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Response of Rice Genotypes (*Oryza glaberrima* Steud and *Oryza sativa* L.) to Flash Flooding in Gombe, Gombe State, Northeastern Nigeria

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Abstract

Flash floods affect rice seedlings severely, therefore improvement and selection of flash flood tolerance in rice plants is very much important. This study was carried out to determine the response of rice genotypes (Oryza glaberrima Steud; O. sativa L.) to flash flooding in Gombe State, Nigeria. In the study 10 varieties of rice were subjected to degrees of sub-mergence under water in randomized complete block design (RCBD) replicated three times.Results indicated FARO 44 was maximum in the shoot elongation at five days after de-submergence under control and ratio of submergence to de-submergence. Principal component analysis (PCA) showed that the first four components (PC) had Eigen values greater than one and accounted for than 81.86% of the total variation, while the rotated component matrix indicated that PC1 was mostly correlated with 7RSD (0.3498), slightly followed by 5RBSBT (0.2254), PC2 was maximally correlated with 5IFWTT (0.3227) while PC3 was highly correlated with 7SHEL (0.7126) and PC5 was highly correlated with 5SHEL (0.8500) and PC6 maximally correlated with 5RBSBT (0.5380). The Genotypes were grouped into three clusters with clusters I (TAG 7400, FARO 57, FARO 44, FARO 51) and II (TAG 6773, TOG 5980-A, TOG 8347, FARO 56, FARO 61) having four and five varieties respectively. Further research can be carried with many characters to be able to select the genotypes that can tolerate flooding better in the study area.

Keywords: *Gombe, flooding, rice genotypes, submergence, principal component analysis*

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I. Introduction

Rice is a staple food for more than half of the world population. In Nigeria, it is not only a staple food but strategic crop and fastest growing commodity (Iwuchukwu *et al*., 2017). Rice is widely cultivated in most agro-ecological zones in Nigeria with potential land area for its production is between 4.6 million and 4.9 million hectares (Osawe *et al*., 2017). The crop is grown in approximately 3.7 million hectares of land in Nigeria with 77 per cent rain-fed, 47 per cent lowland, 30 per cent upland, 17 per cent irrigated, 5 per cent deep water and one per cent mangrove swamp cultivation (Cadoni and Angelucci, 2013).Rice consumption in African countries has shown an increasing trend in recent years, the production rate is not sufficient to meet the demand. The volume of imported rice is increasing annually, which is having a detrimental effect on African countries' economies. Nigeria for instance require about 7 million tonnes of rice in a year but presently producing 3.7 million (Business News, 2019). To resolve these issues, rice production yields must be increased by expanding the production area or by improving yield per unit area. Realization of this goal is impeded primarily by the poor agricultural environment such as floods (Sakagami and Kawano, 2011).

Rice is a cereal belonging to the tribe Oryzeae in the subfamily Pooideae of the family Graminaea (Mustapha, 2018). It is the seed of the monocot plants Oryza sativa (Asian rice) or Oryza glaberrima (African rice). Oryza sativa originated from Yangtze River Valley in China where it was first domesticated in over 5,000 years ago (Vaughan *et al*., 2008). African rice has been cultivated for about 3,500 years and between 1500 and 800 BC, O. glaberrima was propagated from its original center, the Niger River delta of Nigeria and extended to Senegal (Akay *et al*., 2022). However, it never developed far from its original region. Its cultivation even declined in favour of the Asian species, despite its high adaptability to African environments.

Submergence stress is a common environmental challenge for agriculture sustainability in many regions throughout the world. Partial-to-complete submergence of aerial organs considerably reduces the growth and survival of most crop plants (El-Hendawy *et al*., 2012). Acclimation responses to these conditions are speciesspecific and genotype-specific. Modification of morphology and anatomy of shoots and switching the energy conversion modes from aerobic to anaerobic respiration can ameliorate the negative effects of submergence. Flash floods refer to a rapid surge of flooding that subsides after several days and not longer than 10 days (Kawano *et al*., 2009). It involves two drastic environmental changes, from aerobic to anaerobic conditions, and then back from anaerobic to aerobic conditions as the flash flood recedes.Studies on *Oryza sativa*, which is an adapt species to submergence conditions, has revealed that most of genotypes can bear the submergence stress by two contrasting strategies: escape and quiescence (Jackson and Ram, 2003; Perata and Voesenek, 2007).

