Performance of Six Generations on Two Rice Crosses under Submergence Stress and Non-stress Conditions

Abstract
Submergence tolerance has long been regarded as an important breeding objective for rain-fed lowland and deep water rice area. Despite this recognition, there has been limited success in developing rice with improved submergence tolerance in Africa. The present research was aimed at assessing performance of crosses under submergence stressed and non-stressed conditions in Nigeria. Six generations of the crosses were evaluated under optimum and submerged conditions in a complete randomized block design with three replications. Submergence screening was performed in controlled conditions that allowed flooding at a water depth of 1.0 meter for a period of 14 days. The results revealed that significant difference among the generations of the two crosses evaluated. The observed survival rate (%) in Cross I of the generations ranged between 0.00% - 100% while in Cross II, it ranged between 0.00% and 95.24%. The phenotypic coefficients of variation (PCV) and the genotypic coefficient of variation (GCV) for 100 grain weight were moderate to high under the two conditions. Low to moderate PCV and GCV coefficients of variation were observed for the grain width and grain length under both conditions in the two crosses. High heritability (0.96% respectively) and high genetic advance as percentage of mean were recorded for the grain yield and grain weight in the two crosses. The variability observed among the generations was optimum however, advancement of the segregating generations coupled with adequate selection criteria could lead to identification of superior and stable genotypes for farmers' use.

Keywords: Submergence, Rice, Tolerant, Susceptible, Variability

Introduction

The rain fed lowland agriculture system which is typical to sub-Saharan Africa and most developing countries depends entirely on rainfall which is sometimes unpredictable (Collard *et al.*, 2013b). During the rainy season, the high incidence of rainfall can sometimes lead to floods. These flooding incidences have been projected to be on the increase as a result of climate change. Flooding imposes severe pressure on plants, principally because excess water in the plant surroundings can deprive them of certain basic needs, notably oxygen, carbon dioxide and light for photosynthesis. (Septiningsih *et al.*, 2009). More than 16 million hectares of rice land in the world is lowland and deep-water rice areas and are unfavorably affected by flooding due to complete submergence, causing an annual economic loss of more than US$600 million (Septiningsih *et al.*, 2009).

Rainfed lowland rice production occupies more than 70 % of total rice area in Nigeria and this ecology is prone to recurrent flooding caused by heavy rainfall, overflow of nearby rivers and most recently unpredictable weather conditions occasioned by climate change effect. Often, yield losses occurred from the flooding may range from 10 % to total crop loss (Africa Rice, 2017). In 2012, when Nigeria experienced the worst flooding in 40 years, it was reported that floods reduced rice production by about 22 %. 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 and the only possible solution to tackle this problem is the use of flood-tolerant varieties (Africa Rice, 2017).

The submergence tolerant gene *SUB-1A*, derived from an India rice variety grown in Orissa, has been widely used to improved many cultivars around the globe (Karin *et al*., 1982; Emes *et al*., 1988). Studies on flood-tolerant varieties can contribute to achieving this goal by boosting rice production and helping reduce dependence on costly rice imports. Providing farmers with protection against short-term flooding can serve as a type of 'insurance policy' for their rice, making them feel reassured to invest in agriculture, leading to higher rice yields (Africa Rice, 2017). Developing tolerant rice varieties has been documented as an alternative strategy to reduce the impact of submergence problem on farmers (Mackill *et al*. 1993; Zeigler and Puckridge 1995; Wassman *et al*. 2009). This will not increase production costs for farmers and production stability can be maintained (Septiningsih *et al*. 2013a; Rumanti *et al*. 2016a). Previous studies have reported successful development of submergence tolerant varieties by introgressing the *Sub1* locus (Siangliw *et al*., 2003; Toojinda *et al*., 2005). Therefore, the present research was aimed at assessing the performance of some submergence rice lines evaluated under normal and submergence conditions.

Materials and Methods

The experiments were carried out (between 2019 to 2021) at the crossing block (Longitude N 09^{o} 04.921′ and Latitude E 006^{o} 07.206′) and the rice production and research field (N09^{o} 04.238′ and Latitude E 006^{o} 06.638′) of the National Cereals Research Institute (NCRI), Badeggi. NCRI averagely receives an annual rainfall of about 1184mm, with temperature ranging from 25.9 to 31.1 ^{0}C and relative humidity of about 77 %.

