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Research Article

Yield Assessment and Stability Analysis of Some *Lowland Rice* Genotypes in Nigeria

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Abstract
Improved genotypes can contribute immensely to productivity of high yielding varieties when they are released mainly in the ideal and adapted environments. To enhance adoption and sustainable production of new improved lowland rice genotypes in Nigeria, yield evaluation, analysis of stability models on seven (7) lowland rice genotypes (ARS 161-3-5-5-3-B-BD, ARS 563-14-B-ED, ARS 150-TGR-10-NCRIB-12, ART 64-26-1-1-B-B-ED, D 56-NCRI J-1-1, ART 90--46-1-1-B-B-ED and ART 739-2-6-B-BD) and two national checks (FARO 44 and FARO 57) in 2020 and 2021 for nine (9) environments were under taken. The design was randomized complete block having three replicates. AMMI and GGE Biplot analyses were adopted to identify stable and adaptable genotypes across the environments. The stability model indicated that genotypes genotypes ARS 563-14-B-ED, ARS 150-TGR-10-NCRIB-12, ART 90--46-1-1-B-B-ED and ART 739-2-6-B-BD recorded 70%, 21%, 9% and 24% of slopes less than 1 respectively, indicating that they are unresponsive to the environment after a combined two-years analysis. AMMI analysis partitioned the environment into 8 principal components, the variances at all the principal components recorded high but not significant difference at 5% probability except Principal Component 1. This therefore implies that principal component 1 has substantive variances that can be exploited. Principal Component PC1, PC2 and PC3 accounted for 99.70% of AMMI experimental variance and ARS 161-3-5-5-3-B-BD as measured by principal components suggested to be not only high yielding, more stable, but also more ideal in all the tested environments

Keywords: ***Yield, Rice, Stability, Environment, AMMI, Lowland, GGE***

Introduction

Rice is dominant staple food crop of Africans, accounting for about 70% of caloric intake in most communities and countries including inNigeria.The potential land area for rice production inNigeria is between 4.6millionand 4.9million ha representing the main production ecologies of rice in Nigeria which are rainfed lowland, rainfed upland, irrigated lowland, deep water and mangrove swamp as outlined by Nwilene *et al.* (2008). However, Lowlandrice accounts for50%of the total rice produced in Nigeria (Nwilene *et al.*, 2008).

Several authors are in agreement that the world is experiencing exponential rise in demand for crop production, resulting from three key forces of increased human population, meat and dairy consumption from growing affluence, and

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advanced biofuel consumption (1-5). Ray *et al*. 2013 also opined that rice yield trends over the decades are insufficient to double and sustain the current production in the near future due to varietal instability.

Development of new variety and identification of cultivars with wide adaption is paramount to plant breeders in most crop improvement programs (Bashir *et al*., 2016). Therefore, evaluation of new lines over large range of environments and ecologies is fundamental in identifying stable and adaptable genotype to each environment.
In breeding programmes, special focus on farmers preferred traits like stability are either lacking or very minimal. Some improved varieties fail to perform well in target production ecologies due to lack of detailed stability studies. Woyengo, (2011) did buttressed that this negligence has also resulted in several low adoption of released varieties. Therefore, new rice varieties should not only be released based on potential yield and reaction to stresses but also on the basis of stability and adaptation across ecologies.

Genotype stability and adaptability are definitive charactersand should be a priority in achieving food security in Nigeria and Sub-Saharan Africa at large (Muzari*et al*., 2012; Lobell, 2009). Stability of performance of quantitative traits is influenced by genotype, environment and genotype by environment interaction (GEI) effects.

