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DEVELOPMENT OF SUBMERGENCE TOLERANCE RICE FROM SEGREGATING POPULATION OF CROSSES OF SWARNA *SUB-2* GENE WITH TWO MAJOR COMMERCIAL RICE VARIETIES IN NIGERIA

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ABSTRACT

Flooding remains one of the most significant challenges in rice cultivation in Nigeria; therefore, the experiment aimed to develop flood-tolerant rice varieties from crosses between flood-tolerant rice and high-yielding susceptible cultivars. Three parents were used in the cross combination of FAROs 44 and 57, with Swarna Sub-2 as the male parent. The crosses were performed to generate F1 hybrids, which were selfed to produce the F2 generation. The F2 were evaluated in a randomised complete block design in three replications. Parameters such as plant height, tiller count, and percentage survival were recorded. Results showed highly significant differences among the treatments. Plant height increased after submergence, but tiller count decreased in most progenies and the parents. Heritability values ranged from 29% (Plant height before submergence) to 71% tiller count after submergence. The percentage survival after submergence varied from 36.37% (FARO 57) to 69.70% (FARO 44 X Swarna sub-2). The progeny FARO 44 X Swarna sub-2 could be a better option for flood tolerance in flood-prone areas.

Keywords: Flooding, Rice, Submergence, Tolerance

INTRODUCTION

Rice (*Oryza sativa* L.) has become a strategic commodity across most African countries (AfricaRice, 2020). Driven by changing food preferences in both urban and rural areas and compounded by high population growth rates, rice consumption in the Sahel and sub-Saharan Africa (SSA) increased by 5.6% per annum between 2009 and 2012, a rate more than double the population growth rate (AfricaRice, 2020). Rice is a staple food for billions of people worldwide, including in Nigeria, where over half of the population depends on it as a primary source of food (Mayowa *et al*., 2025). In 2008, world rice production was 661 million tons from 155.7 million ha (PWC, 2017). Of these, Asian farmers produced about 600 million tons, representing more than 90% of global rice production. India and China together accounted for 341 million tons, with India producing 148 million. A recent report indicates that in 2023, Nigeria's milled rice production was estimated at 5.2 million metric tons (Mayowa *et al.,* 2025)

Rainfed lowland rice production, which accounts for more than 70% of total rice area in Nigeria, is prone to recurrent flooding caused by heavy rainfall or the overflow of nearby rivers. This often leads to yield losses ranging from 10% to total crop loss (Bashir *et al.,* 2018). In 2012, when Nigeria experienced the worst flooding in 40 years, floods reduced rice production by about 22% (UNDRR, 2017). Flooding is expected to be increasingly problematic under global warming, as studies by AfricaRice on future rice climates projected massive increases in overall precipitation in north and northwest Nigeria (Africa Rice, 2017). Most rice varieties can get severely damaged or killed within a week of severe flooding. Depending on the intensity of flooding, it can reduce yield or prolong the growth duration, and in extreme cases, it can cause total crop loss. The only possible solution to this problem is the use of flood-tolerant varieties.

The available flood-tolerant rice varieties (FARO 66 and 67) in Nigeria are less adopted by Nigerian farmers due to low yields, limited tolerance (< 10 days), and grain quality (NCRI, 2020). The parental lines (FARO 52 and 60) used to develop the varieties contributed to the adoption rate, as they are not major farmers' varieties. The 2020 survey conducted by NCRI revealed the extent of farmers' requests for submergence varieties with the characteristics of FARO 44 and FARO 57 (Most Preferred commercial Rice Varieties in Nigeria). Improving the ability of two rice plants to survive under flooding conditions by studying the genetics underlying the mechanism remains a major constraint for sustainable local rice production in unstable environments undergoing climate change (NCRI, 2017). Previous studies have reported the successful development of submergence-tolerant varieties by introgressing the Sub1 locus (Oladosu *et al.*, 2020). However, in all the studies, background parentage has shown a significant influence on the nature of the progeny and its characteristic features. Thus, it is important to develop more submergence-tolerant varieties using major farmers' cultivars as parents. Therefore, this research aimed to develop fixed lines of flood-tolerant genotypes suitable for flood-prone areas. This will enhance yield levels in farmers' fields and improve food security.

MATERIALS AND METHODS

Study location. The study was conducted at the National Cereals Research Institute (NCRI) in the Badeggi rice field. NCRI Badeggi lies within latitude N09o 04.238′ and longitude E 006o 06.638′. NCRI receives an average annual rainfall of about 1184mm, with temperatures ranging from 25.9 to 31.1 ^{0}C and a relative humidity of about 77 % (Ehirim, 2023)

Sources of Experimental Materials

The parent materials used for the study were three *Oryza sativa* lines, of which one is a donor parent line (Swarna Sub-2), already developed as tolerant to submergence, and the other two are susceptible parents to submergence (FARO 44 and 57). These two susceptible parents are commercially released and highly cultivated in Nigeria. The materials were collected from the NCRI breeding Unit in Badeggi.