The parental materials (Swarna Sub-1 and FARO 44 and 57) and their progenies (crosses) used for the study were sourced from the National Cereals Research Institute, Badegggi, Nigeria. Swarna Sub-1 is a submergence tolerant rice line used as a donor parent line for the crosses (F_1, F_2, BC1 and BC2), while FARO44 and FARO57 are commercially cultivated in Nigeria but susceptible to submergence. Six generations of two crosses (Swarna sub1 × FARO 44 - Cross I and Swarna sub1 × FARO 57 – Cross II**)** made in the Institute were used for the study. The parent FARO44 was designated as P1 in Cross I, FARO57 was designated as P1 in cross II, while Swarna Sub-1 was designated as P2 in the two crosses.

The six generations, namely, Parent one (P1), Parent two (P2), filial generations (F1, F2) and the two backcrosses (BC1, BC2) were raised in a complete randomized block design in normal and submerged conditions, with three replications. The blocks were arranged in a family compact design manner to reduce influence of the exogenous factors on the entries of the same family. Twenty-one days old seedlings were evaluated in both conditions. Recommended packages of practices for rice in the region were followed to raise healthy crops. Submergence screening was performed in controlled conditions that allow flooding with water depth of 1.0 meters for a period of 14 days. The plants were de-submerged and the survival of plants was scored after 20 days of recovery according to Pamplona *et al. (*2007). For each set of the crosses, a minimum of twenty (21) seedlings of both parents (P1 and P2), ten (10) seedlings for F_1, four hundred and two (402) seedlings of F_2 and twenty (20) seedlings each of BC1 and BC2 were evaluated in two seasons. Thirteen (13) agronomic data were taken according to Standard Evaluation System for Rice (IRRI, 2013).

Statistical Analysis

The data generated were subjected to Analysis of Variance and the means were separated using Least Significant Difference (LSD) at 5% probability level. Statistical Package, Statistical Tools Agricultural Research (STAR) was employed to analyse the data.

Results and Discussion

The Table 1 presents the mean square values from the Analysis of Variance (ANOVA) for the 13 agronomic traits assessed among the six generations of the two crosses (Cross I & Cross II) across two cropping seasons. The ANOVA showed significant differences for the grain physical parameters among the generations of the crosses (Table 1). The 100 seed weight (SW) revealed statistical difference among the generations of the two crosses under normal and submerged conditions in both evaluation years. The combined mean square revealed significant difference at 1% probability level for the SW under normal and submerged conditions in the Cross I and Cross II. No significant G×E interaction was shown for the trait in Cross I; however, this was significant in Cross II. The pooled mean square and G×E showed significant differences across the 13 agronomic data investigated. The grain width (GW) among the generations of the two crosses showed significant mean square for all sources of variation, except in the Year II and G×E for the Cross I. All sources of variations revealed significant difference for the Grain Length in the generations of the two crosses. The results showed significant differences for all the traits at vegetative growth, except for the Flag Leaf Width (FLW) and Stem Girth in both crosses under normal condition and G×E for the two traits in the Cross I (Table 1). The mean squares for all the sources of variation revealed significant differences for all the reproductive parameters (50%F, TN, PN, PL & SY) in both crosses (Table 1). The significant difference observed in some of the sources of variation is an indication to take cognizance of the sources. The effect of the genotypes indicated optimum variation among the generations, and this could be exploited for breeding purposes. The significance of G x E revealed the need for evaluation of the lines in more environment or over many years for optimum and reliable results as the source could influence the breeding decision. Similar significant difference was also reported by Singh *et al.* (2007). Rao *et al*. (2017) reported significant difference for majority of the trait reported here except flowering time and maturity. Wening *et al.* (2019) reported significant effect of genotype and G x E for days to flowering among 17 rice genotypes evaluated under optimum and submerged conditions.

