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Assessment of biomass stability performance in African pear fruit (*Dacryodes edulis* (G.Don) H.J. Lam) accessions.

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ABSTRACT

Stability performance among *Dacryodes edulis* accessions is important in its improvement programme. This study was therefore carried out to assess the biomass stability performance in African pear fruit (*Dacryodes edulis* (G.Don) H.J. Lam) accessions in a Completely Randomized Design in 5 replications. Data collected on leaf production, leaf length, leaf breadth, leaf length/breadth ratio, internode distances, collar diameter and biomass assessment were subjected to Additive Main Effects and Multiplicative Interaction (AMMI) Analysis of Variance and Genotype main effect plus the Genotype-by-Environment interaction (GGE). Over 88% of the total sum of square was attributed to treatment main effects, further partitioning of the treatment indicated that genotypes effects accounted for 82.54%, environments 3.12% and interaction 14.37%. GGE biplot revealed that genotype FOR30 (G30) had the largest negative interaction (-10.0) with the environment while the genotype FOR6 (6) had the largest positive interaction (14) with the environments. Genotype FOR13 (G13) followed by FOR21 (G21) and FOR14 (G14) were most stable in high yielding environment due to their relative high PCA1 value and PCA2 value close to zero. AMMI revealed genotypes FOR13, FOR14, FOR4 and FOR21 as the genotypes that reacted less with the environments because their average environmental axis (AEA) values were near zero and are therefore considered to be the stable genotypes. Both AMMI and GGE biplot revealed that genotypes FOR13, FOR14 and FOR21 could be selected for biomass production in *Dacryodes edulis.*

Keywords: Biomass assessment, stability, *Dacryodes edulis*, AMMI, ideal genotype**.**

Introduction

Tree improvement for higher fruit yield and better wood quality requires better understanding of stability performance for some major agro-morphological components. The final fruit yield of a given plant species depends on the interactions between the genotypes, its responses to environmental conditions and management practices (Nassir and Ariyo, 2011) and given the same management, the interactions between the genotypes and environmental conditions are the sole determinant of species performance (Ojo, 2000).

Breeding programme is often limited by the presence of genotype with environment (G×E) interactions. Breeders have to evaluate planting materials in various locations in order to test stability of genotypes over a range of environments (Dagnachew *et al.*, 2014).

According to Domitruk *et al.*, (2001), to obtain useful information for stability of performance, genotypes must be grown in various localities. Assessing a genotype's suitability for a given location is based on its stability at the location. There are genotypes that are less influenced by the environment,

and there are others whose performance is directly related to the state of the environment.

Fehr (1987) stated that yield stability of a plant is influenced by the genotype of individual plants and the genetic relationship between plants.

Dixon *et al.* (1994) defined G × E interaction as the change in a cultivar's relative performance over environments, which results from differential response of the cultivar, to various edaphic, climatic and biotic factors. Genotype by environment is a phenomenon that is very important and is of significance to plant breeders, agronomist and farmers. Propagating materials can be selected and evaluated based on their different responses to the environments. The G × E interaction poses a serious problem in breeding programmes because it can affect any stage of the program and can also play a role in the expression of quantitative traits such as yield (Ojo, 2000).

G × E interaction is very useful to breeders because this can limit the progress in the selection process and since it is a basic cause of differences between genotypes for yield stability, knowledge of this will help in selecting varieties with the best adaptation and that can give stable yields. Cultivars with low G × E interaction and high stable yields are desirable for breeders and farmers, because this is an indication that the environment has less effect on them and their higher yielding abilities are largely due to their genetic composition.

In the last few years, agroforestry plant species have been fully recognized to contribute to both biodiversity conservation and livelihood development and this has led to greater interest in understanding the genetic variations and stability of trees within the ecosystem (Munjuga *et al*., 2008; Leakey, 2010).

African pear fruit is an agroforestry plant species belonging to the Buseraceae family. It is one of the most important edible fruit trees indigenous to the gulf of Guinea and Central African regions. Despite being an indigenous fruit tree that is undergoing domestication, it has attracted international trade (Awono *et al*., 2002; Ajibesin, 2011).

Attempts to improve *D. edulis* for increase fruit and wood are still in its infancy and there are little information on its biomass stability performance. This research work will be useful in providing knowledge with the view to identifying stable genotypes in terms of biomass accumulation for use in developing improved varieties of *D. edulis.*

Materials and Methods

Sources of planting materials

Seeds of *Dacryodes edulis* were collected from Phenotypically superior mother trees and placed in plastic bags, labeled and kept in room temperature for use. Georeference, that is, information (longitude and latitude) of sources of collection as well as some morphological information were taken and recorded as follows in table 1 below

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Table 1: List of 30 accessions used in the study and their sources of collection.