The performance of genotypes exhibits a wide range of variation within and between environments due to genotype × environment (G x E) interaction which refers to the differential response of the genotypes to different environmental conditions which affects the selection of cultivars with wider adaptability (Banik*et al*., 2021)

Studies show that stability of performance are expected to become more relevant issues as greater emphasis is placed on sustainability of agricultural systems (Kang *et al*., 2012). Many statistical procedures have been advocated to analysis for GEI, stability and adaptability of genotypes (Truberg and Huhn, 2000). AMMI model is one, it combines analysis of variance (ANOVA) and principal component analysis (PCA) on the sums of squares to G × E interaction. Also, Singh *et al.,* (2014) had proposed the GGE biplots, which permits the analysis of more genotypes and environments at a time. Isong, *et. al*. (2022) reported that these two procedures when employed can enable the identification of best performing, stable genotype, representative, idealand selective for each environment. While genotype x environmental interactions based on more than one genotype to different environmental responses, ranking of the genotypes according to Gauch, (2006) across environments is complementary to the identification of a genotype for an environment. The objective of this investigation therefore, was to evaluate for higher agronomic traits, Genotype by Environment Interaction effects and yield stability of 9 cultivated genotypes in 9selected lowland rice ecologies in Nigeria

Materials and Methods

The trials were established in nine (9) lowland ecologies located across 7 different states in Nigeria as presented in Table 1. Seven (7) lowland rice genotypes (ARS 161-3-5-5-3-B-BD, ARS 563-14-B-ED, ARS 150-TGR-10-NCRIB-12, ART 64-26-1-1-B-B-ED, D 56-NCRI J-1-1, ART 90--46-1-1-B-B-ED and ART 739-2-6-B-BD) and two local checks (FARO 44 and FARO 57) were evaluated in 2020 and 2021 growing seasons. The design of the experiment was Randomized Complete Block with 3 replications. The distance of 20cm within and between rows on plots 3m x 4m was adopted, single seedling per stand was transplanted at 21 days after seeding at the 9 locations. Weeding was done in three phases, hand weeding, in combination of two herbicides treatments. NPK was basally applied and supplementary urea application was done in three splits. The fertilizer rate was 60N:30P:30K. Birds were well controlled by bird scarers, observations and data collection were made on days to 50% flowering, number of tillers per square meter, number of panicles per square meter, plant height (cm), panicle length (cm), days to maturity and grain yield (kg/ha). The observations were according to the standard evaluation systems by IRRI (1996). Means separation using Least Significant Difference (LSD) was performed after the Analysis of variance (ANOVA) showed significant differences amongst the means. A combined analysis of variance for the two years was carried out before AMMI and GGE Biplot analyses were used to identify stable and adapted genotypes to the environments. Statistical Tools for Agricultural Research (STAR, 2014) and Plant Breeding Tools (PBTools, 2013) packages were used for the data analysis.

Results and Discussion

Results in Table 2 show the yield performance and other agronomic traits of the 7 Lowland Rice Genotypes in 2020 and 2021, while the pooled mean of yield performance at 9 locations is presented in Table 3. The genotype ARS 161-3-5-5-3-B-BD recorded the highest number of days to 50% flowering, highest Number of tillers per square meter, highest number of panicles per square meter, longest panicle length (cm) and highest grain yield of 7165.95kg/ha, surpassing the two checks FARO 44 (5391.30kg/ha) and FARO 57 (4532.98kg/ha). However, the average grain yield of the population was 5466.49kg/ha. Significant differences at 5% probability level were also recorded for all the characters except plant height and panicle length according to the pooled means analysis in Table 2. The joint yield performance in Table 3 showed that ARS 161-3-5-5-3-B-BD also recorded the highest yield value (10194.78) at Edozhigi while FARO57 a check variety recorded the lowest yield at Badeggy lowland ecology. This yield results at Edozhigi appears to be an improvement from the yield result (2964.31kg/ha) reported by Mohammed *et. al*. (2022) on FARO 51.

