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Evaluation of Yield Components and Genotype x Environment Interaction on Grain Yield of Submergence Lowland Rice Genotypes

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ABSTRACT

The study was to evaluate yield components for submergence tolerance rice lines using AMMI model analysis across 6 locations in Nigeria. The genetic materials used were Four O. sativa genotypes conferred with submergence gene. Three commercially released rice varieties (FARO 44, FARO 52 and NERICA L-19) and one local cultivar from each location of trial were inserted appropriately as checks. The trial was conducted in a Randomized Complete Block Design with 3 replications. Grain yield was analyzed using additive main effects and multiplicative interactions (AMMI). Result showed that ART 350:10-2-1-B-12-B and ART 351:12-2-B-5-B outperformed most of the check varieties in the agronomic parameters. Although, the genotypes showed no significant difference, the environmental effects were significantly different at 5% probability level. Principal components (PC) 1 and 2 also showed significant difference and contributed a total of 89.73% (59.35% and 30.38% respectively) of the total observable variation. The AMMI model deployed indicated that the largest proportion of the total variation in the rice grain yield for the genotypes studied under submergence condition was attributed to the environment. While Gwagwalada and Kaduna proved to be the best environments under study, the mean grain yield over environments indicated that ART 350:10-2-1-B-12-B and ART 351:12-2-B-5-B recorded the highest value of 3.9 and 3.8 tons/ha respectively.

Key words: *Rice, AMMI, Interaction, Stability, Yield components.*

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's seven billion people[9]. Rice is an increasingly important staple food crop in Nigeria, and play a critical role in contributing to national food security, income generation, poverty alleviation and socio-economic growth in Nigeria. As an essential food crop globally, it is grown in both temperate and tropical regions of the world. Rice is cultivated under diverse ecologies, including irrigated, rainfed upland, rainfed lowland to deep water ecology. Irrigated rice accounts for 55% of world area and about 75% of total rice production. Rainfed lowland represents about 25% of total rice area, accounting for 17% of world rice production while upland rice covers 13% of the world rice area and accounts for 4% of global rice production.

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Deepwater rice, although it has less area (90,000 km^2), provides food for 100 million people[13]. Rice, as many field crops is greatly influenced by seasonal and environmental fluctuations. Knowledge of Genotype x Environment (G x E) interaction and genotypic stability are of immense importance. Breeders prefer varieties that are distinguished with high yield, good grain quality and are capable of adapting to wide range of environments. Plant breeders are often in agreement when the importance of good phenotypic stability arises, however, they tend to proffer divergent views on the most appropriate definition of stability and a statistical measure of stability in yield trails[12]. Submergence is a common natural disaster that impairs rice production in many rice growing areas throughout the world. Africa is prone to flooding and this problem is becoming progressively more serious with climate change. Flooding of agricultural fields will result in crops being submerged. This can occur at any stage of crop development and in all rice production systems, including the irrigated lowlands at the seedling stage because of poor water management. In the flood plains, sudden floods can submerge the rice crop and water-logging can persist during the life cycle of the crop. In savanna and forest zones of West and Central Africa, inland valleys prevail and rice in valley bottoms may experience water-logging for several days after excessive rainfall. Water has slower rate of gaseous exchange, less capacity to hold gases such as oxygen and CO_2, and a higher extinction coefficient for light than air. In addition, flood water in African countries is usually turbid because it washes a lot of bare soil before percolation, severely limiting the penetration of light required for photosynthesis. Under complete submergence, photosynthesis and respiration of rice plants are suppressed, leading to low concentrations of carbohydrates, reduced growth and finally death of tissues[10]. Evaluation of genotypes over a range of environments will enable plant breeders to identify genotypes that are adapted to a particular environment and those that are stable over a range of environments. Because of the intensity of efforts required for developing new varieties, identification of genotypes with wide adaption is of utmost importance to plant breeders in most crop improvement programs[1]. The crop environment is referred as all factors outside of the genetic constituents of the genotype[4]. Given the importance of rice as a staple food and trying to meet the demand of rice as food for the ever increasing population, the objective of the study was to evaluate genotypes of *O. sativa* conferred with genes of submergence for yield and tolerance to submergence (stagnant flooding) in 6 locations across Nigeria.