Rice cultivation in lowlands are usually practiced during the rainy season in northern Nigeria leading to flash floods and partial or total submergence of the plant (Aliyu et al., 2015). Genotypes with flash flood resistance (FFR) should have the ability to quickly adapt to these environmental changes. The key factor for adaptation from aerobic to anaerobic environments is energy supply. Carbon assimilation during submergence will be affected by several factors such as CO2 supply, solar irradiance, and underwater photosynthetic capacity, which is impaired by chlorosis. Efficient utilization of energy during submergence is also important for adaptation to an anaerobic environment. Rapid shoot elongation is a typical response by some rice genotypes for survival following submergence (Kawano et al., 2008).Young rice seedlings often experience submergence stress following occasional periods of heavy rain and drought caused by extended dry spells between the rainy periods. Rice plants grown under such conditions should be resistant to both submergence and drought. In particular, young seedlings easily suffer from complete submergence by flash floods with rapid increases in water level, as the seedlings are too short to develop a canopy above the water surface. Rice productivity in lowland areas which are prone to flash floods is much higher than that of upland fields (Sakagami and Kawano, 2011). Reports of flooding damage to rice plants have been increasing with expansion of rainfed lowland rice cultivation which major rice cultivation in Gombe state (Hallegatta et al., 2010). Flooding imposes severe selection pressure on plants, principally because excess water in their surroundings can deprive them of access to certain basic resources such asoxygen, carbon dioxide, and light for photosynthesis (Sakagami and Kawano, 2011). Rice plants in lowlands areas are often damaged by floods caused by heavy rain. It is therefore important to study the effects of submergence on rice plants which are genetically and environmentally influenced, so as to develop sustainable rice production in the study area. Thus, this study evaluated the response of rice genotypes (*Oryza glaberrima* Steud; *O. sativa* L.) to flash flooding in Gombe, Northeastern Nigeria.

II. Materials and Methods

Pot experiment was conducted at the Biological Garden, Federal College of Education (Technical), Gombe (Latitudes 10^0 13’ and 10^0 20’N; Longitudes 11^0 02’ and 11^0 16’E with 461m above sea level) from April to July, 2019 to evaluate response of rice genotypes to flash floods. Gombe has two distinct seasons, dry season (November to April) and wet season (May to October) with an average temperature of 26^0C and annual rainfall of 907mm in the Sudan savannah (Mbaya et al., 2019). Five cultivars each of *Oryza glaberrima* (TAG 7400, TAG 6773, TOG 5980-A, TOG 8347 and TOG 16704) and *Oryza sativa* (FAROs 44, 51, 52, 57 and 61) obtained from International Institute of Tropical Agriculture (IITA), Ibadan were selected and used for the experiment (Table 1).

Table 1. Seed Properties of *Oryza glaberrima* and *Oryza sativa* Genotypes

S/no	Trt.	Designation.	SC	SL (mm)	SW (g)
1	T_1	TAG 7400	red	5.02	0.0321
2	T_2	TAG 6773	red	5.03	0.0321
3	T_3	TOG 5980-A	red	4.01	0.0354
4	T_4	FARO 57	white	8.02	0.0290
5	T_5	TOG 8347	red	8.03	0.0236
6	T_6	FARO 52	white	7.02	0.0235
7	T_7	TOG 16704	red	4.03	0.0239
8	T_8	FARO 44	white	8.02	0.0528
9	T_9	FARO 51	white	8.01	0.0280
10	T_{10}	FARO 61	white	8.04	0.0284

KEY: Trt. = Treatments (Rice Genotypes), SC = Seed Colour, SL = Seed Length (mm), SW = Seed Weight.