Table 2 presents the mean performance and coefficients of variation for flag leaf width (FLW), flag leaf length (FLL) and straw girth (SG) among the six generations of the crosses (Cross I and Cross II) evaluated under normal and submerged conditions. Minimum and maximum values of 1.43cm (P1) and 1.94cm (BC2) respectively were observed for flag leaf width among the generation of Cross I under normal condition. Under Cross I submerged condition, mean values ranged between 1.53cm (P2) and 2.24cm (BC2). For the Cross II, ranges from 1.26cm to 1.70cm and 1.24cm to 1.70cm were recorded under normal and submerged conditions respectively. In both crosses under the two conditions, the F1 recorded higher means than the two parents. High phenotypic coefficients (PCV > 20%) of variation were registered under the two conditions in both crosses; however, low (PCV < 10%) and moderate (PCV: 10 – 20%) coefficients were observed in Cross I under normal and Cross II under submerged conditions respectively (Table 2). The F1s recorded longer flag leaf length in the two crosses, except under normal condition in Cross II. A range of 33.6cm to 40.37 with low phenotypic and genotypic coefficients of variation was recorded for Cross I under normal condition. The PCV and GCV were high for the trait under submerged in Cross I and normal condition in Cross II. Cross II under submerged conditions showed low coefficients of variation (Table 2). None of the crossed generations (F1, F2, BC1 & BC2) registered wider straw girth than the parental lines under normal conditions in the two crosses (Table 2). Low to high broad sense heritability ($H^2 > 60\%$) and low to moderate genetic advance as percentage of mean (6.38% to 18.65%) were recorded for the flag leaf width, flag leaf length and steam girth in the crosses (Table 2). Low to high genotypic and phenotypic coefficients of variation were observed for the straw girth under the two conditions.

Mean values for internode length, days to 50% flowering and plant height assessed among six generations of the two rice crosses are presented in the Table 3. High phenotypic and genotypic coefficients of variation were observed for the internode length in both crosses and under the two conditions. In the two crosses, the F1 values were higher than that of the mid parents; however, the population means in Cross I under both conditions were higher than that of Cross II (Table 3). Moderate to high coefficients of variation (PCV & GCV) were observed for days to 50% flowering in the two crosses (Table 3).The F1 generations recorded high days to 50% flowering than their mid parents in both crosses under the two conditions. In both crosses, F1 generations had taller plants under submerged conditions than those under normal conditions. PCV and GCV were moderate to high for plant height in the two crosses (Table 3). High heritability coupled with high genetic advance as percentage of mean was recorded for internode length in the two crosses (Table 3). Days to 50% flowering recorded high heritability in the two crosses and this was coupled with moderate to high genetic advance as percentage of mean (Table 3).

The GAM for the plant height ranged between low and moderate in the crosses. Low number of panicles, number of tiller and panicle length were observed in the F1 generations under submerged condition when compared to the F1 generations under normal conditions (Table 4). The population means for the number of panicles, number of tiller and panicle length were all higher under normal condition than submerged condition in the two crosses. High PCV and GCV were observed for the number of panicles in both crosses under the two conditions (Table 4). Number of tillers among the generations registered high PCV in both crosses except for Cross II under submerged condition. Moderate to high GCV were observed for the number of tillers in the two crosses. High PCV and moderate to high GCV were observed for the panicle length among the generations of the two crosses (Table 4). High heritability and high genetic advance as percentage of mean was observed for the number of panicle. The panicle number registered low to moderate GAM in the two crosses (Table 4).

Table 5 shows mean values and coefficients of variation for grain yield, grain weight, grain width and grain length of the six generations of the two rice crosses evaluated under normal and submerged conditions. Grain yield per plant of the two F1s, under normal and submerged conditions, ranged between 16.13g and 30.55g, with reduced grain yield under submerged condition observed in both crosses. The F1 and F2 generations of the crosses recorded high yield than the mid parents under the two conditions. High PCV and GCV were registered for the grain yield among the generations of the two crosses. The F1 as well as F2 generations of both crosses recorded high 100 grain weight than the mid parents (Table 5). The population means for grain weight under normal condition were higher than that under submerged condition. The coefficients of variation (PCV & GCV) for 100 grain weight were moderate to high under the two conditions (Table 5). Low to moderate PCV and GCV coefficients of variation were observed for the grain width and grain length under both conditions in the two crosses (Table 5). High heritability and high genetic advance as percentage of mean were recorded for the grain yield and grain weight in the two crosses (Table 5).

Variations in traits studied have been assessed based on mean, range, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). Variation based on mean and range only gives insight on the variables while the actual variability independent of units is estimated through phenotypic and genotypic coefficient of variations (Shivanna, 2008). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (GCV) could be described as high (>20%), moderate (10-20%) or low when it is less than 10% (Deshmukh *et al.*, 1986). According to Deshmukh *et al.* (1986) moderate to high GCV and PCV were observed for most of the traits studied. The magnitude of differences between PCV and GCV was low for most of the traits, revealing low influence of environmental factors on the phenotypic expression for the traits. The moderate to high heritability coupled with those of the genetic advance as percentage of mean observed for most of the studied traits suggested that selection for the traits could be easy and fairly possible using selection breeding. The effect of submergence on phenotypic variation of rice plants has been widely assessed by several researchers (Ahmed *et al*. 2013; Nugraha *et al*. 2013). Possible selection criteria for submergence superior rice genotypes were documented by Wening *et al.* (2019). Rao *et al.* (2017) reported that high phenotypic variation among six generations of a rice cross evaluated under submerged condition.