MATERIAL AND METHODS

Field trials were conducted during the wet season of 2016. The study was conducted in six locations (Kaduna, Badeggi, Ebonyi, Enugu, Lafiagi and Gwagwalada) at various longitude and latitude within five agro ecological zones, across five states and the Federal capital territory of Nigeria. The trials were conducted in a Randomized complete block design with 3 replications. Each plot size was 5m x 2m. Four *O. sativa* genotypes (ART350:10-2-1-B-12-B, ART350:6-15-5-B-11-B, ART351: 12-2-B-3-B, ART351: 12-2-B-5-B) conferred with submergence gene were used for the experiment, 3 commercially released rice varieties (FARO44, FARO52 and NERICA L-19) and one local cultivar from each location of trial were inserted as checks making a total of 8 entries for the trial. Seedlings were transplanted at 21 days after sowing at the rate of two to three seedlings per hill in a spacing of 20cm x 20cm within and between rows. Water was maintained at 5cm deep before submergence. Basal fertilizer application (during transplanting) was 200kg/ha of complex 15-15-15 NPK. First (21 DAT) and second (42 DAT) topdressing at tillering and booting stages respectively was with 50kg/ha of Urea each. Data were collected for Plant height (PH), Days to 50% flowering (DFF), number of tillers per square meter (NT), number of panicles per square meter (NP) and grain yield (GY). Weed was controlled with Orizo Plus a formulation of propanil and 2-4-D at 4 liters per ha, with supplementary hand weeding. Analysis of variance and stability model for Genotype × environment interaction on rice grain yield was determined using AMMI (Additive Main effect and Multiplicative Interaction), GGE-biplot and Boxplot analysis as described by Finlay and Wilkinson[5]. Data analyzes was done by employing Breeding View in the Breeding Management System (BMS 3.0.9) software.

RESULTS AND DISCUSSION

Evaluation of yield components and Genotype x Environment interaction on grain yield of submergence lowland rice genotypes was conducted and the observations made were analyzed for mean performance of yield and its components, analysis of variance and stability parameters across locations. Table 1 indicates the Geographical description and coordinates of the trial locations, Mean performance under submergence condition is in Tables 2, 3 and 4. Analysis of variance and stability parameters are presented in Tables 5 and 6 respectively. Distribution pattern of grain yield, Environmental scaling and GGE biplot for best rice genotypes are also explained in figure 1, 2 and 3 respectively.