Thirty seeds of each of the cultivars were pre-germinated and sown at the depth of 1 cm in pot of dimension of 20.5cm x 12.8cm which were hitherto filled with dry soil obtained from paddy fields. The seedlings were later thinned to ten per pot. Twelve-day-old seedlings were submerged in an outdoor concrete tank (5130 L) to a depth of 1 m for 7 days and subsequently re-exposed to air for 5 days, while controls were set out in concrete tank without submergence. The treatments were arranged in a randomized complete block design replicated three times. Three plants were selected from each cultivar for measurements of plant length a day before submergence (DBS) and fresh shoot weight. The damage caused by submergence was calculated as the inhibition of plants growth after de-submergence relative to non-submerged (controls). Other variables measured are: Shoot height (SHT), Shoot elongation 5 days after de-submergence (5SHEL), Shoot elongation 5 days under control plot (5SHELC), Shoot elongation during 7 days of submergence (7SHEL),Shoot elongation

7 days under control plot (7SHELC),Ratio of submergence at 7 days (7RSBT), Ratio of submergence to de-submergenceat 5 days (5RBSBT), Fresh shoot weight (FWT), Increase FWT during submergence at 7 days (7IFWT), Increase FWT after de-submergence at 5 days (5IFWT),Increase FWT during submergence at 7 days under control plot (7IFWTC), Increase FWT during submergence at 5 days under control plot (5IFWTC),Ratio of FW submergence to de-submergenceat 7 days (7RSD), Ratio of FW submergence to de-submergence at 5 days (5RSD).

All the data collected were subjected to analysis of variance (ANOVA), correlation, principal component (PCA) and cluster analyses to determine physiological traits among the cultivars using STAR software (STAR, 2013) and SPSS v20. The PCA with Eigen values >1 and which explained at least 5% of the variation in the data were considered using the criteria set by Brejda*et al.*(2000).

III. Results and Discussions

Effect of Submergence on some Physiological Properties of the Rice Genotypes

The results of the responses of genotypes to submergence on some physiological properties of rice genotypes are shown on Table 2a. Results on shoot height (SHT), shoot elongation rate (7 SHEL, 7 SHELC, 5 SHELC) and ratio of shoot elongation rate (7 RSD) were not significant ($p \leq 0.05$). However, significant effects ($p \leq 0.05$) of genotype responses were observed on shoot elongation rate during the 5 days of de-submergence of the submerged (5 SHEL) and ratio of shoot elongation of submergence to non-submergence at 5 days after de-submerged (5 RBSBT). Faro 44 recorded the greatest shoot elongation after de-submerged (1.07 dcm^{-1}) followed by Faro 52 with 0.69 dcm^{-1}, while TOG 16704 had the least (0.16 dcm^{-1}). This indicated that Faro 44 which belongs to Oryza sativa grow faster after de-submergence indicating high tolerant to flash flooding. This finding is in agreement with that Vu *et al*. 2010 who reported that vigorous shoot growth rate before submergence enable seedlings to escape and survive submergence stress. Pre-emergence stored carbohydrate are also reported to be associated with enhanced survival under flooding conditions possibly by supply the required energy for maintenance of metabolism through anaerobic respiration (Sarkar *et al.*, 2006). Similarly, Faro 44, TOG 8347 and TOG 6773 recorded high ratios of shoot elongation of submergence to non-submergence at 5 days after de-submerged with values 1.84, 1.19 and 1.20 respectively.

The results of the responses of genotypes to submergence in respect of shoot fresh weight (FWT), increase in fresh weight (7 IFWTC, 7 IFWT, 5 IFWTC and 5 IFWT) and ratios of increase in fresh weight (5 and 7 RSD) were presented on Table 2b. Results indicated that all the physiological properties (FWT, 5,IFWT, 7 IFWT, 5 and 7 RSD) were not significant. This indicated that genotypes showed little or no variation in FWT during and after submergence (Table 2b).

