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FULL LENGTH ARTICLE

GGE biplot analysis of fluted pumpkin (*Telfairia occidentalis*) landraces evaluated for marketable leaf yield in Southwest Nigeria

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Abstract The study was undertaken with the objective to examine the nature and to quantify the magnitude of genotype × environment interaction (GEI) effects on marketable leaf yield of fluted pumpkin, *Telfairia occidentalis* (Hook. F.) and to determine the winning genotype (s) for the test environments in Southwest Nigeria. The experiment was conducted using twenty-five landraces of fluted pumpkin in four environments [comprising two different locations (Abeokuta and Akure) for two consecutive years (2012 and 2013)]. Randomized complete block design with three replicates was employed. The combined analysis of variance over environments explained that fluted pumpkin marketable leaf yield was significantly ($p < 0.001$) affected by environments, genotypes and GEI. The result showed differential performance of fluted pumpkin landraces at different test environments and hence the interaction was crossover type. The genotype main effect plus genotype × environment interaction (GGE) biplots were applied to analyse and visualize pattern of the interaction components. The first two PCs explained 86.40% (PC1 = 66.93%, PC2 = 19.47%) of the total variation of the GGE model (i.e. G + GE). Landraces Fts34, Ftn44 and Ftk20 were most stable but Ftd1 and Ftw21 were more desirable. Landraces Fta39 (398.80g) and Ftw21 (299.60g) were high yielding and are adapted to Akure and Abeokuta respectively. Akure is considered a better location for the evaluation of fluted pumpkin for marketable leaf yield.

1. Introduction

Fluted pumpkin *Telfairia occidentalis* (Hook. F.) belongs to the family *Cucurbitaceae*, commonly grown in the forest zone of West and Central Africa (Odiaka and Schippers, 2004). It is

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suggested that the crop originated in South Eastern Nigeria particularly around Imo State, Nigeria (Esiaba, 1982; Akoroda, 1990), where it has the widest diversity (variation in pod and seed characteristics, plant vigour, anthocyanin content, leaf size and their succulence) (Chweya and Eyzaguirre, 1999; Fayeun et al., 2012). Fluted pumpkin is grown in almost all the agro-ecological zones of Nigeria for its edible parts which include the young vines, leaves, petioles and seeds (Odiaka et al., 2008). It provides regular income for farmers because it is a facultative perennial crop that is harvested at regular interval (Akoroda, 1990; Fayeun et al., 2012). Fluted pumpkin has valuable nutritional and medicinal benefits. The seed is rich in oil and the leaf is rich in protein, magnesium, iron and fibre (Akoroda, 1990; Ehiagbonare, 2008).

Successful cultivation of any given crop species or cultivar in an agro-climatic region depends on its adaptability and yield stability. Genotype by environment interaction (GEI) causes variation in yield performance across environments. The perturbation of GEI is a serious puzzle for plant breeders. Unravelling this has led to greater interest and therefore advances, in understanding the factors influencing plant growth and development (Xu, 2010). Hence, several statistical methods for studying GEI effects have been developed (Eberhart and Russell, 1966; Kang et al., 1987; Crossa, 1990; Gauch, 1992; Yan, 2001). Among these methods, Additive Main effects and Multiplicative Interaction (AMMI) (Gauch, 2006) and Genotype plus Genotype × Environment interaction (GGE biplot) (Yan et al., 2000) models are commonly used by researchers for analysing multi-environment trial (MET) data. AMMI and GGE biplot analyses are useful for easy graphical explanation of complex genotype by environment two way table. Both GGE biplot and AMMI models make use of principal component analysis; GGE biplot differs from AMMI based on how the two-way table of G × E means is treated before performing singular value decomposition (SVD). The AMMI applies SVD to the data minus the genotype and environment means, while GGE biplot applies SVD to the data minus the environment means only (Gauch, 2006).

The GGE biplot methodology composed of two concepts, the biplot concept (Gabriel, 1971) and GGE concept (Yan et al., 2000) which are used to visually analyse results of site regression (SREG) analysis of MET data. This methodology uses a biplot to show the two factors (G plus GE) that are important in cultivar evaluation and they are also sources of variation in MET data (Yan et al., 2000). GGE biplot best fits for mega-environment analysis (like 'Which-won-where' pattern), genotype evaluation (mean vs. stability), and test environment evaluation which provides discriminating power vs. representativeness (Yan et al., 2007; Amira et al., 2013; Atnaf et al., 2013) of the test environment. The popularity of GGE biplot is linked to its versatility and ability to analyse a range of data types with a two-way structure.

Since the introduction of GGE biplot and the associated user-friendly software (Yan, 2001), there have been numerous applications of the method to MET analyses and other types of data with two-way structures. Yan et al. (2000) used the GGE biplot technique to show that winter wheat production environments in Canada should be grouped into two mega-environments, as opposed to a traditional grouping of 4 subareas. Yan and Rajcan (2002) employed the GGE biplot technique to soya bean (*Glycine max*) MET data and identified a single mega-environment with frequent crossover GEI. In the same study it was demonstrated that GGE biplots could be utilized successfully to investigate genotype × trait data to reveal interrelationships among soya bean traits and compare genotypes on the basis of multiple traits. Dehghani et al. (2006) used GGE biplot to identify three barley (*Hordeum vulgare*) mega-environments in Iran. Yan and Kang (2003) demonstrated the application of the GGE biplot technique for the analysis of trait × quantitative trait loci interactions in barley. Sharma et al. (2010) used GGE biplot to determine the performance, stability, and superiority of winter wheat breeding lines in irrigated environments in Central and West Asia. The aims of this study were to examine the nature and to quantify the magnitude of genotype × environment interaction effects on fluted pumpkin marketable leaf yield and to determine the winning genotype (s) for test environments in Southwest Nigeria.