Number of panicles was not significantly different in Kaduna, Badeggi and Ebonyi. Number of panicles at 5% level probability showed significant difference at three locations (Enugu, Lafiagi and Gwagwalada). Genotypes ART351:12-2-B-5-B, ART 350:10-2-1-B-12-B and NERICA L-19 recorded the highest number of panicles (319) at Enugu (319), Lafiagi (295) and Gwagwalada (689) respectively. Amongst the test genotypes, ART 350:6-15-5-B-11-B recorded the highest (281) mean number of panicles across locations. There was significant difference for number of tillers in Gwagwalada at 5% probability level. There was significant difference at 5% level of probability for plant height across all the locations. ART 350:10-2-1-B-12-B and FARO 52 recorded the highest mean (114cm) for plant height. All the genotypes studied were medium to tall plants, this is in agreement with the findings of Joho[6]. Days to 50% flowering at Kaduna, Badeggi, Lafiagi and Gwagwalada showed significant difference. All the genotypes were early flowering (40 – 60) across the locations while ART 350:6-15-5-B-11-B flowered very late (66 days). Furthermore, there was significant difference for grain yield at 5% probability level in Kaduna, Badeggi, Lafiagi and Gwagwalada. In Kaduna, ART 350:10-2-1-B-12-B recorded the highest grain yield of 5.6tons/ha. Across the locations, ART 350:10-2-1-B-12-B and ART 351:12-2-B-5-B recorded the highest mean yield of 3.9 and 3.816 tons/ha respectively. Local check varieties across the locations had the lowest grain yield of 3.1 tons/ha. Finlay and Wilkinson regression analysis and ANOVA showed a high significant difference from location to location as indicated in Table 5. Genotypic sensitivity showing the changes in the environmental quality is indicated by the slope (b value) in Table 6. According to Eberhart and Russell[3], an ideal cultivar would have both a high average performance over a wide range of environments plus stability. The existence of genotype x environment interaction (GEI) raises the need to identify high yielding and stable genotypes. Values of b greater than 1 means the genotype have higher than average sensitivity (b=1), such genotypes are less stable. While values of b less than 1 means the genotype is less sensitive and more stable. It should therefore be noted that genotypes trying to survive the submergence condition should express sensitivity to the environment and also with substantial yield advantage over the check varieties. According to Table 5, ART 350:10-2-1-B-12-B gave the highest mean yield (3.9tons/ha) with a sensitivity value of above one (1.37) indicating its dynamic stability response to the different submergence environments. However, ART 351:12-2-B-5-B showed better dynamism in the different environments (1.19) though yielded lower (3.8tons/ha) than ART 350:10-2-1-B-12-B but the check varieties NERICA L-19, FARO 44, FARO 52 and LOCAL CHECK showed insensitivity with b values less than 1. They were stable but did not respond to the environments hence their yields (3.7, 3.2, 3.6 and 3.1kg/ha respectively) were less than that of test entries that responded to the flood. This is in agreement with the report of Maji *et al.*[7], he opined that an ideal genotype is the genotype with high performance combined with good stability at different environments. Box Plot displays samples in a statistical population without making any assumptions to the underlying statistical distribution,[8]. Figure 1 revealed that, Gwagwalada had the highest mean grain yield of 6.6tons/ha (Table 3) with large variance followed by Kaduna having mean yield of 5.6tons/ha. However, Enugu, Badeggi and Lafiagi performed almost the same across the environments while Ebonyi least performed across the six environments with respect to yield, this is reflected in the smaller variance. Przystalski *et al.*[11] reported that, the genetic variance tends to be larger in better environments than in poorer environments.

Generally, environmental scores showing AMMI biplots are joined to the origin by side lines. Sites with short vectors do not exert strong interactive forces, while those with long vectors exert strong interaction. Yan *et al*.[14] reported that, a short vector indicates location(s) in which there is a small range of genotype performance. In the AMMI 2 biplot (Figure 2), the environmental (locations) scores are joined to the origin by side lines. Sites (Lafiagi, Ebonyi, Enugu and Badeggi) with short vectors do not exert strong interactive forces, and those with long vectors exert strong interaction.

Figure 3 describes two mega environments. Kaduna, Lafiagi and Ebonyi are in one cluster while Enugu, Badeggi and Gwagwalada are grouped in another cluster having almost similar environmental quality. The partitioning of GGE through GGE biplot analysis of grain yield showed that, PC1 and PC2 explained 59.35% and 30.38% of GGE sum of squares respectively, explaining a total of 89.73% of the observed variation. GGE biplot shows that the cosine of the angle between two environment vectors is proportional to the correlation between those two environments having an angle of less than 90 degrees. The two clustered environments were not negatively correlated indicating that the genotypes performed almost the same across the two environments. The distance between Gwagwalada and Kaduna in the GGE biplot is related to the independence of the genotype performance close to those two environments, while the closeness of Enugu, Ebonyi, Badeggi and Lafiagi location signifies that genotype response pattern are similar in yield performance suggesting that one location should best be used for further yield evaluation.

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

Location	Longitude	Latitude	State	Agroecology
Kaduna South	7.368278	10.496589	Kaduna State	Northern Guinea Savannah
Onu Ebonyi	8.112012	6.323061	Ebonyi State	Humid Forest/Derived savannah
Badeggi	6.143420	9.056826	Niger State	Southern Guinea Savannah
Amaechi idodo	7.694096	6.457854	Enugu State	Rain Forest
Lafiagi	5.404427	8.852528	Kwara State	Southern Guinea Savannah
Gwagwalada	7.075395	8.951734	Abuja	Southern Guinea Savannah

Table 2: Mean performance of four rice genotypes and four checks under Submergence condition for number of panicle and number of tillers