Genotypes	Accessions Codes	Source	Latitude (^{0})	Longitude (^{0})
G1	FOR1	Jericho, Oyo State	3.86	7.67
G2	FOR2	Agbofieti, Oyo State	3.86	7.67
G3	FOR3	Ofosu, Ondo State	5.14	6.75
G4	FOR4	Ore, Ondo State	4.88	6.75
G5	FOR5	Akoko, Ondo State	5.42	7.36
G6	FOR6	Okpanam,Delta state	6.24	6.65
G7	FOR7	Ibusa, Delta State	5.78	6.55
G8	FOR8	Asaba, Delta State	6.20	6.73
G9	FOR9	Umunede, Delta state	6.27	6.31
G10	FOR10	Iseleukwu, Delta State	6.22	6.48
G11	FOR11	Okogbo, Edo State	5.88	6.20
G12	FOR12	Iguere, Edo State	6.24	6.66
G13	FOR13	Iduonmiwina, Edo State	5.90	6.18
G14	FOR14	Igbekhue, Edo State	5.90	6.15
G15	FOR15	ObozogbeniroEdo State	5.30	6.15
G16	FOR16	Ugbokoniro, Edo State	5.96	6.14
G17	FOR17	Ubokonumagba, Edo State	6.56	6.58
G18	FOR18	Ugbougo, Edo State	6.00	6.13
G19	FOR19	Evbousa, Edo State	5.62	6.15
G20	FOR20	Aideyanoba Edo State	5.92	6.11
G21	FOR21	Idu, Edo state	6.22	6.81
G22	FOR22	Iguemokhia, Edo State	5.83	6.14
G23	FOR23	Ugo Edo State	6.00	6.09
G24	FOR24	Evbousa, Edo State	5.62	6.15
G25	FOR25	Avbugo, Edo State	5.82	6.20
G26	FOR26	Evbowe, Edo State	6.06	6.14
G27	FOR27	Ona, Edo State	5.64	6.20
G28	FOR28	Ekobi, Edo State	6.46	6.63
G29	FOR29	Urhonigbe, Edo State	6.51	6.58
G30	FOR30	Sakpoba,Edo State	5.64	6.20

Experimental site

The experiments were conducted in four locations in Nigeria.

Location 1: Federal University of Agriculture Abeokuta (FUNAAB), Ogun state. (7^o 15'N; 3^o 25'E; 159 m above sea level),

Location 2: Moist forest Research Station, Benin City, Edo State (6° 20'N; 5° 38'E; 86m above sea level). Location 3: Forestry Research Institute of Nigeria (FRIN), Ibadan, Oyo State. (7° 16'N; 3° 47'E; 255m above sea level).

Location 4: Rainforest Research Station, Ore, Ondo State. (6° 44'N; 4° 52'E; 87m above sea level.

Experimental set-up and plant management.

Seeds were sown in 17cm by 20 cm diameter depth in the propagating pots that were arranged in a completely randomized design (CRD) with five replications. The soils were well drained, with an average pH value close to 7.0 in all the experimental locations. The cultural operations carried out were manual weeding and adequate watering to maintain soil moisture

Data collection

Number of leaves per plant: This was done by counting the number of leaves
Plant height (cm): The heights of the seedlings was taken from the soil surface to the tip of the main stem with the aid of a meter rule.
Collar diameter (mm): collar diameter of the seedlings was measured using digital venier caliper.
Leaf length (cm): This was measured from the stalk to the apex of the leaf using meter rule.
Leaf breadth (cm): This was measured at the middle of the leaf using ruler
Leaf length/ breadth ratio : This was determined as the ratio of the leaf length to breadth
Fresh weights (g): The plants at removed, separated into root stem and leaves and their various weight are taken immediately.
Dry weights (g): The separated plants parts are placed in the oven and weigh at constant temperature of 70°C until a constant weight is attained after 72 hours.
Biomass accumulation (g): the total biomass accumulated are measured as total dried parts of the plant (aerial and root).
All post-harvest data were collected first at six weeks and then subsequently at two weeks interval for nine months.