2. Materials and methods

The experiment was conducted at two locations (Teaching and Research Farm Directorate of Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria (7°25′N, 03°25′E), with sandy loam soil and the Teaching and Research Farm of Federal University of Technology, Akure (FUTA), Ondo State, Nigeria (7°16′N, 05°12′E), with sandy clay loam soil) for two consecutive years (2012 and 2013), making four environments (Fig. 1). The twenty-five landraces of fluted pumpkin used for this experiment were collected from two agro-ecological zones in Southern Nigeria: rain forest (16) and derived savannah (9). The experiment was arranged in a randomized complete block design (RCBD) with three replications. Each replication had 25 plots of 2 m by 2 m, with 1 m inter-plot spacing. Seedlings raised using sawdust as growth medium were transplanted directly on manually prepared field two weeks after planting. One seedling was transplanted per hole at a spacing of 1 m by 1 m resulting in 9 plant stands per plot. The vines were supported with trellis. Manual weeding was done at 3 weekly intervals. Organic farming practices were maintained as there was no application of fertilizers and pesticides throughout the experimentation. Data were collected at harvest (8 weeks after transplanting) on marketable leaf yield. Marketable leaf yield data were the weight of freshly harvested main vine including the branches and the leaves cut at 100 cm above soil level. It was weighed in gram using electronic balance. The marketable leaf yield data of the twenty-five fluted pumpkin landraces were subjected to analysis of variance (ANOVA). The GGE biplot was constructed using the first two principal components (PC1 and PC2) derived from subjecting environment centred yield data (Yan et al., 2000). The GGE model used was as follows:

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

where Y_{ij} is measured mean of genotype i ($= 1, 2, \ldots, n$) in environment j ($= 1, 2, \ldots, m$), μ is the grand mean, β_j is the main effect of environment j, $\mu + \beta_j$ being the mean yield across all genotypes in environment j, λ_1 and λ_2 are the singular values (SV) for the first and second principal components (PC1 and PC2), respectively, ξ_{i1} and ξ_{i2} are eigenvectors of genotype i for PC1 and PC2, respectively, η_{1j} and η_{2j} are eigenvectors of environment j for PC1 and PC2, respectively, and ε_{ij} is the residual associated with genotype i in environment j.

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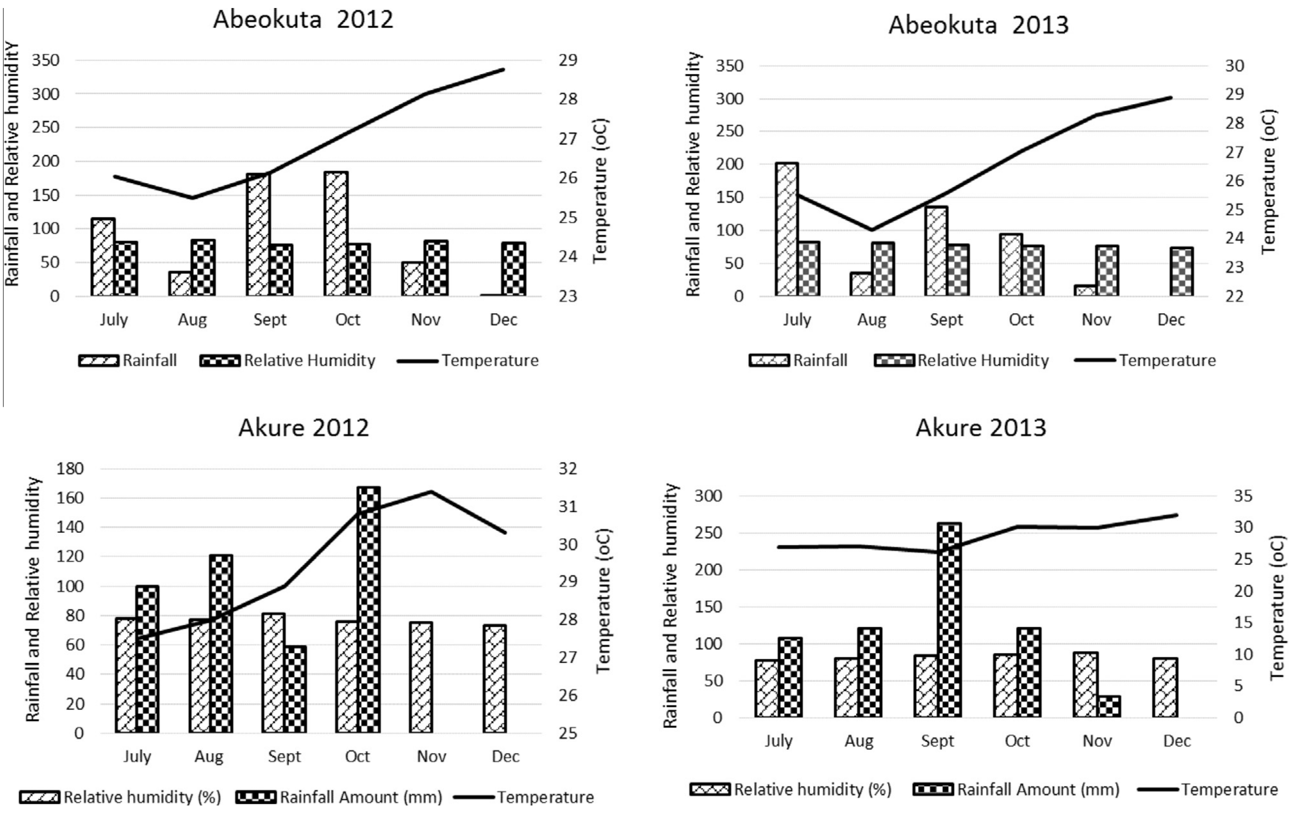