Trt	Designation	Number of Panicles / M^2							Number of Tillers / M^2						
		Kaduna	Badeggi	Ebonyi	Enugu	Lafiagi	Gwagwalada	Mean	Kaduna	Badeggi	Ebonyi	Enugu	Lafiagi	Gwagwalada	Mean
1	ART350:10-2-1-B-12-B	365	258	316	318	295	493	271	238	215	243	239	254	438	341
2	ART350:6-15-5-B-11-B	304	270	307	295	261	432	281	228	232	230	249	226	519	312
3	ART351:12-2-B-3-B	307	255	330	291	269	496	263	238	217	237	226	203	460	325
4	ART351:12-2-B-5-B	366	258	297	319	249	556	263	253	217	219	263	206	419	341
5	FARO52 (check)	338	291	300	279	263	419	262	224	226	244	246	241	389	315
6	FARO44 (check)	329	269	333	242	240	350	239	228	247	234	204	218	305	294
7	NERICA L-19 (check)	305	264	282	268	244	689	297	221	226	214	236	205	676	342
8	LOCAL CHECK	295	245	290	272	240	271	212	224	209	227	222	213	175	269
	Lsd 0.05%	**NS**	**NS**	**NS**	**25.52**	**13.78**	**142.1**	**24.32**	**NS**	**NS**	**NS**	**NS**	**NS**	**153.0**	**26.72**
	CV %	**12.2**	**7.0**	**5.3**	**6.2**	**3.6**	**19.2**	**14.1**	**7.3**	**6.5**	**8.9**	**9.8**	**7.9**	**18.9**	**12.7**

Table 3: Mean performance of four rice genotypes and four checks under Submergence condition for Grain yield and Days to 50% flowering

Trt	Designation	Grain yield (tons/ha)							Days to 50% flowering						
		Kaduna	Badeggi	Ebonyi	Enugu	Lafiagi	Gwagwalada	Mean	Kaduna	Badeggi	Ebonyi	Enugu	Lafiagi	Gwagwalada	Mean
1	ART 350:10-2-1-B-12-B	5.6	2.4	2.6	3.3	3.4	6.6	3.9	72	53	60	62	75	67	65
2	ART 350:6-15-5-B-11-B	3.1	2.8	2.4	3.3	2.4	4.7	3.1	77	51	59	61	83	65	66
3	ART 351:12-2-B-3-B	4.9	2.7	2.3	3.4	2.7	5.7	3.6	68	49	59	59	72	62	61
4	ART 351:12-2-B-5-B	5.3	2.8	2.5	3.6	2.8	5.9	3.8	71	49	61	54	72	55	60
5	FARO 52 (check)	4.5	3.3	2.6	2.8	2.9	5.6	3.6	80	57	60	55	78	57	65
6	FARO 44 (check)	3.5	2.3	2.7	3.7	2.4	4.9	3.2	76	49	58	56	70	63	62
7	NERICA L-19 (check)	3.8	2.8	2.6	3.2	2.6	7.2	3.6	74	54	59	59	78	60	64
8	LOCAL CHECK	4.7	2.2	2.6	2.7	2.8	3.6	3.1	62	63	59	58	77	60	63
	Lsd 0.05%	**767.1**	**455**	**NS**	**NS**	**527.5**	**429.5**	**300.1**	**2.08**	**2.3**	**NS**	**NS**	**7.26**	**4.89**	**1.7**
	CV %	**9.9**	**9.8**	**9.3**	**12**	**11**	**14.8**	**12.9**	**1.6**	**2.4**	**3.2**	**6**	**5.5**	**4.6**	**4.2**

Table 4: Mean performance of four rice genotypes and four checks under Submergence condition for Plant height