Data analyses

AMMI analysis of variance (Gauch and Zobel, 1996) and GGE biplot (Yan and Kang, 2003) were used to analyze the data collected and results were presented in figures and tables.

Results

The AMMI Analysis of variance for 30 genotypes of *Dacryodes edulis* tested in four environments is presented in Table 2. Over 88% of the total sum of square was attributed to treatment effect. 82.52% of the total treatment effect was attributed to genetic effect, 3.12% to environmental effects while genotype × environment (G×E) effect was 14.37%. The GE interaction effects partitioned into three interaction principal component analysis axes is more than five times the Mean square of the error. The interaction principal component axis (IPCA1) captures 64.26 % of the interaction sum of square. Similarly, the second and third interaction principal component axes (IPCA 2 and IPCA3) recorded 25.10% and 10.64% of the GEI sum of square.

Mean biomass accumulation and the value of first PCA scores from AMMI analysis for 30 genotypes of *Dacryodes edulis* studied in four environments are presented in Table 3. Genotype mean yield ranged from 3.521 to 11.595 for genotype FOR10 and genotype FOR20 respectively. The GIPCA-1 values ranges from 0.001 for genotype FOR25 to 1.110 for genotype FOR17.

Table 2: AMMI Analysis of variance for 30 genotypes of *Dacryodes edulis* tested in four environments

Source	Df	SS	MS	% Total SS	%TRT	%G x E
Total	599	3931	6.56			
Treatments	119	3465	29.12**	88.41		
Genotypes	29	2860	98.61**		82.54	
Environments	3	108	35.88**		3.12	
Interactions	87	498	5.72**		14.37	
IPCA1	31	320	10.31**			64.26
IPCA2	29	126	4.34**			25.10
IPCA3	27	53	1.95			10.64
Error	464	454	0.98	11.54		

**** significant @p≤0.05**

Genotypes FOR 20, FOR29, FOR28, FOR21 and FOR27 among others performed well in Abeokuta as well as Ore. FOR16, FOR12, FOR19, FO R13, FOR 25, FOR 15 and FOR 6 were good genotypes for Benin and Ibadan

AMMI model for biomass production (g/plt) showing the mean of genotypes (G) and Environment (E) against Component 1 and 2 was presented in Figure 1. Eleven genotypes fell into the high biomass production quadrants while 19 genotypes were low production. AMMI identified G13 as the highest biomass producing genotype followed by G21 and G22. The poorest genotype in terms of biomass production was G30. The four environments fell into two quadrants. Environment 2 (Benin) and Environment 3 (Ibadan) as the high yielding environments while Environment 1 (Abeokuta) and Environment 4 (Ore) as the poorest yielding environment.

Table 3: Means and the first PCA scores from AMMI analysis of Biomass accumulation for 30 *Dacryodes edulis* genotypes studied in four environments

Genotypes	Envt 1 (Abeokuta)	Envt 2 (Benin)	Envt 3 (Ibadan)	Envit 4 (Ore)	Mean	GIPCA-1

FOR20	**12.279**	11.423	10.8	11.877	**11.595**	-0.586
FOR29	11.751	9.322	11.262	**11.999**	11.084	-0.911
FOR28	11.069	10.526	9.886	10.69	10.543	-0.483
FOR21	9.965	9.343	10.00	9.98	9.822	-0.409
FOR27	9.789	7.338	7.402	9.456	8.496	-1.063
FOR16	9.754	**11.799**	9.913	9.224	10.173	0.282
FOR5	9.628	9.027	9.015	9.438	9.277	-0.454
FOR23	8.884	7.782	9.145	9.073	8.721	-0.514
FOR14	8.294	9.106	13.204	9.5	10.026	0.334
FOR26	8.21	8.055	9.731	8.582	8.645	-0.175
FOR30	7.456	6.329	7.972	7.729	7.372	-0.501
FOR24	6.192	5.434	**4.832**	5.806	5.566	-0.55
FOR1	6.129	6.29	6.492	6.074	6.246	-0.184
FOR12	6.084	7.616	6.339	5.695	6.434	0.158
FOR19	6.074	7.208	7.496	6.132	6.727	0.147
FOR22	5.721	5.223	6.991	6.089	6.006	-0.281
FOR2	5.646	5.915	6.343	5.67	5.893	-0.130
FOR13	5.573	6.788	8.049	5.94	6.588	0.249
FOR25	5.474	6.291	6.059	5.344	5.792	0.001
FOR4	4.895	5.109	5.064	4.768	4.959	-0.185
FOR15	4.767	7.56	7.2	4.775	6.076	0.649
FOR6	4.661	4.661	6.318	4.79	5.108	0.168
FOR11	4.446	4.446	5.062	3.92	4.469	0.478
FOR8	4.294	4.294	7.376	4.6	5.141	0.586
FOR18	4.188	4.188	6.646	4.227	4.812	0.625
FOR3	4.111	4.111	6.249	4.497	4.742	0.079
FOR17	3.515	3.515	6.987	3.518	4.384	1.110
FOR7	3.343	3.343	4.915	3.178	3.695	0.473
FOR9	3.034	3.034	4.999	3.29	3.589	0.154
FOR10	**2.948**	2.948	5.45	**2.738**	**3.521**	0.935
Environment	**-1. 425**	**1.745**	**1.037**	**-1.358**		

