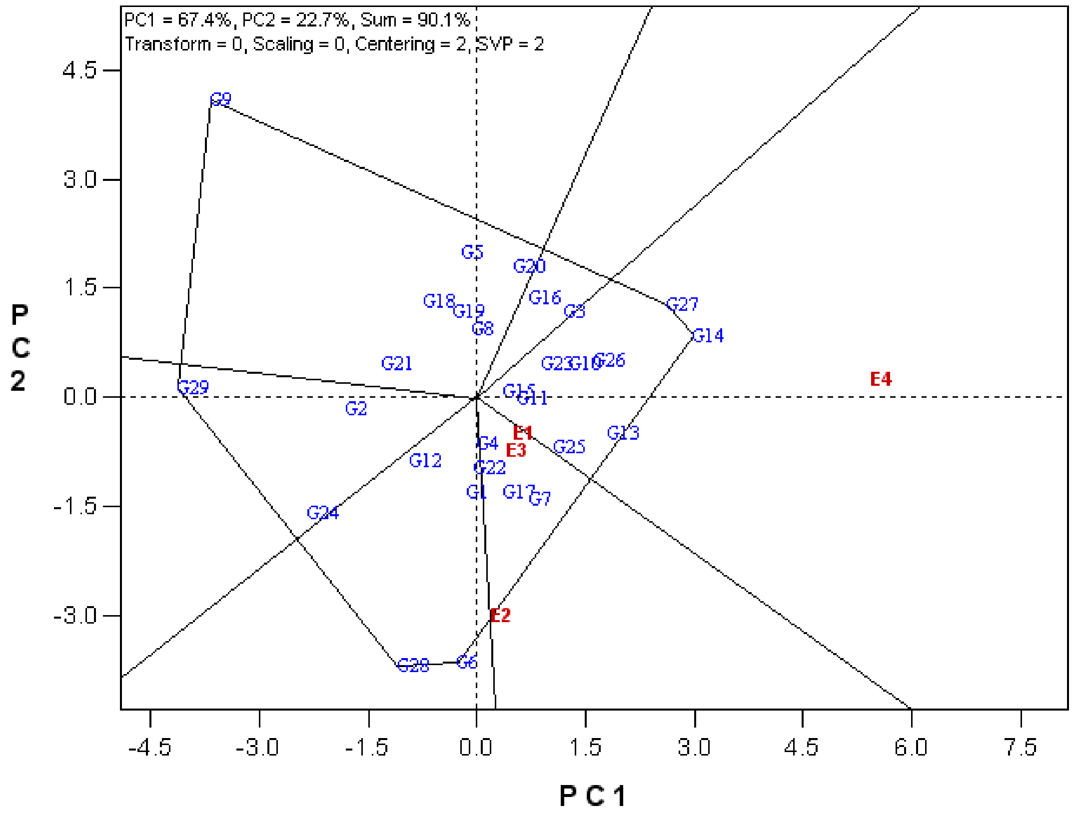

Figure 4: GGE biplot for best genotypes in different environments for seed weight.

DISCUSSION

Multilocational trials are necessary in order to confirm the distinctiveness, uniformity and stability of newly developed crop varieties in readiness for recommendation to farmers. The interaction that exists between genotypes and environment in diverse environments makes selection of any genotype for recommendation challenging for breeders. Hence, there is need to select for distinctiveness, uniformity and stability, whenever such interactions become of practical value in a testing programme [23]. Thus, the Additive Main effect and Multiplicative Interaction (AMMI) analysis of variance for the twenty-nine okra accessions evaluated over four environments showed strong evidence that environment, genotype and genotype x environment interaction were highly significant at $P \leq 0.01$, and accounted for 70.8, 10.2 and 19.0% of the total treatment sum of squares respectively suggesting that the twenty-nine accessions and the environments in which they were evaluated were significantly different from one another. The GXE interaction, implicated IPCA 1, which was significant and could account for most of GXE interaction. This suggests that the climatic and soil conditions of the various environments interfered with the performance of the accessions, especially since the IPCA 1 axes of AMMI model usually relates to the length of the growing environment, temperature changes, variation in soil or combination of all factors and maturity group of the genotype [24] [25][26].

The result of AMMI revealed that V45-2 (G10), LD88/1-8-5-2 (G7), NH99/DA (G11), NH88/1-8-16-2 (G25) and 47-4 (G17) were the most stable genotypes because their interaction with the environment was not enough to hinder yield as indicated by their IPCA scores of zero and near zero suggesting that these accessions can be cultivated in any of the 4 environments for their stability. LD88/1-8-11-1 (G6), OSADEP Purple tall (G14) and NH99/9 (G27) were generally high yielding and had high interactions, indicating that they were unstable and responsive to changes in the environment. LD88/1-8-5-2 (G7), V45-2 (G10), 47-4 (G17) and NH88/1-8-16-2 (G25) appeared to be the overall best of genotypes, combining high stability with yield, therefore can be recommended for cultivation in any of the environments for high yield and stability. Genotypes with large interaction with the environment are unpredictable in performance and can only be grown in limited environments. Of the four environments, Abeokuta dry season (E3) produced the least interaction effect followed by Ilishan dry season (E1) and may be most appropriate environments for okra production and evaluation. Selection in these environments will be effective as the relative performance of these genotypes would be fairly stable.