Figure 1 Meteorological data (relative humidity, rainfall and temperature) of Abeokuta and Akure in 2012 and 2013. *Sources:* Agrometeorology and Water Management Department, FUNAAB and Agro-climatological and Ecological Project, Ondo State Ministry of Agriculture.

GGEBiplotGUI package of R statistical software version 3.0.2 (R Core Team, 2013) was used to analyse GGE Biplot following the methods of Yan et al., (2000).

3. Results and discussion

3.1. Analysis of variance and descriptive analysis

Analysis of variance revealed highly significant ($P < 0.01$) effects of environment, genotypes and the GEI for marketable leaf yield (Table 1). This result depicted that the marketable leaf yield of the fluted pumpkin landraces was different at different testing environments, thus confirming the existence of GEI. The large GEI effect in this study suggests the possible presence of different mega-environments with different winner genotypes (Yan and Kang, 2003). This necessitates further analysis to identify the most stable and high yield landrace(s) for marketable leaf yield and the most ideal testing environment(s). The mean marketable leaf yield of the twenty-five landraces grown in four environments is presented in Table 2. Mean yield ranged from 70.80 g for Fts34 to 398.80 g for Fta39. Ten of the landraces had above the average yield of 199.15 g. Generally, landraces Fta39 (398.80 g), Ftd1 (368.50 g), Ftn12 (366.00 g), Ftw21 (299.60 g) and Ftm11 (252.20 g) were best five while Fts34 (70.80 g), Ftn44 (94.80 g), Ftk20 (109.80 g), Fty28 (122.50 g) and Fty30 (130.10 g) were the least five. Among the environments, Abeokuta in both years had below the average yield. The highest yield was recorded in Akure 2013 (233.10) while Akure 2012 (198.10) was very close to average yield.

Table 1 Analysis of variance for marketable leaf yield data obtained from fluted pumpkin trials conducted in Abeokuta and Akure in 2012 and 2013 (environments constitute year–location combinations).

Source	DF	MS	*P*-value
Environment	3	44958.43**	<.0001
Replications (environment)	6	46.60	0.1768
Genotypes	24	86138.29**	<.0001
Genotypes × environment	72	27095.20**	<.0001
Error	192	30.865	
Total	299		

DF = Degree of freedom.
MS = Mean squares.
** Significant at $P < 0.01$.

3.2. GGE biplot analysis

The stability analysis of the 25 fluted pumpkin landraces using GGE biplot displayed the genotype main effect (G) and the GEI, which are the two most important sources of variation for cultivar evaluation in a MET (Yan et al., 2007). The GGE biplot of marketable leaf yield of fluted pumpkin evaluated in four environments is presented in Fig. 2. It is based on an environment-metric preserving (SVP = 2), and the data

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Table 2 Means of average marketable leaf yield for 25 landraces fluted pumpkin studied in four environments.

Genotypes	Abeokuta 2012	Akure 2012	Abeokuta 2013	Akure 2013	Genotype mean
Fts33	135.30	175.40	141.70	244.10	174.10
Fty28	97.20	49.90	184.10	158.90	122.50
Fte42	185.60	165.30	319.20	333.10	250.80
Ftr13	255.00	228.60	144.00	149.80	194.30
Ftw21	**310.80**	256.90	**332.70**	298.10	299.60
Ftk16	41.20	160.90	57.70	276.00	133.90
Fte40	242.80	200.20	142.00	124.30	177.30
Ftg23	224.40	188.60	148.90	141.00	175.70
Ftg22	258.90	64.30	274.10	34.50	157.90
Ftk20	90.30	133.60	53.90	161.20	109.80
Fte41	301.60	205.50	222.70	126.90	214.20
Fty29	192.00	77.90	239.00	116.70	156.40
Ftn43	246.00	217.70	180.70	183.70	207.00
Fty30	190.00	157.70	87.80	85.10	130.10
Ftk17	212.50	263.00	54.70	172.80	175.80
Ftn44	102.10	127.50	34.10	115.30	94.80
Ftn45	126.60	177.50	189.50	307.50	200.30
Ftn46	202.00	144.10	292.30	251.70	222.50
Ftm11	302.10	268.90	220.90	216.90	252.20
Ftg24	168.20	71.00	215.50	117.80	143.10
Fta39	183.40	**488.50**	217.30	**705.70**	**398.80**
Ftd1	302.10	420.80	267.10	484.10	368.50
Ftn12	151.90	349.20	316.00	646.90	366.00
Ftn47	158.40	268.50	43.70	248.40	179.80
Fts34	45.70	90.60	18.70	128.30	70.80
Environment mean	189.00	198.10	175.90	233.10	**199.15**

The bold values are the highest for corresponding genotypes in their respective environments.