;

In Figure 2, GGE biplot for biomass yield (g/plt) showing the mean of genotypes (G) and Environment (E) against Component 1 and 2. By plotting both genotype and environment on the same graph, the association between them became more

obvious. Genotype FOR30 (G30) had the largest negative interaction (-10.0) with the environment while the genotype FOR6 (6) had the largest positive interaction (14) with the environments. From the graph, genotype FOR13 (G13) followed by FOR21 (G21) and FOR14 (G14) were most stable in high producing environment due to their relative high PCA1 value and PCA2 value close to zero. While looking at the environments, the entire environment falls into the high yielding environment (Quadrant II and IV) and the angle between them was less than 90^0 which indicates that any of the environment can be chosen for planting of the *D. edulis*.

Table 4 shows the list of the first four AMMI selections per environment for Biomass production. Genotype FOR16 were the overall best in Benin (Environment 2), followed by genotypes FOR20, FOR28 and FOR21. Genotype FOR14, FOR29 and FOR20 were the overall best each for Ibadan, Ore and Abeokuta respectively. The winning environment according to the AMMI is Benin while the least performing environment with respect to biomass yield is Abeokuta (environment 1)

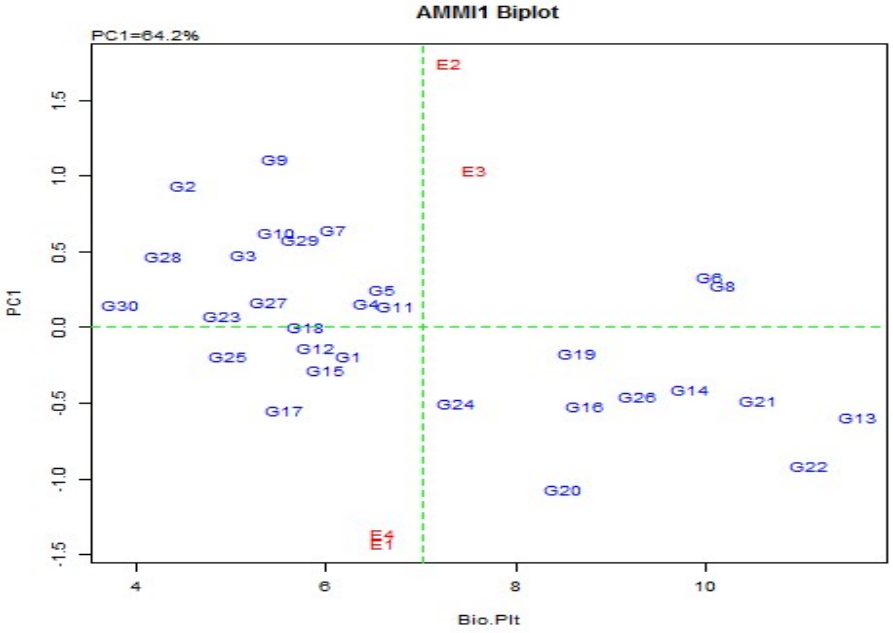

Figure 1: AMMI model for biomass production (g/plt) showing the mean of genotypes (G) and Environment (E) against Components 1 and 2.