The survival rate (%) of the generations after 20 days of recovery from submergence is presented in the Table 6. The Cross I recorded survival rate ranging between 0.00% - 100% in the wet season of 2019 and 9.52% - 100% in the wet season of 2020. The percentage stem elongation for the Cross I ranged from 0.00% to 12.87% in the two years. For the Cross II, the survival rate ranged between 0.00% and 95.24% in the two evaluation years (Table 6). The percentage shoot elongation was between 0.00% and 11.22% in the two years. The high percentage survival observed in the F1 generations of the two crosses indicates successful introgression of the submergence tolerance genes in the crosses. The tolerant genotypes can be assessed by the survival rate (IRRI 2014). Similar range of survival rate submergence tolerant genotypes was reported by Wening *et al.* (2019), when screening some rice genotypes under artificial condition. Also, the trial reported by Rao *et al.* (2017) revealed survival range 20% and 98% in a cross between a submergence tolerant and susceptible genotypes. Yullianida *et al.* (2014) reported significantly correlation between the survival rate and the grain yield.

Conclusion

The present research results revealed optimum variability among the lines for phenotypic traits studied. Moderate to high broad sense heritability and genetic advance as percentage of mean were observed in the majority of the traits considered. Considering the results of the study, the variability observed among the lines could be exploited in advance generations of the crosses.

References

AfricaRice (2017). Nigeria releases AfricaRice "flood-tolerant" rice strains**.** *AfricaRice News blog*, Thursday, August 3, 2017. http://africarice.blogspot.com/2017/08/nigeria-releases africarice-flood.html

Ahmed, F., Rafii, M. Y., Ismail, M. R., Juraimi, A. S., Rahim, H. A., Asfaliza, R., (2013). Waterlogging tolerance of crops: breeding, mechanism of tolerance, molecular approach, and future prospects. *BioMed. Research International*, 1-10.

Collard, B. C. Y., Septiningsih, E. M., Das, S. R., Caradang, J. J., Pamplona, A. M., Sanchez, D. L., (2013b). Developing new flood tolerant varieties at the International Rice Research Institute (IRRI). *SABRAO Journal Breeding and Genetics*, 45: 42-56.

Deshmukh, S. N., Basu, M. S. and Reddy, P. S. (1986). Genetic variability, character association and path coefficients of quantitative traits in virginal bunch varieties of groundnut. *Indian Journal of Agricultural Sciences,* 56, 816-821.

Emes, M. J., Wilkins, C. P., Smith, P. A., Kupkanchanakul, K., Hawker, K., Charlton, W. A. and Cutter, E.G. (1988). Starch utilization by deepwater rice during submergence. *Proceedings of the 1987 International Deepwater Rice Workshop*, Bangkok, Thailand, 319–326.IRRI (2013). *Standard Evaluation System (SES) for Rice,* International Rice Research Institute, Manila, Philippines..

Karin, S., Vergara, B. S. and Mazaredo, A. M. (1982). Anatomical and morphological studies of rice varieties tolerant of and susceptible to complete submergence at seedling stage. *Proceedings of the 1981 International Deepwater Rice Workshop*, Bangkok, Thailand: 287–291.

Mackill, D. J., Amante, M. M., Vergara, B. S. and Sarkarung, S. (1993). Improved semidwarf rice lines with tolerance to submergence of seedlings. *Crop Science*, 33: 749-753.

Nugraha, Y., Vergara, G.V., Mackill, D. J. and Ismail, A. M. (2013). Response of Sub1 in introgression lines of rice to various flooding conditions. Indonesia Journal of Agricultural Science, 14: 15-26.

Pamplona, A., Ella, E., Singh, S., Vergara, G. V., Ismail, A. and Mackill, D. J. (2007). Screening procedure for tolerance of complete submergence in rice. *Sub1 Rice News,* 1 (2).

Rao, M., Grithlahre, S., Bisen, P., Loitongbam, B., Dar, M.H., Zaidi, N.W., Singh, U.S. and Singh, P.K. (2017). Generation Mean Analysis for Grain Yield and Its Component Traits in Submergence Rice. *SABRAO Journal of Breeding and Genetics*, 49(4): 327-335.