Relying on an approach first outlined by Yates and Cochran (1938) and later exploited for plant breeding purposes by Finlay and Wilkinson (1963) that Interacting genotypes responsible for the Genotype x Environment interaction in the analysis of variance, slopes not equal to one is regarded as stable, those unresponsive to environments will have a low slope ($b < 1$) while, unstable or responsive genotypes are observed with steep slope ($b > 1$). Therefore, the genotypes ARS 161-3-5-5-3-B-BD, ART 64-26-1-1-B-B-ED, D 56-NCRI J-1-1, FARO 44 and FARO57 expressed various degree of percentages of slopes greater than 1 and are observed as having steep slope and unstable or responsive to the environment. Also, Fentaw*et al*. (2015) reporting on lowland rice in the present of genotype environment interaction showed higher percentage of slopes less than 1, however, genotypes ARS 563-14-B-ED, ARS 150-TGR-10-NCRIB-12, ART 90--46-1-1-B-B-ED and ART 739-2-6-B-BD recorded 70%, 21%, 9% and 24% of slops less than 1 respectively, indicating that they are unresponsive to the environment according to Yates and Cochran (1938)

The slope values in the stability model according to FINLAY-WILKINSON (1963) expressing the sensitivity of each genotype, the indication is that eight of the nine genotypes were positively significant at 1%probability, only FARO 44, a check variety though positive but not significant at 1% probability, confirming the description of Eberhart and Russell (1966) as less sensitivity less adaptable in the tested environments.

To test for significance of variances, AMMI was employed which partitioned the environment into 8 principal components. The genetic variances at all the principal components recorded high but not significance differences at 5% probability except at Principal Component 1 at were significance. The implication therefore is that principal component 1 has substantive variances according to Singh *et al*. (2014) and their effect on most of the genotypes will be positive. This buttresses the reports by Bose *et al.* (2014) when genotype, environment and their interactions was relied upon for selection of upland rice varieties.

Grain yield, according to AMMI bipot in the multiplicative model analysis shows that Principal Component PC1, PC2 and PC3 accounted for 99.70% of AMMI experimental variance when combining the sum of squares of the two cropping seasons. The which-won-where view of the GGE biplot in figure 1 presented genotype 1 as leading in the yield and most responsive within the sector and in all the environments as described by Mostafavi*et al*.

(2011). Genotype 2 was next to Genotype 1 leading in another sector, however in all the tested environment, genotype 1 was yet leading. Therefore, genotype 1 could be said to be superior in yield at all locations, and also more responsive in all the environments. Mean and stability of ARS 161-3-5-5-3-B-BD measured by principal components across environments signified that the genotype was not only more stable, but also more ideal in all the tested environments

Conclusion and Recommendations

Variability analyzed for the genotypes indicated that significant difference at 5% probability for yield and some other agronomic traits. Across the 9 locations, significant difference at 5% difference was also observed. The t –values expressing the sensitivity of each genotype indicated that eight of the nine genotypes were positively significant at 1%probability, only FARO 44. the genotypes ARS 161-3-5-5-3-B-BD, ART 64-26-1-1-B-B-ED, D 56-NCRI J-1-1, FARO 44 and FARO57 expressed various degree of percentages of slopes greater than 1 and are observed as having steep slope and unstable or responsive to the environment. The environments were partitioned by AMMI model into 8 principal components by in which variances at all the principal recorded high but not significant differences at 5% probability for 7 Principal Components. Principal Component PC1, PC2 and PC3 accounted for 99.70% of AMMI experimental variance and ARS 161-3-5-5-3-B-BD as measured by principal components suggested to be not only more stable, but also more ideal in all the tested environments

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Table 1: Geographic description and coordinates of the trial locations in the 2016 cropping season