G1=FOR1 G2 =FOR2 G3 FOR3 G4= FOR4 G5= FOR5 G5 =FOR5 G6 = FOR6 G7= FOR7 G8= FOR8 G9 = FOR9 G10 = FOR10 G11 = FOR11 G12 = FOR12 G13 = FOR13 G14 = FOR14 G15 = FOR15 G16 = FOR16 G17 = FOR17 G18 = FOR18 G19 = FOR19 G20 =FOR20 G21 = FOR21 G22 = FOR22 G23= FOR23 G24 = FOR24 G25 = FOR25 G26= FOR26 G27 = FOR27 G28 = FOR28 G29= FOR29 G30 = FOR30

E1 = Abeokuta E2= Benin E3=Ibadan E4= Ore

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www.jfrm.org.ng

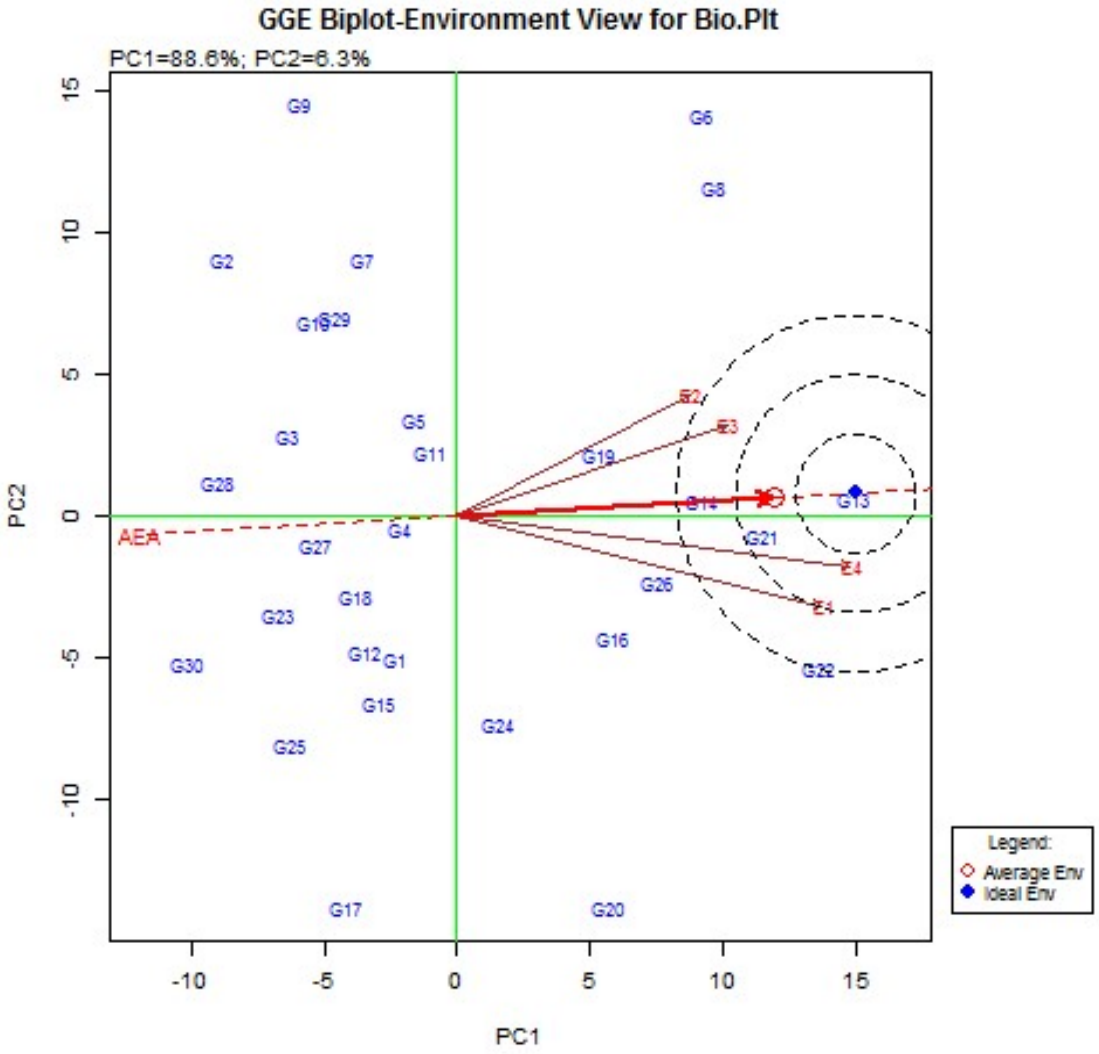

Figure 2: GGE biplot for biomass production (g/plt) showing the mean of genotypes (G) and Environment (E) against Components 1 and 2.