Similarly, the GGE ANOVA also revealed a significant GxE interaction at $p \leq 0.01$ and accounted for 11.6% of the total treatment sum of squares. This is also an indication that the environment interferes with the genotype performance, hence may ultimately affect the stability of the performance of the genotype with respect to the characters considered in this study. In relation to the ideal genotype and the average environment coordinate as indicated by GGE biplot, LD88/1-8-5-2(G7), OLA99/13(G13), 47-4(G17) and NH88/1-8-16-2(G25) were closest to the ideal genotype position. This suggests that these accessions were better in yield and were more stable than all the other accessions in all environments studied. They will be suitable for recommendation in the 4 environments. An ideal variety is one that combines yield with stability of performance [27]. Furthermore, OSADEP Purple tall (G14) and NH99/9 (G27), were better adapted in Abeokuta rainy season (E4). Meanwhile Clemson spineless (G9) and CCN2005/1 (G29) were the poorest in yield and stability. Their poor yield may be associated partly to the GxE interaction as well as the poor genetic capacity of these accessions. Hence, these accessions will not be the choice for recommendation in respect to overall performance. Abeokuta dry season (E3) and Ilishan dry season (E1) can be considered better environment for okra genotype evaluation partly because they produced little interaction with the genotypes and because there was lower rainfall which reduces the magnitude of pathogens. This result corresponds to the results from AMMI biplot. Both AMMI and GGE biplots identified three common genotypes that were overall best in performance in relation to yield and stability. This suggests that for reliability and optimum result it is better to combine the result of the two analytical tools for yield and stability in the recommendation of genotypes to farmers. Therefore, LD88/1-8-5-2 (G7) 47-4 (G17) and NH88/1-8-16-2 (G25), have better prospect to perform better across the four environments and be stable. Between locations similarities and within location differences in rainfall pattern as well as the performance of crop genotype accordingly suggests that climatic information might be useful in the clarification of genotype by trial interaction [28].

In conclusion, both AMMI and GGE analytical tools produced similar results and can be combined together to generate a more reliable result in GEI and yield stability prediction. LD88/1-8-5-2 (G7) 47-4 (G17) and NH88/1-8-16-2 (G25), have better prospect to perform better across the four environments and be stable. Furthermore, Abeokuta dry season (E3) and Ilishan dry season (E1) can be considered better environment for okra genotype evaluation.

REFERENCES

[1] S.A. Eberhart, W. A. Russel, Crop Sci., **1976** 6:36-40
[2] J.N. Perkins, J. L., Jinks, *Heredity*, **1968,** 23: 339-356
[3] D.L. Pfahler, H. L., Liriskens, *Theor. Appl. Genet.*, **1979,** 54:1-4
[4] H.T. Nguyen, D. A. Steper, K. L. Hunt, *Crop Sci.* **1980.** 20: 221- 224

[5] B.R. Ntare, M. Aken'ova, *Crop Sci*. **1985,** 25: 208-211
[6] O.J. Ariyo, *Theor. Appl. Genetics*, **1987** 74:83-86
[7] M.S. Kang, (ed) **1990**. Genotype by environment interaction and plant breeding, Department of Agron. Louisiana State University, Baton Rouge, Louisiana
[8] W. Yan, L. A., Hunt, Q., Sheng, Z., Szlavnics, *Crop Sci*., **2000,** 40: 597-605
[9]W. Yan, M. S., Kang, **2002.** GGE Biplot analysis: A graphical tool for breeders, geneticists and agronomists. CRC Press, Boca Raton, FL. 271pp
[10] L. Abubakar, S.G. Ado, Asian J. of Crop Sci., **2010**, 2(3):175-185
[11] W. Powell, P. D. Cahgari, M. S. Phillips, J. L. Jinko, *Heredity,* **1986,** 56:255-262
[12] O.J. Ariyo, M. A. Ayo-Vaughan, *J. of Genetics and Breeding*. **2000,** 54:35-40
[13] O.J. Ariyo, *Annals of Appl. Biol.,* **1990,** 116:335-341
[14] H.G. Gauch, **1993**. MATMODEL Version 2.0: AMMI and related analysis for two-way data matrices. Microcomputer power, Ithaca, New York.
[15] H.G. Gauch, **1985**, Integrating Additive and Multiplicative Models from analysis of yield trials with assessment of predictive success, Mimeo 85-87. Soil, crop and atmospheric sciences, Cornell University, Ithaca, New York.
[16] O.J. Ariyo, K. A. Okeleye, A. A. Oyekanmi, *Assets series* A **2002.** 2 (2): 111-117
[17] A.G.O. Dixon, E. N. Nukenine, *African Journal of Root Crops*, **1997** Vol. 3. No. 1:46-50
[18] R.A. Kempton, *J. of Agric. Sci*. **1984,** 103:123-135.
[19] R.W. Zobal, M. J. Wright, H. J., Gauch, *Agron. J.* **1988,** 880: 388-392
[20] W. Yan, P. L. Cornelius, J. Crossa, L. A. Hunt, Crop Sci., **2001,** 41:656-663
[21] W. Yan, I. Rajcan, *Crop Science*, **2002,** 42:11-20
[22] R.G. Steel, R. H. Torrie. **1980.** Principles and procedure of statistics. 2nd edition MCGraw-Hill, Inc. New York
[23] S.M. Funnah, C. Mak, *Experimentation Agriculture* **1980,** 16: 387- 390
[24] H.G. Gauch, R. E. Furnas, *Agron. J*. **1991,** 83: 916-920
[25] J.A. McCallum, D.G. Grant, E.P. McCartney, J. Scheffer, M.L. Shaw, R.C. Butler, New Zealand J. Crop Hortic. Sci., **2001,** 29:149-158
[26] A. Rashid, G. R. Hazara, N. Javed, M. S. Nawazx, G. M. Ali, Asian J. of Plant Science, **2002,** Vol. 1 (5):591-592.
[27] S.G. Ado, M.F. Ishiyaku, Nig. J. Genet., **1999,** 14:73-81
[28] F.A. Van Euuwijk, A., Elgersma, *Heredity,* **1993,** *70:447-457*