S/No.	Location	Longitude	Latitude	State	Agro-Ecological zone
1	Warri	$005^0$46.922'	$05^0$3130'	Delta	Mangrove swamp forest
2	Wushishi	6.1113	9.7221	Niger	Southern Guinea Savanna
3	Olam	8.320915	7.9203988	Nazarawa	Derived Guinea Savanna
4	Akure	5.15979	7.27773	Ondo	Humid Rain Forest
5	Badeggi	6.143420	9.056826	Niger	Southern Guinea Savanna
6	Kebbi	$005^0$19.673'	$11^0$26.142'	Kebbi	Sudan Savanna
7	Numan	11.9009	9.5968	Adamawa	Southern Guinea Savanna
8	Abakaliki	8.1120	6.3231	Ebonyi	Derived Guinea Savanna
9	Edozhigi	06°07' E	09°45' N,	Niger	Southern Guinea Savanna

Table 2: Performance of yield and some traits of Lowland Rice Genotypes in 2020 and 2021

Genotypes	DFF	PH (cm)	PL (cm)	NTPMS	NPPMS	DM	GY (kg/ha)
ARS 161-3-5-5-3-B-BD	85.04	114.09	27.27	487.44	513.55	110.64	7165.95
ARS 563-14-B-ED	78.75	116.18	26.00	431.44	396.50	112.34	5666.8
ARS 150-TGR-10-NCRIB-12	78.38	114.45	25.49	404.76	399.00	103.34	5424.31
ART 64-26-1-1-B-B-ED	75.94	106.02	26.11	436.28	397.22	98.54	5419.8
D 56-NCRI J-1-1	76.79	116.26	25.94	404.11	404.11	108.54	4771.47
ART 90--46-1-1-B-B-ED	75.51	115.15	26.07	352.58	391.78	110.43	5059.84
ART 739-2-6-B-BD	79.58	119.64	25.53	403.39	398.22	104.67	5765.97
FARO 44	76.88	114.27	26.17	434.49	405.13	102.46	5391.30
FARO57	79.78	118.26	26.54	373.28	383.82	109.45	4532.98
Mean	**78.52**	**114.92**	**26.12**	**414.20**	**409.93**	**106.71**	**5466.49**
CV%	**4.80**	**7.25**	**4.98**	**15.75**	**6.94**	**2.87**	**14.07**
SE	**1.77**	**3.93**	**0.61**	**30.75**	**13.41**	**2.50**	**362.45**
LSD	**5.698**	**NS**	**NS**	**98.73**	**43.0481**	**8.89**	**1163.558**

DFF= Days to 50% flowering, NTPSM = Number of tillers per square meter, NPPSM = Number of panicles per square meter, PH = Plant height (cm), PL = Panicle Length (cm), DM = Days to maturity, GY = Grain yield (kg/ha)

Table 3. Joint Yield Performance of Lowland Rice Genotypes in 2020 and 2021

GENOTYPES	Wushishi	Olam	Akure	Badeggi	Kebbi	Numan	Abakiliki	Warri	Edozhigi
ARS 161-3-5-5-3-B-BD	5572.82	8989.13	6605.60	6526.55	5748.37	5811.32	7128.31	7916.73	10194.78
ARS 563-14-B-ED	6299.81	5250.01	5655.88	4963.94	5656.41	5645.66	5079.94	5918.10	6531.51
ARS 150-TGR-10-NCRIB-12	5776.87	5593.91	5614.35	4453.90	4919.27	5292.15	4889.67	6677.35	5601.36
ART 64-26-1-1-B-B-ED	6107.79	5672.56	4896.09	4411.48	4650.07	4893.35	4455.49	7702.53	5988.80
D 56-NCRI J-1-1	5046.09	4598.11	5931.90	3643.90	4749.60	3763.01	3980.57	6257.80	4972.27
ART 90--46-1-1-B-B-ED	5159.18	5360.43	5365.69	5333.86	4261.56	4594.64	3520.16	6535.59	5407.44
ART 739-2-6-B-BD	5555.76	7507.18	6860.21	5772.67	5286.85	5659.89	4890.30	5472.36	4888.52
FARO 44	5174.84	6901.29	5476.79	4033.55	4376.37	4302.89	4586.02	5846.90	7823.08
FARO57	4477.75	4953.17	3974.94	3253.46	4783.38	3978.66	4286.04	6211.92	4877.51
Means	**5463.43**	**6091.75**	**5597.94**	**4710.37**	**4936.87**	**4882.39**	**4757.39**	**6504.36**	**6253.92**
CV%	**14.82**	**23.33**	**16.70**	**25.27**	**6.35**	**9.15**	**14.28**	**10.13**	**1.89**
SE	**467.48**	**820.48**	**539.83**	**687.20**	**180.90**	**257.79**	**392.16**	**380.35**	**96.55**
LSD	**1531.95**	**2688.75**	**1769.06**	**2251.98**	**592.83**	**844.79**	**1285.12**	**1246.42**	**343.48**