Trt	Designation	Plant Height (cm)						
		Kaduna	Badeggi	Ebonyi	Enugu	Lafiagi	Gwagwalada	Mean
1	ART 350:10-2-1-B-12-B	113	103	108	121	119	119	114
2	ART 350:6-15-5-B-11-B	84	101	102	114	122	142	111
3	ART 351: 12-2-B-3-B	85	103	95	125	120	133	110
4	ART 351: 12-2-B-5-B	97	105	102	114	105	120	107
5	FARO 52 (check)	98	108	107	132	123	119	114
6	FARO 44 (check)	77	86	96	98	101	99	93
7	NERICA L-19 (check)	99	124	97	116	106	114	109
8	LOCAL CHECK	93	103	99	128	119	127	112
	Lsd 0.05%	**6.62**	**3.07**	**6.77**	**8.88**	**8.05**	**12.60**	**3.23**
	CV %	**4.1**	**1.7**	**3.8**	**4.3**	**4.0**	**5.9**	**4.5**

Table 5: Analysis of variance using Finlay and Wilkinson Regression Analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr
Genotypes	7	4692286	670327	1.90	0.0998
Environments	5	57852282	11570456	32.74	<0.001
Interactions	35	12369880	353425		
IPCA 1	11	6374883	579535	5.43	0.0016
IPCA 2	9	4393153	488128	4.57	0.0048
Residuals	15	1601844	106790		

Table 6: Stability parameters for grain yield across 6 locations under submergence condition

S/N	Genotype	Mean yield (tons/ha)	Sensitivity (b value)	Dynamic stability	Static stability	Mean square deviation
1	ART 350:6-15-5-B-11-B	3.1	0.6578	1188	749	178
2	ART 351: 12-2-B-3-B	3.6	1.1320	339	1904	62
3	ART 351: 12-2-B-5-B	3.8	1.1916	204	2133	98
4	ART 350:10-2-1-B-12-B	3.9	1.3744	116	2863	161
5	NERICA L-19	3.7	1.4009	359	3209	461
6	FARO 44	3.2	0.7649	985	1009	203
7	FARO 52	3.6	0.9392	359	1389	141
8	LOCAL CHECK	3.1	0.5438	1381	785	446

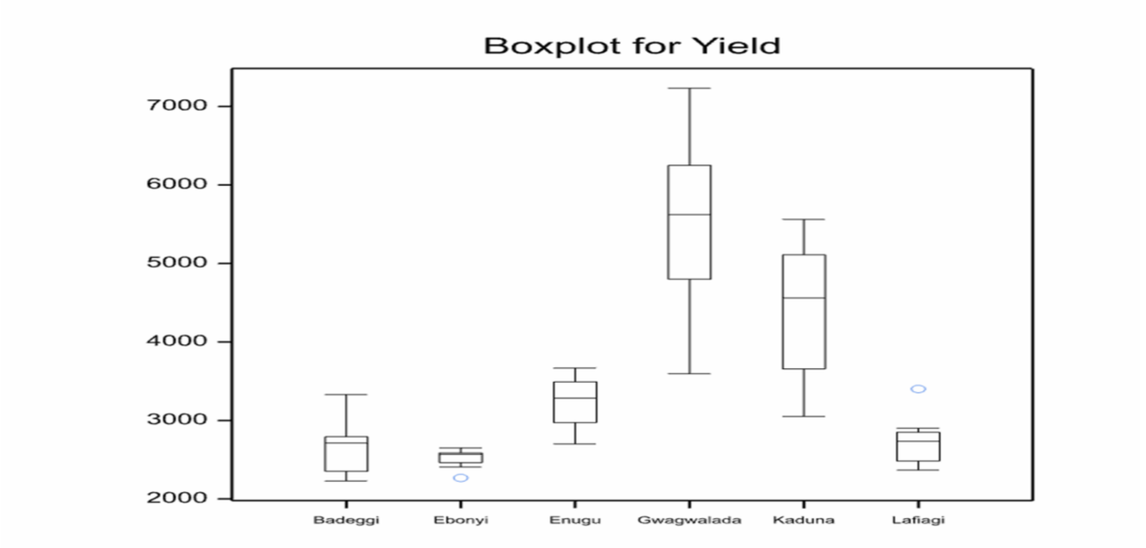


Fig. 1: Distribution pattern of grain yield of 8 rice genotypes across six submergence environments