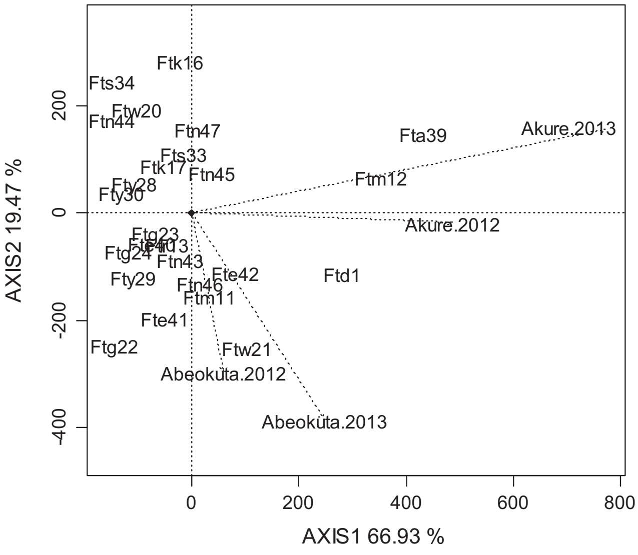

Figure 2 GGE biplot of marketable leaf yield of twenty-five landraces of fluted pumpkin in two year trials across two locations.

were not transformed ("Transform = 0"), not scaled ("Scaling = 0"), and environment centred ("Centring = 2"). The first two PCs explain 86.40% (PC1 = 66.93%, PC2 = 19.47%) of the total variation the GGE model (i.e. G + GE). The PC1 in a GGE biplot identifies the genotypes mean performance while PC2 identifies the GEI associated with each landrace, which is a measure of variability (stability).

Landraces Fta39, Ftm12, Ftd1, Ftw21, Fte42, Ftn46, Ftm11 and Ftn45 with PC1 values greater than 0 are high yielding and have good adaptability. The reverse is the case for other landraces with PC1 values less than 0. The landraces, which lie near the origin (PC2 value near 0.00) are stable, and examples are Fty30 (a stable but poor yielder) and Ftm12 (a stable and good yielder).

3.3. *Performance of the landraces across environments and stability*

Figs. 3a–3d present the performances of the 25 landraces of the fluted pumpkin in Abeokuta 2012, Akure 2012, Abeokuta 2013 and Akure 2013 respectively. In ranking the genotypes based on their performance in an environment, a line drawn that passes through the biplot origin is called the average tester coordinate (ATC) (Yan and Kang, 2003). Along the line is the ranking of the genotypes. In Abeokuta 2012, landraces Ftw21, Ftg22, Fte41, Ftd1, Ftm11, Ftn44, Fte42, Fty29, Ftn43, Ftg24, Ftr13, Fte40, and Ftg23 had above average yield of 189.47g, Ftn12 had average yield and all others had below average. In Akure 2012, landrace Fta39 was the highest yielder while Fts34 was the lowest yielder. Only nine landraces (Fta39, Ftn12, Ftd1, Ftw21, Fte42, Ftm11, Ftg22, Ftn46 and Ftn47) were higher than average yield of 198.07g while the other 16 genotypes were lower than average yield. There was consistency in the rank of Ftw21 as the highest yielder in Abeokuta 2012 and Abeokuta 2013 as displayed in Figs. 3a and 3c. Fig. 3c shows that 10 landraces performed below average while Fte40, Ftg22 and Ft24 were very close to the mean yield and the remaining were higher than the average yield. The ranking of landraces performance for Akure 2013 showed that Fta39

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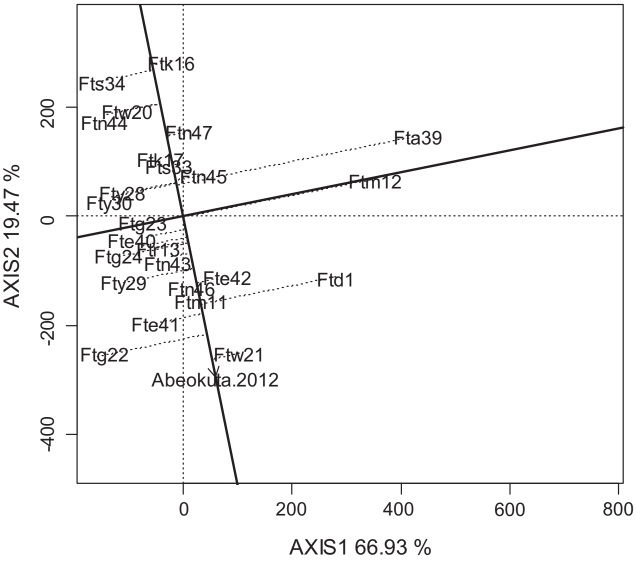

Figure 3a The marketable leaf yield performance of the twenty-five landraces of fluted pumpkin at Abeokuta in 2012.