Table 4. Stability model - FINLAY-WILKINSON

S/No.	Genotypes	Slope	SE	t.value	Prob	MSReg	MSDev
1	ARS 161-3-5-5-3-B-BD	1.41	0.18	7.65	0.122	2354428.50	40276.23
2	ARS 563-14-B-ED	0.30	0.19	1.57	0.160	103518.10	41984.92
3	ARS 150-TGR-10-NCRIB-12	0.79	0.05	17.31	0.127	744572.80	2484.39
4	ART 64-26-1-1-B-B-ED	1.05	0.22	4.87	0.182	1305623.60	55146.78
5	D 56-NCRI J-1-1	1.13	0.04	28.10	0.186	1505320.80	1906.46
6	ART 90--46-1-1-B-B-ED	0.81	0.04	18.74	0.306	780077.60	2220.96
7	ART 739-2-6-B-BD	0.76	0.05	14.51	0.176	691849.40	3286.52
8	FARO 44	1.42	0.24	5.89	0.205	2396414.10	69042.74
9	FARO57	1.33	0.31	4.32	0.349	2096753.70	112415.24

Table 5. Multiplicative Model - AMMI Analysis

	percent	acum	Df	Sum.Sq	Mean.Sq	F.value	Pr.F
PC1	60.50	60.50	15.00	6550412.83	436694.19	0.36	0.19
PC2	35.30	95.80	13.00	3823558.45	294119.88	0.24	1.00
PC3	2.20	98.00	11.00	239932.92	21812.08	0.02	1.00
PC4	1.00	99.00	9.00	112874.41	12541.60	0.01	1.00
PC5	0.40	99.40	7.00	47527.04	6789.58	0.01	1.00
PC6	0.30	99.70	5.00	33126.18	6625.24	0.01	1.00
PC7	0.20	99.90	3.00	20869.44	6956.48	0.01	1.00
PC8	0.00	99.90	1.00	409.54	409.54	0.00	1.00

Table 6. Multiplicative Model – GGE Analysis

	percent	acum	Df	Sum.Sq	Mean.Sq	F.value	Pr.F
PC1	93.50	93.50	15.00	1.25E+08	8332605.63	6.78	0.00
PC2	3.70	97.20	13.00	4.98E+06	382735.25	0.31	0.99
PC3	2.50	99.70	11.00	3.39E+06	308396.89	0.25	0.99
PC4	0.10	99.80	9.00	1.20E+05	13317.04	0.01	1.00
PC5	0.00	99.80	7.00	6.36E+04	9086.89	0.01	1.00
PC6	0.00	99.80	5.00	4.58E+04	9159.05	0.01	1.00
PC7	0.00	99.80	3.00	2.13E+04	7103.84	0.01	1.00
PC8	0.00	99.80	1.00	2.73E+03	2732.02	0.00	1.00