Table 2a: Effect of Submergence on Some Physiological Properties of the Rice Genotypes

Genotypes	**SHT (cm)**	**7 SHELC (dcm^{-1})**	**7 SHEL (dcm^{-1})**	**5 SHELC (dcm^{-1})**	**5 SHL (dcm^{-1})**	**7 RSBT**	**5 RBSBT**
TOG 7400	35.10	1.20	1.79	1.50	0.20b	1.50	0.20b
TOG 6773	39.43	0.57	0.90	0.90	0.36ab	2.72	1.20ab
TOG 5980-A	40.37	0.88	1.92	1.14	0.19b	2.30	0.20b
FARO 57	36.30	0.62	1.51	0.69	0.42ab	2.34	0.60ab
TOG 8347	40.00	1.32	1.97	0.83	0.31ab	1.21	1.19ab
FARO 52	41.83	0.80	1.57	1.16	0.69ab	1.83	0.42b
TOG 16704	47.77	0.96	1.92	0.85	0.16b	1.87	0.30b
FARO 44	33.73	1.25	1.23	0.97	1.07a	0.81	1.84a
FARO 51	34.63	0.75	1.57	1.35	0.38ab	1.68	0.44b
FARO 61	35.70	0.56	1.42	0.78	0.22b	2.35	0.29b
S.E.	5.18	0.41	0.71	0.64	0.24	0.63	0.38
CV (%)	16.47	56.14	54.93	76.80	71.88	41.18	69.22

Key: SHT: Shoot height a day before submergence; 7 SHELC: Shoot elongation rate during the 7 days of non-submergence; 7 SHEL: Shoot elongation rate during the 7 days of submergence; 5 SHELC: Shoot elongation rate during the 5 days de-submergence of non-submergence; 5 SHEL: Shoot elongation rate during the 5 days of de-submergence of the submergence treatments; 7 RSBT: Ratio of shoot elongation of submergence to non-submergence treatments during 7 days of submergence; 5 RBSBT: Ratio of shoot elongation of submergence to non-submergence at 5 days after de-submerged.

Table 2b: Effect of Submergence on Some Physiological Properties of the Rice Genotypes

Genotypes	**FWT (g)**	**7 IFWTC (mg d^{-1})**	**7 IFWT (mg d^{-1})**	**5 IFWTC (mg d^{-1})**	**5 IFWT (mg d^{-1})**	**7 RSD**	**5 RSD**
TOG 7400	170.00	32.47	14.13	50.93	13.63	0.43	0.31
TOG 6773	219.00	37.67	7.97	45.63	9.73	0.24	0.21
TOG 5980-A	189.00	30.13	13.07	53.47	6.80	0.40	0.14
FARO 57	179.67	23.93	4.87	24.80	10.57	0.20	0.57
TOG 8347	206.00	33.93	5.60	50.77	12.53	0.21	0.30
FARO 52	195.33	31.03	11.07	45.90	7.30	0.35	0.27
TOG 16704	226.00	35.10	5.97	51.20	15.07	0.17	0.56
FARO 44	171.33	29.37	11.20	44.83	3.50	0.37	0.08
FARO 51	171.33	33.23	11.23	48.27	13.10	0.37	0.30
FARO 61	187.00	30.60	7.80	40.50	14.67	0.29	0.33
S.E.	36.21	9.53	5.18	16.91	6.61	0.16	0.27
CV (%)	23.16	36.75	68.25	45.40	75.74	62.98	108.35

Key: FWT: Fresh shoot weight a day before submergence, 7 IFWTC: Increase in FWT during the 7 days of non-submergence; 7 IFWT: Increase in FWT during the 7 days of submergence; 5 IFWTC: Increase in FWT during the 5 days de-submergence of non-submergence; 5 IFWT: Increase in FWT during the 5 days of de-submergence of the submergence treatments; 7 RSD: Ratio of FWT of submergence to non-submergence treatments during 7 days of submergence; 5 RSD: Ratio of FWT of submergence to non-submergence at 5 days after de-submerged.

IV. Correlation

Generally the measured characteristics of the rice genotypes exhibited negative and weak correlation (Table 3). Positive highly significant correlations were only found between FWT and 7IFWTT (r = 0.639) and 5IFWTT (r = 0.559); and between 7IFWTT and 5IFWTT (r = 0.735). Highly significant negative correlation was recorded between 5RSD and 7IFWTT and 5IFWTT (r = - 0.493 and – 0.606 respectively) and between 5SHEL and 5RBSBT (r = -0.455).