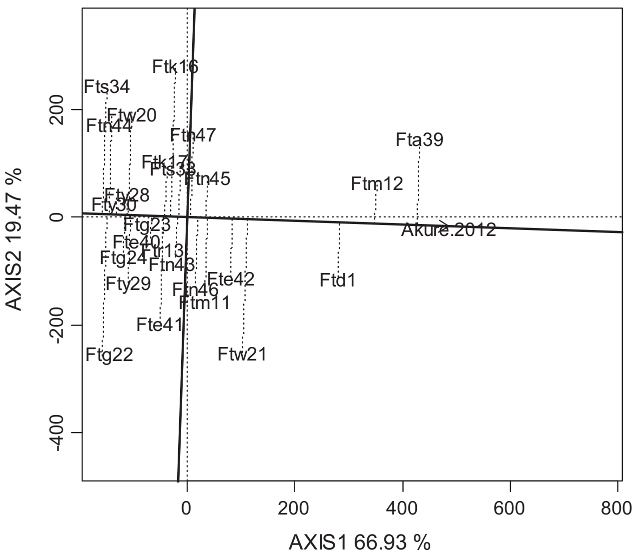

Figure 3b The marketable leaf yield performance of the twenty-five landraces of fluted pumpkin at Akure in 2012.

had the highest mean yield while Ftg22 had the least (Fig. 3d). Interestingly, Ftk16 that was far below average yield in the other environments was ranked among the best 8 landraces in Akure 2013. The performances of fluted pumpkin landraces were different at different testing environments due to the existence of large GEI. As revealed by differential yield ranking of landraces, the GEI was crossover type (Figs. 3a–3d and Table 2). The two locations had different winner landraces. This situation complicates selection process and cultivar recommendation in breeding programmes (Atnaf et al., 2013).

Based on Fig. 4, it is possible to assess both mean yield performance and stability performance through a biplot. The single-arrowed line is the average environment co-ordinate (AEC), and it passes through the biplot origin and points to

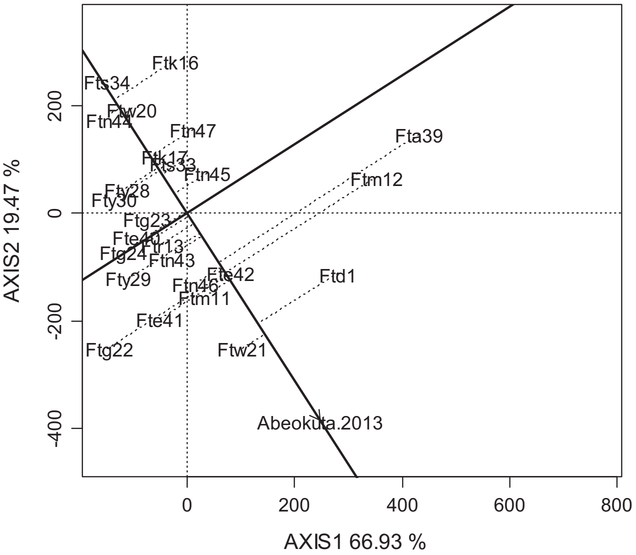

Figure 3c The marketable leaf yield performance of the twenty-five landraces of fluted pumpkin at Abeokuta in 2013.

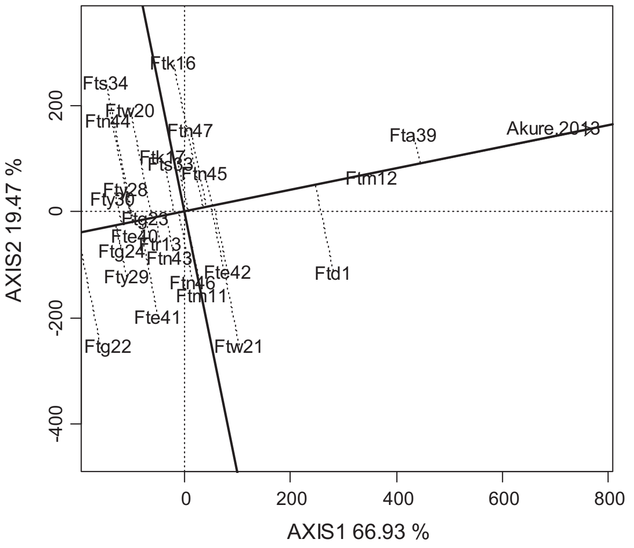

Figure 3d The marketable leaf yield performance of the twenty-five landraces of fluted pumpkin at Akure in 2013.