The F1 hybrids were developed by crossing Swarna Sub-2, a donor parent, with two commercially released varieties, FARO 44 and FARO 57, in 2024. The F1 was advanced to F2. The progenies of F2 were evaluated under submerged conditions for 14 days of flooding after transplanting, when the plants were 21 days old, in the year 2025.

Experimental design and layout

The trial was carried out in a randomised complete block design with three replications. The three parents were planted alongside the F2 test entries, replicated three times. Each entry was planted in a 1-metre row, with plants spaced 20 cm apart.

Screening of the Crosses under Submergence Conditions

The crops were raised in a nursery bed and transplanted after 21 days. Each stand was planted with a single seedling. Submergence screening was performed under controlled conditions, with flooding to a depth of 1.0 meters for 14 days. The crops were de-submerged, and plant survival was scored after 20 days of recovery, as described by Pamplona *et al.* (2007).

Data Collection.

The following data were collected

i. Percentage Survival of the Test Entries = $\frac{Number\ of\ Seedling\ Survived}{Number\ of\ Seedling\ Transplanted} \times 100$

ii. Percentage Survival of the Resistant Entries = $\frac{Number\ of\ Seedling\ Survived}{Number\ of\ Seedling\ Transplanted} \times 100$

iii. Plant height (cm): The length from ground level to the tip of the longest panicle was measured at maturity.

iv. Number of tillers per plant: The number of tillers per plant was counted for each genotype at maturity. All the tillers were counted for both before and after submergence.

Crosses and their numbering

T1= FARO 44 X Swarna sub-2

T2= FARO 57 x Swarna sub2

T3= FARO 44 X Swarna sub-2

T4= FARO 57 x Swarna sub2

T5= FARO 44 X Swarna sub-2

T6= FARO 57 x Swarna sub2

T7= FARO 44 X Swarna sub-2

T8= FARO 57 x Swarna sub2

T9= FARO 44 X Swarna sub-2

T10= FARO 57 x Swarna sub2

T11= FARO 44

T12= Swarna sub 2

T13= FARO 57

Data analysis

Phenotypic and Genotypic Coefficient of Variation

The formula suggested by Singh and Chaudhary (1985) was followed for the computation of the Phenotypic and Genotypic coefficients of Variation among the generations.

Genotypic coefficient of variation (GCV) = $\frac{\sqrt{\sigma_g^2}}{\overline{X}} \times 100$

Phenotypic coefficient of variation (PCV) = $\frac{\sqrt{\sigma_{ph}^2}}{\overline{X}} \times 100$

Where:

σ_g^2 = Genotypic variance

σ_{ph}^2 = Phenotypic variance

$\overline{X}$ = Mean

RESULTS

Table 1 shows the results of plant and tiller count before and after submergence. There were significant differences among the treatments for both plant height and tiller count. Plant height before submergence showed that T11 was the tallest, followed by T1, and was significantly taller than the other three treatments. Height after submergence also showed significant differences, with T11 being the tallest and differing significantly from the others, except T2 and T4. There was a progressive increase in height after submergence. Tiller count before submergence showed significant differences, with T12 having the highest number of tillers, followed by T9 and T2, which were significantly different from the others. Tiller count after submergence also showed significant differences among the treatments, with T7 having the highest number of tillers and being significantly equal to T3, T5, and T9.

Table 1: Plant height (cm) and tiller count before and after submergence of rice at Badeggi

Treatment	Plant height before submergence (cm)	Plant height after submergence (cm)	Tiller count before submergence	Tiller count after submergence
T1	61.47a	83.62bc	6.83h	8.97cd
T2	56.17bc	87.37ab	10.42abc	9.00cd
T3	61.02ab	84.59bc	8.58efg	9.68abc
T4	60.90ab	86.97ab	9.90bcd	9.30bc
T5	57.75abc	75.60d	9.25cdef	9.68abc
T6	54.89c	84.21bc	8.38fg	9.70abc
T7	58.10abc	75.96d	9.83bcde	10.70a
T8	57.23abc	85.42bc	8.67defg	8.20d
T9	58.83abc	83.47bc	10.63ab	10.15ab
T10	49.80d	86.02bc	10.07bc	9.52bc
T11	61.62a	91.33a	8.80defg	9.25bcd
T12	59.66abc	81.76c	11.60a	6.50e
T13	57.82abc	65.25e	7.80gh	6.50e
Mean	58.10	82.43	9.29	9.01
SE±	2.41	2.38	0.61	0.51
CV	5.08	3.53	8.04	6.99
Sig Level	**	***	***	***

Means with the same letters are significantly the same at P < 0.05, LSD

Table 2 shows the effect of submergence on plant height and tiller number. Plant height increased progressively as plants increased under water. However, the tiller count decreased after submergence. The change in plant height (After - Before) is statistically significant for all 13 treatments (P< 0.05). The positive Mean Difference indicates that plant height increased after the submergence period in all treatments, suggesting that growth occurred through elongation in the submerged condition. The change in tiller count (After - Before) is statistically significant only for treatments T1, T11, and T12.