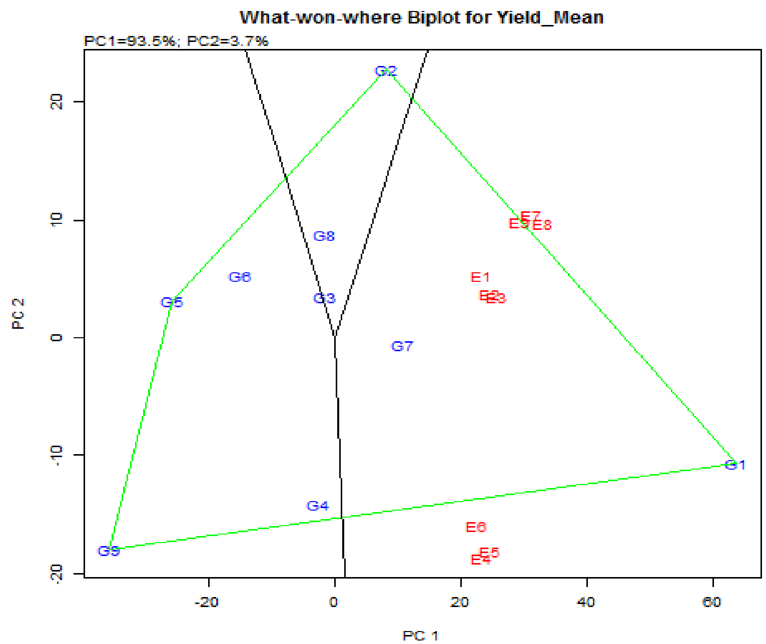

Figure 1: The which-won-where view of the GGE biplot showing which genotypes performed best in which environment

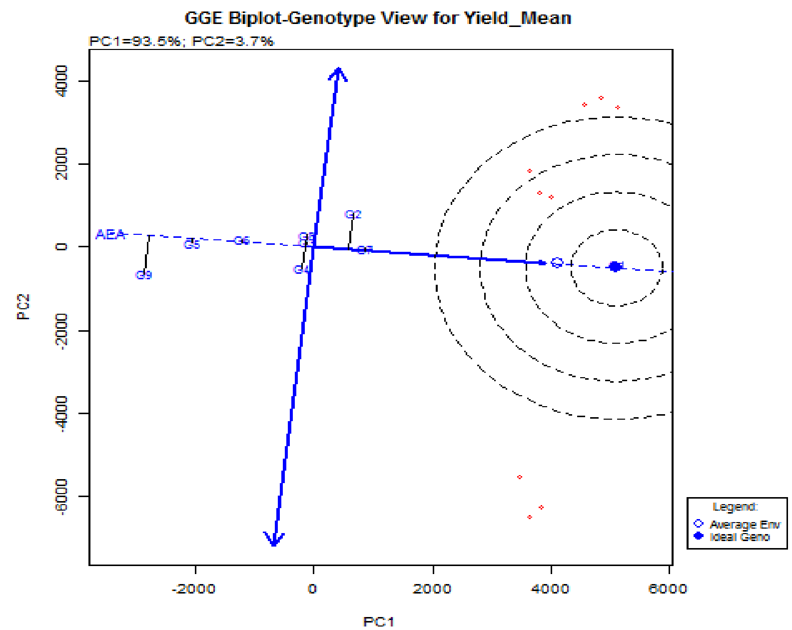

Figure 2: Mean performance and stability of ARS 161-3-5-5-3-B-BD and other Lowland Rice Genotypes in grain yield, measured by principal components across different environments

ENVIRONMENTS		GENOTYPES	
E1	Wushishi	**G1**	ARS 161-3-5-5-3-B-BD
E2	Olam	**G2**	ARS 563-14-B-ED
E3	Akure	**G3**	ARS 150-TGR-10-NCRIB-12
E4	Badeggi	**G4**	ART 64-26-1-1-B-B-ED
E5	Kebbi	**G5**	D 56-NCRI J-1-1
E6	Numa	**G6**	ART 90--46-1-1-B-B-ED
E7	Abakiliki	**G7**	ART 739-2-6-B-BD
E8	Warri	**G8**	FARO 44
E9	Edozhigi	**G9**	FARO67