higher mean yield across environments. Hence, Fta39 had the highest mean yield, followed by Ftm12, Ftd1, Ftw21, Fte42, Ftm11, Ftn46 and Fte41 in descending order while Ftn43 and Ftn45 had mean yield value close to the grand mean. Fts34 had the lowest mean yield followed by Ftn44, Ftk20, Fty30, Ftg24, Ftk17, Ftg22, Fty29, Ftg23, Fte40, Fts33, Ftn47 and Ftr13 in ascending order. The double-arrowed line is the AEC ordinate. Stability of each landrace is explored by its projection onto the AEC, and it points to greater variability (poorer stability) in either direction. The shorter the absolute length of projection of a genotype, the more stable it is. Hence, Fte42 was highly stable while Fta39 was highly unstable though had the highest yield. An ideal genotype should have the highest mean performance and be absolutely stable (Yan and Kang, 2003). Fig. 5 defines an

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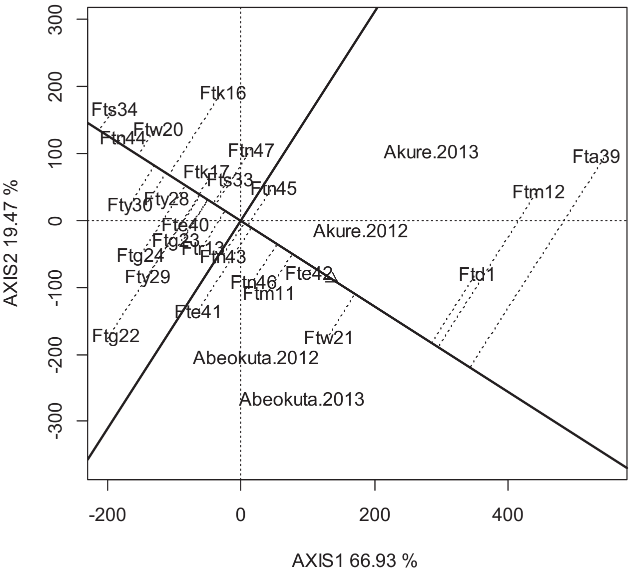

Figure 4 GGE biplot showing ranking of genotypes for both mean yield and stability performance across environments.

"ideal" genotype (the centre of the concentric circles) to be a point on the AEA ("absolutely stable") in the positive direction and has a vector length equal to the longest vectors of the genotypes on the positive side of AEA ("highest mean performance"). Therefore, genotypes located closer to the 'ideal genotype' are more desirable than others. Thus, Ftd1 (368.50 g) and Ftw21 (299.60 g) were more desirable than Fta39 (398.80 g) even though it had highest marketable leaf yield. Fig. 5 illustrates an important concept regarding "stability". The term "high stability" is desirable only when associated with mean performance (Yan and Tinker, 2006), and it shows that Fts34, Ftn44 and Ftk20 are highly "stable". But two of them (Ftn44 and Ftk20) were lower in yield than the least stable genotypes Ftk16, Ftg22 and Fty29 which performed reasonably well in at least some environments.

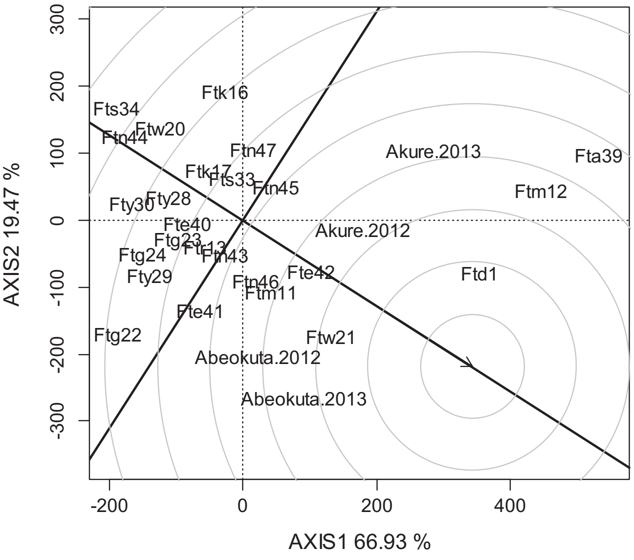

Figure 5 Ranking genotypes based on both mean and stability relative to an ideal genotype.

3.4. Mega-environment analysis

The display of the 'Which-won-where' pattern in the polygon view is helpful to estimate possible existence of different mega-environments in the target environment (Yan et al., 2000; Yan and Rajcan, 2002; Yan and Tinker, 2006). Fig. 6 displays a polygon view of twenty-five fluted pumpkin landraces tested at four environments based on Table 2. With this biplot, a hexagon was constructed by connecting the vertex landraces with straight lines and as a result, the rest of the landraces were placed inside the hexagon. Landraces Fta39, Ftd1, Ftw21, Ftg22, Fts34 and Ftk16 were at the vertexes of the hexagon. Six projecting lines from the origin divided the hexagon into six sectors. From the hexagon view of this biplot, test environments and landraces fell into two and five sectors respectively. Abeokuta 2012 and Akure 2012 were relatively closer to the biplot origin while Abeokuta 2013 and Akure 2013 were farther. One of the sectors (sector 2) in the hexagon had no representative landrace and test environment. The necessary and sufficient condition for mega-environment delineation is a repeatable which-won-where pattern rather than merely a repeatable environment-grouping pattern (Yan and Kang, 2003; Yan and Rajcan, 2003). Repeatable performance of the landraces was observed in Abeokuta and Akure as the two locations fell into sectors 1 and 3 respectively in both years. Hence, Akure and Abeokuta could be considered as two separate mega-locations for fluted pumpkin genotype evaluation and recommendation. These two locations are diverse agro-ecologies in south-western Nigeria with different rainfall patterns and soil types. Interestingly, the genotypes that won in Abeokuta in the two years were sourced from Ilorin, Kwara State, that shares similar climatic and soil type with Abeokuta while the best two genotypes in Akure were sourced from rainforest zone Fta39 (Umudike, Abia State) and Ftd1 (Esan, Edo State). Landraces Fta39 and Ftm12 are vertices in sector 1, and both landraces were adaptable to the two Akure environments. However, Fta39 was higher yielder than Ftm12. Two other landraces in sector 1 were Ftn45 and