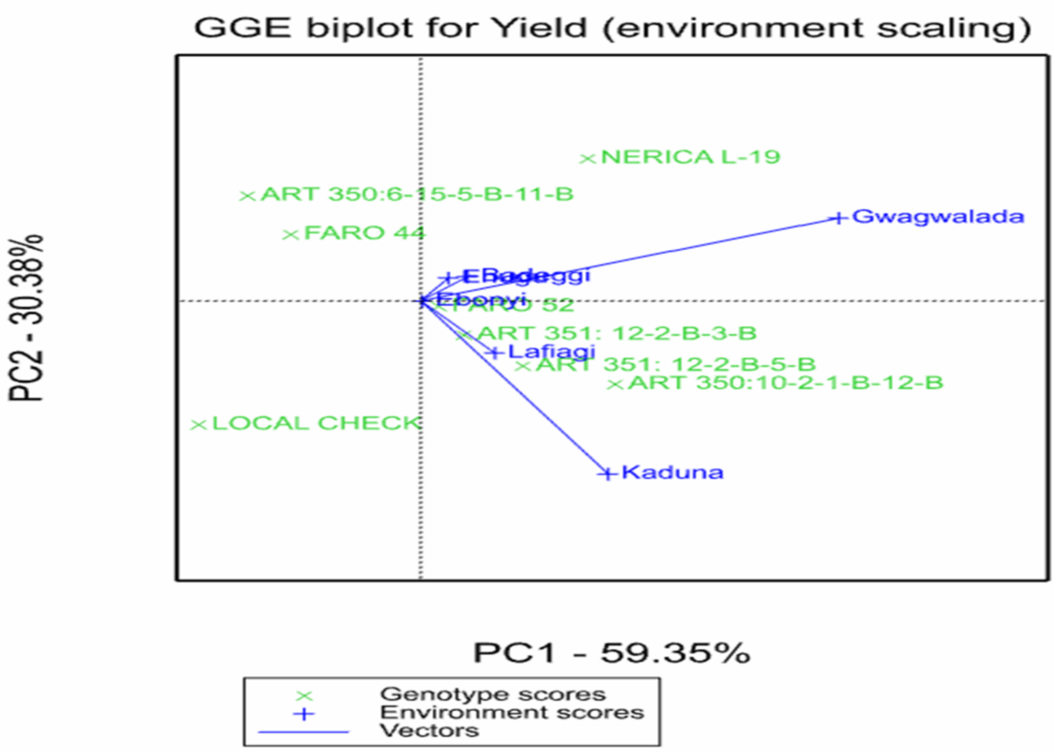
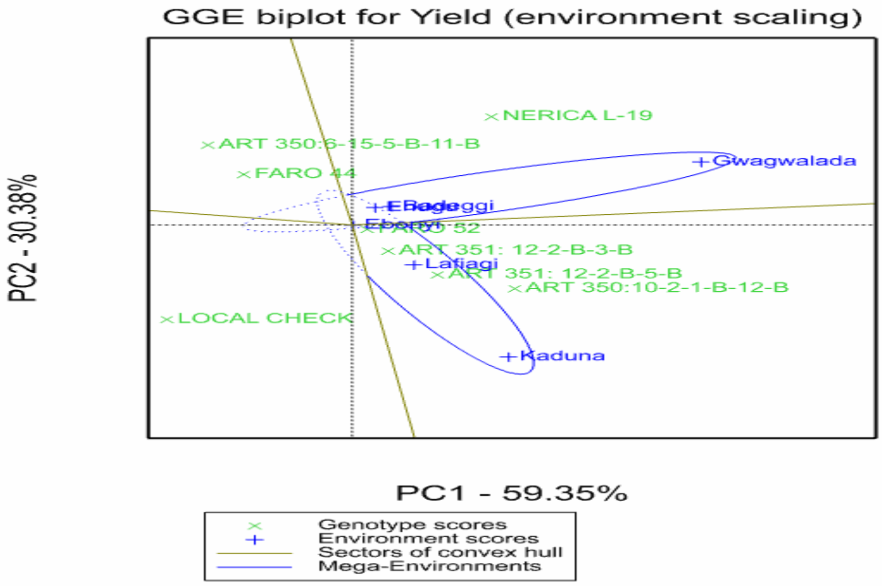


Fig 2: Environmental scaling for 8 submergence lines in 6 locations



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