Table 3: Correlation matrix of some agronomic traits of the Genotypes under flash flood condition

	SHT	7SHEL	5SHEL	7RSBT	5RBSBT	FWT	7IFWTT	5IFWTT	7RSD
SHT	1								
7SHEL	.031	1							
5SHEL	.247	.086	1						
7RSBT	.026	-.192	.060	1					
5RBSBT	-.294	-.066	-.455*	-.302	1				
FWT	.106	-.219	-.117	-.176	.007	1			
7IFWTT	-.271	-.015	-.210	-.001	.131	.639**	1		
5IFWTT	-.090	.032	-.108	-.034	.064	.559**	.735**	1	
7RSD	-.298	.035	.044	-.246	.035	-.122	-.099	-.017	1
5RSD	.292	-.079	.250	.180	-.316	-.297	-.493**	-.606**	-.281

* Correlation is significant at the 0.05 level and ** is significant at the 0.01 level (2-tailed).

Principal Component Analysis

Principal component analysis was conducted for some traits for 10 rice varieties with regard to level of tolerance to sub-mergence. The results showed that, the four principal components (PC1, PC2, PC3, and PC4) accounted for 81.86% of the total variation in the selected properties and had the Eigen values greater than one, while PC5 and PC6 showed Eigen value close to one and more 5% of the variance. PC1 contributed 33.18% of the total variation whereas PC2, PC3, PC4, PC5, PC6 contributed 28.78%, 11.88%, 8.02%, 6.48% and 5.67% respectively to the total variation (Table 4).

Table 4. Proportion of variability and Eigen values accounted by the Principal Components (PC).

Statistics	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Standard deviation	2.1554	2.0072	1.2899	1.0597	0.9523	0.8907	0.7524	0.4600	0.2459	0
Proportion of Variance	0.3318	0.2878	0.1188	0.0802	0.0648	0.0567	0.0404	0.0151	0.0043	0
Cumulative Proportion	0.3318	0.6196	0.7385	0.8187	0.8835	0.9401	0.9806	0.9957	1.0000	1
Eigen Values	4.6458	4.0288	1.6639	1.1231	0.9068	0.7933	0.5661	0.2116	0.0605	0

The rotated component matrix (Table 5) indicated that PC1 was mostly correlated with 7RSD (0.3498), slightly followed by 5RBSBT (0.2254), PC2 was maximally correlated with 5IFWTT (0.3227) while PC3 was highly correlated with 7SHEL (0.7126) and PC5 was highly correlated with 5SHEL (0.8500) and PC6 maximally correlated with 5RBSBT (0.5380).

Table 5. Factor loadings for the tested characters

Variables	PC1	PC2	PC3	PC4	PC5	PC6
SHT	-0.4418	0.0364	0.0283	-0.0696	0.1343	0.0547
7SHEL	-0.0151	-0.0879	0.7126	-0.2654	-0.0690	0.0697
5SHEL	-0.0088	-0.2400	-0.0091	0.2707	0.8500	-0.1034
7RSBT	0.1573	-0.2593	-0.2926	-0.4467	-0.0721	-0.5244
5RBSBT	0.2254	0.2866	-0.2544	-0.1133	0.0688	0.5380
FWT	-0.4319	0.0740	-0.1914	0.0440	0.0898	-0.1665
7IFWTT	-0.3404	0.2734	0.1252	-0.1850	-0.0312	-0.0378
5IFWTT	-0.2837	0.3227	-0.0782	-0.3508	0.0625	-0.1445
7RSD	0.3498	0.2423	0.0482	0.1504	-0.0823	-0.3526
5RSD	0.0265	-0.4201	-0.2173	0.1172	-0.2738	0.2740

Scree plot

Scree plot presented the percentage of variance associated with each principal component obtained in a graph between Eigen values and principal component. PC1 and PC2 accounted for 61.96%of the total variability with Eigen values of 4.65 and 4.03 respectively. The maximum variation was observed in PC1 and decreased gradually in comparison to other 9 PCs (Fig. 1).