Rumanti, I. A., Nugraha, Y., Wening, R. H., Gonzaga, Z. J. C., Suwarno, Nasution, A., (2016a). Development of high-yielding rice varieties suitable for swampy lands in Indonesia. *Plant Breeding and Biotechnology*, 4: 413-425.

Septiningsih, E. M., Collard, B. C. Y., Heuer, S., Bailey-Serres, J., Ismail, A. M. and Mackill, D. J. (2013a). Applying genomics tools for breeding submergence tolerance in rice (pp. 9-30). In: RK. Varshney, R. Tuberosa (eds.). *Translational Genomics for Crop Breeding 2: Abiotic Stress, Yield and Quality*. John Wiley and Sons Inc., Hoboken, New Jersey, U.S.A.

Septiningsih, E. M., Pamplona, A. M., Sanchez, D. L., Neeraja, C. N., Vergara, G. V., Heuer, S., Ismail, A. M. and Mackill, D. J. (2009). Development of submergence tolerant rice cultivars: the Sub1 locus and beyond**.** *Annals of Botany*, 103: 151-160.

Siangliw, M., Toojinda, T., Tragoonrung, S., and Vanavichit, A. (2003). Thai jasmine rice carrying QTL ch9 (SubQTL) is submergence tolerant. *Annals of Botany*, 91, 255–61.

Singh R.P, Kumar M.S, Madhavilatha L (2007). Variability and relationship studies of yield and yield attributing traits in diverse lines of international irrigated observational nursery of rice (*Oryza sativa* L.). *Journal of Research ANGRAU*, 35: 16-22.

Shivanna, S. (2008). Genetic diversity, combining ability and stability analysis of selected castor lines. PhD thesis submitted to the University of Agricultural Sciences, Bangalore, 28-45

Toojinda, T., Siangliw, M., Tragoonrung, S. and Vanavichit, A. (2003). Molecular genetics of submergence tolerance in rice: QTL analysis of key traits. *Annals of Botany* 91(2), 243 253.

Wassman, R., Jagadish, S. V. K., Heuer, S., Ismail, A., Redona, E., Serraj, R., (2009). Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies. *Advance Agronomy*, 101: 59-122.

Wening, R. H., Rumanti, I. A., Purwoko, B. S., Suwarno, W. B. and Khumaida, N. (2019). Screening of Submergence Tolerant Rice under Artificial Condition Based on Multiple Selection Indices. *Plant Breeding and Biotechnology*, 7(4): 360 - 374. https://doi.org/10.9787/PBB.2019.7.4.360

Yullianida, Suwarno, Ardhie, S. W. and Aswidinnoor, H. (2014). Ujicepat toleransi tanaman padi terhadap cekaman rendaman pada fase vegetatif (abstract in English). *Jurnal Agronomi Indonesia*, 42: 89-95.

Zeigler, R. S. and Puckridge, D. W. (1995). Improving sustainable productivity in rice-based rainfed lowland systems of South and Southeast Asia. *GeoJournal*, 35: 307-324.

Table 1: Mean Square for 13 agronomic traits of two rice crosses evaluated under normal and submergence condition over two years