G1=FOR1 G2 =FOR2 G3 FOR3 G4= FOR4 G5= FOR5 G5 =FOR5 G6 = FOR6 G7= FOR7 G8= FOR8 G9 = FOR9 G10 = FOR10 G11 = FOR11 G12 = FOR12 G13 = FOR13 G14 = FOR14 G15 = FOR15 G16 = FOR16 G17 = FOR17 G18 = FOR18 G19 = FOR19 G20 =FOR20 G21 = FOR21 G22 = FOR22 G23= FOR23 G24 = FOR24 G25 = FOR25 G26= FOR26 G27 = FOR27 G28 = FOR28 G29= FOR29 G30 = FOR30

E1 = Abeokuta E2= Benin E3=Ibadan E4= Ore

Table 4: List of first four AMMI selections per environment for biomass yield

Number	Environment	Mean	Score	1	2	3	4
2	Benin	7.803	1.745	FOR16	FOR20	FOR28	FOR21
3	Ibadan	7.573	1.037	FOR14	FOR29	FOR20	FOR21
4	Ore	6.620	-1.358	FOR29	FOR20	FOR28	FOR21
1	Abeokuta	6.606	-1.425	FOR20	FOR29	FOR28	FOR21

Discussion

The stability of performance of the thirty accessions across the four locations as measured by biomass accumulation and investigated by AMMI (Gauch and Zobel, 1996) provided some proof as to the location effects and its interactions with the genotype on biomass production (Ayaz *et al*., 2001). The advantage of using AMMI is that it offers a remarkably cost effective strategy for increasing the accuracy of yield estimates and can assist plant breeders to investigate the GxE interactions (Gauch and Zobel, 1996).

The AMMI model also explains the structural variation in the G×E interaction. The main effect treatments were partitioned into genotype (G), environment (E) and G×E interaction. The high percentage (88.41%) contribution to the sum of square showed that the locations represented a contrasting environment for G×E analysis in *Dacryodes edulis* and the genotypes reacted indifferently to the environments. Fox *et al.* (2010) and Gauch (1992) noted that the usefulness of AMMI in superior genotypes selection even in multi locational trial and as such, successful selection of genotypes with yield and structural display of the relationship between such genotypes and the given environment is enhanced using AMMI biplot (Cooper *et al*., 1996; Crossa *et al*., 1991). However the best cultivar should be high yielding and stable across environments (Samonte *et al.,* 2005), that is, an ideal genotype should have the highest mean performance and be absolutely stable (Yan and Kang, 2003). Such an ideal genotype is defined by having the greatest vector length of the high-yielding genotypes and with zero GE (or highest stability). AMMI revealed that genotypes FOR13, FOR14, FOR4 and FOR21 as the genotypes that reacted less with the environments because their AEA values were near zero, they are also high yielding with the exception of genotype FOR4 which had below average yield. These genotypes could be recommended for planting in any of the environments. The genotypes with high environmental interaction are very dynamic, unstable and responsive to changes in the environments. Any genotype that has large interaction with the environment cannot be predicted in performance, thus they can be cultivated in limited environments.

Environmental conditions such as soil and climatic conditions play a critical role in plant production. They have the ability to influence the reproductive development of a particular genotype either to boost the production or retard its development. There are various degrees in which these factors affect the plant and it also depends on the genetic makeup of the plant (Ojo, 2000). Poor yield or crop failure may be as a result of biotic and abiotic stresses and this may lead to lack of stability of particular genotypes (Trethowan and Kazi, 2008). These factors vary from location to location

and from year to year in the same location and account for the stability of that environment and adapted genotypes. The source of variation accounted for environment was 3.12%, this further buttressed that *Dacryodes edulis* tolerate a wide variability of climate and soil type (Omonhinmin and Idu, 2012). However, Environment 2 (Benin), the winning environment according to the AMMI had the least interaction effect which is the most stable environment thus may be appropriate ecology for *Dacryodes edulis* in this part of the country and this further explains why the plants are mostly found there.

Conclusion

The AMMI model analysis provides estimate of the magnitude of significance of the effect of GEI and its interaction principal component relative to G and E effects. The genotypes that were stable over the environments in terms of biomass accumulation and still performed very well on the average can be selected for planting in any of the environments. Genotypes FOR13 (G13) and FOR21 (G21) were identified as the most ideal genotypes followed by genotypes FOR14, FOR26, FOR19, FOR19 and FOR22. AMMI selected environment 2 (Benin) based on its low IPCA2 values and high IPCA1 values as the ideal environment for the planting of *D. edulis.*

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