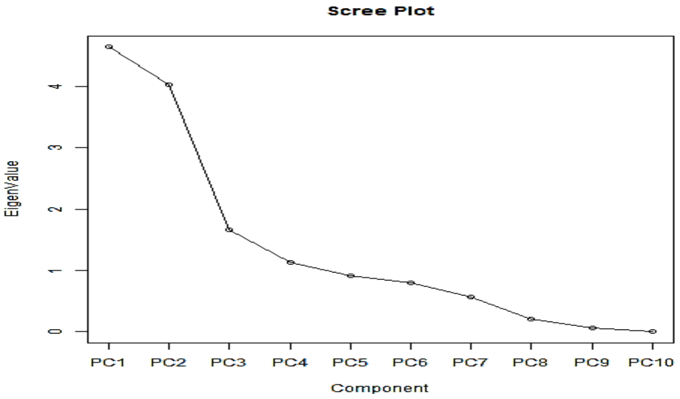

Figure 1.Scree plot of the Eigen values and principal components

Cluster Analysis

Three main cluster groups were used in a Dendogram (Figure 2)where each cluster group contains different number of genotypes measured using Euclidean distance and Ward's clustering method. The results revealed that cluster I consists of four genotypes (TOG 7400, FARO 57, FARO 44, FARO 51), cluster II five (TOG 6773, TOG 5980-A, TOG 8347, FARO 56, FARO 61) and cluster III one (TOG 16704).

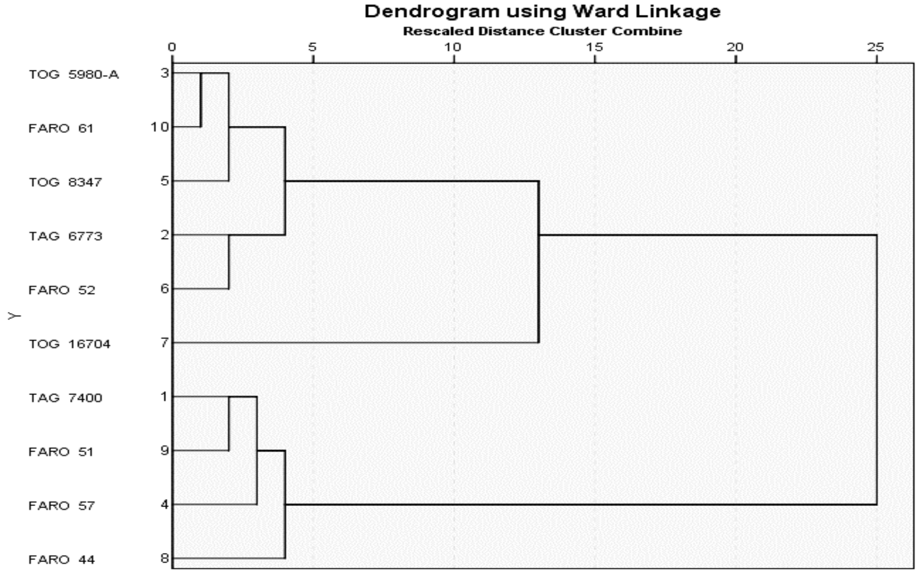

Figure 2. Classification of the 10 Rice Genotypes in a Dendogram

V. Conclusion

Principal component analysis was used to determine the variation and to estimate the contribution of the selected characters for total variability. The principal component analysis shows the characters with maximum variability to be 7RSD and 5RBSBT in PC1, 5IFWTT in PC2, 7SHEL in PC3 and 5SHEL and 5RBSBT in PC5 and PC6 respectively. The genotypes fell into two clusters except for TOG 16704 which was alone. Faro 44 grouped under cluster 1 appears to exhibit flash flood tolerance better than other genotypes. Further research to evaluate other characteristics responses to varying degrees of submergence is recommended.

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