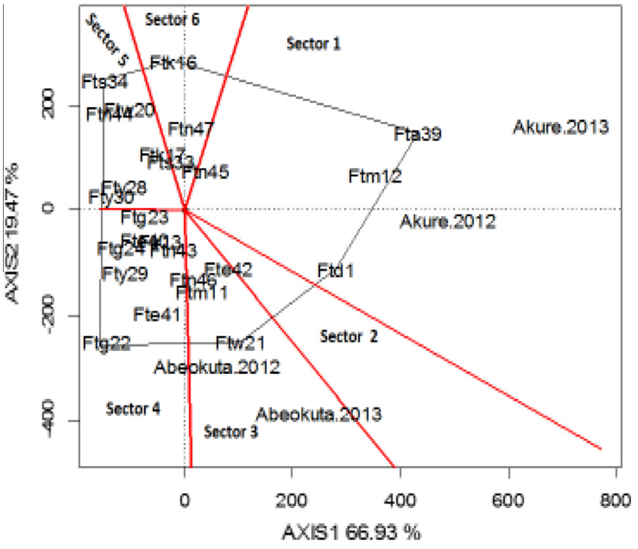

Figure 6 Polygon view of the GGE biplot showing which fluted pumpkin landrace had the best marketable leaf yield in which environment.

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Ftm12. Sector 3 had Ftw21 as the vertex landrace with genotypes Fte42, Ftn46 and Ftm11 as representative landraces and these landraces were adaptable to Abeokuta environments. Sectors 4, 5 and 6 had Ftg22, Fts34 and Ftk16 as their vertex landraces respectively, and these sectors were devoid of representative test environments. All the landraces in these three sectors apart from Ftn43 and Fte41 had below average yield performance with respect to the four tested environments.

3.5. Test environment evaluation

The purpose of test-environment evaluation is to identify test environments that effectively identify superior genotypes for a mega-environment. An "ideal" test environment should be both discriminating of the genotypes and representative of the mega-environment (Yan et al., 2007). The environment-vector view of the GGE biplot (Fig. 7) presents a summary of the interrelationships among the environments. The test environments are connected to the biplot origin by lines, called environment vectors. The angle between the vectors of two environments is related to the correlation coefficient between them. The cosine of the angle between the vectors of two locations approximates the correlation between them (Yan, 2002). Acute angles indicate a positive correlation, obtuse angles a negative correlation and right angles no correlation. A short vector may indicate that the test environment is not related to other environments (Yan, 2002). Based on the angle between the environmental vectors, Akure 2012 and Akure 2013 had an acute angle and were positively correlated, likewise Abeokuta 2012 and Abeokuta 2013. The large angles between the two locations were consistent in both years. Akure 2013 and Abeokuta 2012 were not correlated because a right angle was observed between them. The distance between two environments represents their dissimilarity in discriminating the genotypes. Thus, the four environments fell into two different groups which correspond to their geographical locations. According to Fig. 7, effects of year were not pronounced in grouping the environments. The little variation noticed in Abeokuta and relatively large variation in Akure in the performance of the landraces across the two years may be attributed to rainfall fluctuation. Therefore, within year similarity and between year differences in crop performance indicated that meteorological information might be useful in the classification of genotypes by trial interaction (Van Euwijk and Elgersma, 1993). Fig. 8 displays the discriminating power and representativeness of the test environments. The concentric circles on the biplot help to visualize the length of the environment vectors, which is proportional to the standard deviation within the respective environments and is a measure of the discriminating ability of the environments (Yan and Tinker, 2006). The longer the environment vectors length the more the discrimination. Thus, among the four environments, Akure 2013 was most discriminating and Abeokuta 2013 was least discriminating. In both years Akure had longer environment vectors length than Abeokuta. The second most important aspect of test environment evaluation is its representativeness of the mega-environment. It is visualized by the angle between the environment vector and abscissa of average environment axis. The smaller the angle, the more representative the test environment would be. Akure 2012 had small angles with the abscissa of average environment axis. Hence, Akure 2012 was most representative for fluted pumpkin marketable leaf yield whereas Abeokuta 2012 was least representative. Fig. 9 showed the discrimination and representativeness view of the GGE biplot to rank test environments relative to an ideal test environment (represented by centre of the concentric circles). It is a point on the AEA in the positive direction ("most representative") with a distance to the biplot origin equal to the longest vector of all environments ("most informative") (Yan and Tinker, 2006). Akure 2012 is closest to this point and is, therefore, best, whereas Abeokuta 2012 was poorest for selecting cultivars adapted to the whole region. In 2013 Akure (2013) was also closer to the ideal environment than Abeokuta (2013). Out of the four environments Akure 2013 was most discriminating and Akure 2012 was most representative for fluted pumpkin