Table 2: T-test comparison of plant height and tiller number before and after submergence

Treatment	Trait	Mean Difference	t-statistic	p-value	Significant (alpha=0.05)
T1	Plant Height	22.1500	8.5832	0.0133	Yes
T1	Tillers	2.1333	4.7571	0.0415	Yes
T2	Plant Height	31.2050	17.2259	0.0034	Yes
T2	Tillers	-1.4167	-1.3567	0.3077	No
T3	Plant Height	23.5667	25.5310	0.0015	Yes
T3	Tillers	1.1000	1.5466	0.2620	No
T4	Plant Height	26.0700	12.1533	0.0067	Yes
T4	Tillers	-0.6000	-0.6694	0.5722	No
T5	Plant Height	17.8500	5.7972	0.0285	Yes
T5	Tillers	0.4333	1.1855	0.3576	No
T6	Plant Height	29.3200	18.7252	0.0028	Yes
T6	Tillers	1.3167	2.1144	0.1688	No
T7	Plant Height	17.8600	4.8375	0.0402	Yes
T7	Tillers	0.8667	0.8810	0.4713	No
T8	Plant Height	28.1867	11.9996	0.0069	Yes
T8	Tillers	-0.4667	-0.6793	0.5670	No
T9	Plant Height	24.6400	14.1391	0.0050	Yes
T9	Tillers	-0.4833	-0.7804	0.5169	No
T10	Plant Height	36.2167	13.1614	0.0057	Yes
T10	Tillers	-0.5500	-0.4795	0.6789	No
T11	Plant Height	29.7100	25.4173	0.0015	Yes
T11	Tillers	0.4500	5.1962	0.0351	Yes
T12	Plant Height	22.1000	439.0820	0.0000	Yes
T12	Tillers	-5.1000	-8.3843	0.0139	Yes
T13	Plant Height	7.4300	49.3872	0.0004	Yes
T13	Tillers	-1.3000	-1.7321	0.2254	No

Result of Table 3 indicates that plant height before Submergence (PH bf S) had a much higher environmental variance (14.14) than Genotypic Variance (5.87), Plant Height after Submergence (PH af S) showed a significantly higher genotypic variance (42.33) compared to Environmental Variance (8.12), Tillers (Before and after Submergence) both tiller traits showed Genotypic Variance notably higher than environmental variance, similar to plant height after submergence.

The traits Plant Height After Submergence (PH af S), Tillers Before Submergence (TIL bf S), and Tillers After Submergence (TIL af S) all showed high heritability and high or moderate GAM.

Table 3: Genotypic variances for plant height and tiller count before and after submergence

Trait	Mean	Genotypic Variance	Environmental Variance	Phenotypic Variance	H^2	GCV (%)	PCV (%)	Genetic Advance (GA)	GAM (%)
PH bf S	58.10	5.87	14.14	20.01	0.29	4.17	7.70	2.70	4.65
PH af S	82.43	42.33	8.12	50.46	0.84	7.89	8.62	12.28	14.89
TIL bf S	9.29	1.48	0.53	2.01	0.74	13.09	15.27	2.15	23.13
TIL af S	9.01	1.41	0.57	1.98	0.71	13.17	15.62	2.06	22.89

Table 4 presents the results for plants that survived after submergence for 14 days. The result shows highly significant differences among the test entries. The progeny T9 had the highest survival percentage (69.70%) and was only significantly different from T5. The least surviving plant is T13 (36.37%), which is FARO 57.

Table 4: Percentage survival of rice plants after 14 days of submergence

Treatment	**Survival count**	**Survival percentage**
T1	34.00bc	61.80bc
T2	32.67bcd	59.43bcd
T3	32.33cd	58.80cd
T4	28.00ef	50.90ef
T5	36.33ab	66.07ab
T6	29.33de	53.33de
T7	34.00bc	61.83bc
T8	32.33cd	58.77cd
T9	38.33a	69.70a
T10	30.33cde	55.17cde
T11	24.67f	44.87f
T12	29.00de	52.70de
T13	20.00g	36.37g
Mean	30.87	56.13
SE±	1.97	3.39
CV	7.41	7.39
Sig. level	***	***

Means with different letter in a column are significantly different at $P < 0.05$

DISCUSSION

Flooding of rice fields has been one of the most devastating environmental factors affecting rice production and yield. Genetic variances were observed among the entries scored. This indicates the progenies' ability to respond differently to submergence. The plant's height increased in most progenies and the parents; this might be due to plant elongation under flood stress. Rice plants escape from a flooded condition by elongating their internodes. Similar results were reported by Ja'a far *et al.* (2025), who found that stem elongation occurs in most varieties when exposed to submergence for 14 days. The authors also noted that the escape strategy involves elongation of the stem as found in IR 64. The number of tillers decreased sharply after submergence and varied among the test progenies. They showed some segregation and genetic variation among the progenies. Percentage survival was moderate in some progenies and very low in the susceptible parents. This indicates that tolerant genes might have been transferred to the progenies. Ehirim *et al.* (2023) observed survival rates ranging from 0% to 100% in crosses between Swarna-sub1 and commercial varieties in Nigeria. Among all the mitigating measures, developing tolerant rice varieties has been prioritised as a sustainable strategy that can reduce the impact of the submergence problem in the major rice production areas of the country

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