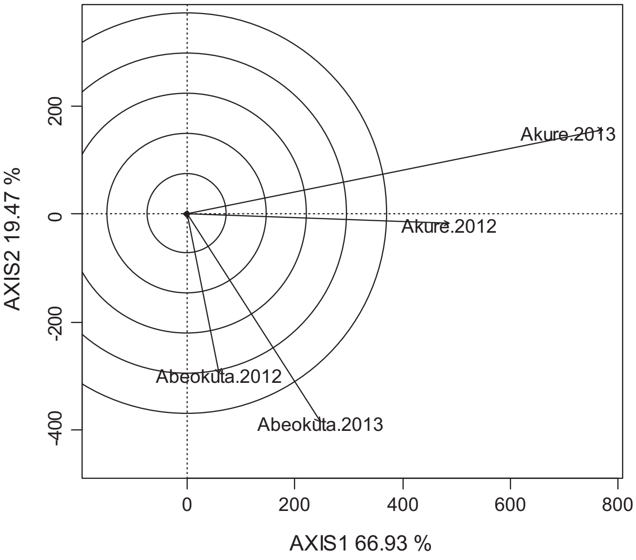

Figure 7 The environment-vector view of the GGE biplot to show similarities among test environments in discriminating the landraces.

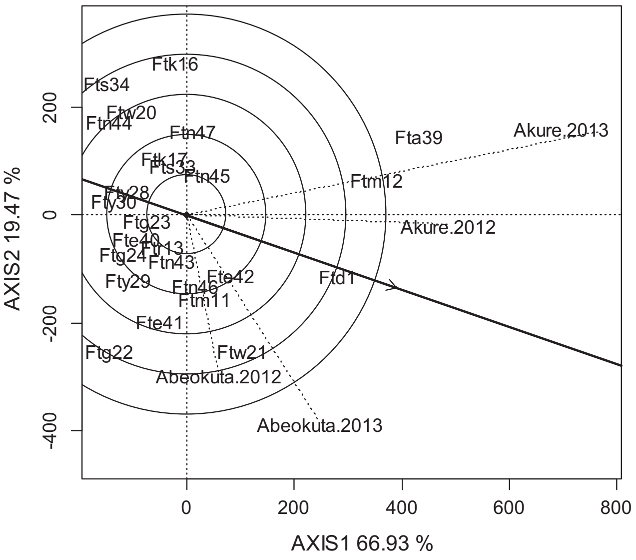

Figure 8 The discrimination and representativeness view of the GGE biplot to show the discriminating ability and representativeness of the test environments.

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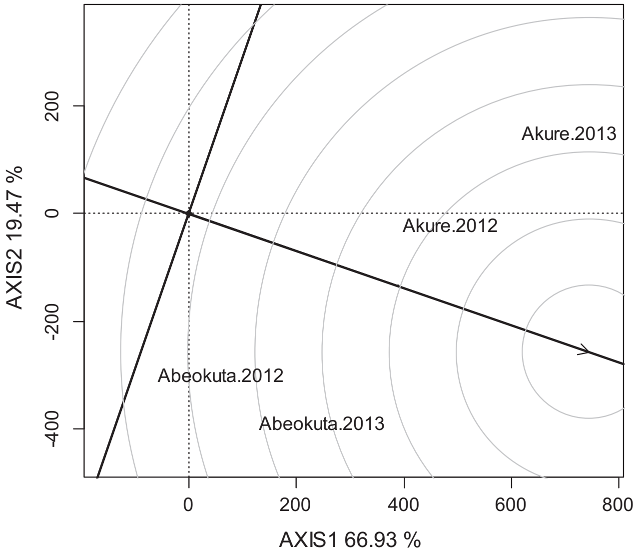

Figure 9 The discrimination and representativeness view of the GGE biplot to rank test environments relative to an ideal test environment.

marketable leaf yield. Removing Abeokuta environments from the test environments will not lead to any loss of information but will help to reduce unnecessary cost on genotype evaluation (Yan and Kang, 2003). Therefore, Akure as a location should be given more consideration in the evaluation of fluted pumpkin than Abeokuta. Akure emerging as a better test environment may be attributed to the fact that Akure shares the same agro-ecological zone with the believed centre of origin (Imo State) of this crop (Akoroda, 1990; Odiaka et al., 2008).

In conclusion, the analysed twenty-five landraces of fluted pumpkin showed high variability for marketable leaf yield. The four environments used for this study could be considered as two mega-environments for fluted pumpkin testing. Landrace Fta39 had the highest average yield and the most unstable. Landraces Fts34, Ftn44 and Ftk20 were most stable but Ftd1 and Ftw21 were more desirable. Landraces Fta39 and Ftw21 were high yielding and are adapted to Akure and Abeokuta respectively. These landraces should be recommended for growing in these specific locations. This study identified Akure and Abeokuta as two distinct mega-locations for fluted pumpkin genotype evaluation and recommendation. However, Akure is a better location for the evaluation of fluted pumpkin for marketable leaf yield.

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