	Cross I (Swarna sub1 × FARO 44)						Cross II (Swarna sub1 × FARO 57)							
	Normal		Submerged		Combined		Normal		Submerged		Combined		Pooled	
Traits	Year I	Year II	Year I	Year II	Genotype	G x E	Year I	Year II	Year I	Year II	Genotype	G x E	Entries	G x E
FLW	0.09^{ns}	0.13^{ns}	2.03**	1.66**	2.75**	0.38^{ns}	0.07^{ns}	0.09^{ns}	1.34**	1.08**	1.81**	0.26*	4.48**	0.29*
FLL	21.43*	24.50*	953.70**	787.23**	891.52**	298.44*	16.07*	17.93*	599.19**	485.28**	538.96**	193.17**	1397.34**	215.43**
SG	0.13**	0.13**	3.60**	2.98**	2.56**	1.42^{ns}	0.10**	0.10**	2.71**	2.31**	2.15**	1.02**	4.57**	1.07*
50%F	285.02**	327.57**	6944.92**	5762.07**	8471.23**	1616.11**	284.56**	329.38**	4110.21**	3342.17**	5502.37**	854.65**	13778.94**	1086.71**
TN	40.37**	42.68**	516.50**	424.85**	632.27**	130.70**	24.96**	31.12**	428.64**	345.56**	527.71**	100.86**	1147.86**	100.98**
PH	148.63*	252.97*	5814.89**	4744.96**	3873.56**	2362.62**	92.89*	173.73*	5144.30**	4148.75**	3517.93**	2013.91**	7382.91**	1876.89**
PN	50.72**	57.80**	153.38**	135.33**	301.19**	32.01**	34.43**	37.78**	130.51**	111.38**	240.89**	24.40**	538.74**	24.65**
PL	23.90*	26.12*	472.74**	392.87**	352.92**	187.56**	18.68*	19.55*	362.87**	293.06**	270.70**	141.15**	612.31**	142.50**
IL	43.52**	46.20**	181.43**	146.28**	282.31**	45.03**	33.19**	33.00**	137.43**	113.37**	221.29**	31.90**	501.00**	33.35**
GY	393.08**	527.48**	433.71**	375.69**	1276.61**	151.11**	275.10**	339.01**	303.96**	260.79**	868.53**	103.44**	2124.74**	112.01**
GW	0.64**	0.59**	4.01**	4.51**	4.17**	1.86^{ns}	0.52**	0.47**	3.84**	3.14**	3.63**	1.44**	7.78**	1.42*
GWt	0.03**	0.04^{ns}	4.02**	3.24**	3.85**	1.16^{ns}	0.01**	0.03**	3.21**	2.69**	3.00**	0.98**	6.73**	0.93*
GL	2.10**	2.18**	75.83**	63.34**	72.01**	23.81*	1.23**	1.78**	48.02**	40.74**	44.82**	15.65**	113.48**	17.39*

Note: FLW – Flag leaf width (cm), FLL – Flag leaf length (cm), SG – steam girth (cm), 50%F- Days to 50% flowering, TN – Number of tiller, PH – Plant height (cm), PN – Number of panicles, PL – Panicle Length (cm), IL – Internode Length (cm), GY – Grain yield (g/plant), GW – Grain weight (g), GWt – Grain width (mm), GL – Grain length (mm), Year I – 2019; Year II – 2020.

Table 2: Mean Values and Coefficients of Variation for Flag Leaf Width, Flag Leaf Length and Straw Girth assessed among Six Generations of the Two Rice Crosses

	Flag Leaf Width (cm)				Flag Leaf Length (cm)				Straw Girth (cm)			
	Cross I		Cross II		Cross I		Cross II		Cross I		Cross II	
Generations	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged
P1	1.43	0.00	1.26	0.00	39.64	0.00	35.04	0.00	2.87	0.00	2.52	0.00
P2	1.58	1.53	1.35	1.24	33.60	31.75	29.64	28.73	2.81	2.52	2.42	2.36
F1	1.82	1.96	1.53	1.52	36.16	40.12	32.01	31.09	2.51	2.71	2.19	1.96
F2	1.80	1.64	1.55	1.51	39.68	36.60	34.60	33.10	2.28	2.68	2.00	2.07
BC1	1.80	1.70	1.59	1.58	40.37	44.69	35.24	33.58	2.70	2.40	2.36	2.48
BC2	1.94	2.24	1.70	1.70	40.25	45.46	35.00	35.45	2.64	2.34	2.30	2.07
Mean	1.79	1.81	1.50	1.26	38.01	39.72	33.59	26.99	2.59	2.53	2.30	1.82
Minimum	1.43	1.53	1.26	1.24	33.60	31.75	29.64	28.73	2.28	2.34	2.00	2.07
Maximum	1.94	2.24	1.70	1.70	40.37	45.46	35.24	35.45	2.87	2.71	2.52	2.48
LSD	NS	0.87	NS	0.61	4.06	6.04	3.49	5.81	0.14	0.22	0.12	0.46
PCV (%)	20.39	41.44	39.36	24.49	7.65	35.72	33.65	9.26	6.99	34.07	33.76	8.67
GCV (%)	8.60	35.16	34.59	10.36	5.93	34.91	32.57	7.19	6.57	30.70	31.44	8.20
H^2	0.18	0.27	0.77	0.18	0.60	0.95	0.94	0.60	0.88	0.98	0.92	0.89
GAM	6.38	12.50	13.50	7.71	8.10	16.04	15.48	9.83	10.87	18.65	14.85	13.63

LSD – Least significance Difference, PCV – phenotypic coefficient of variation, GCV - genotypic coefficient of variation, GAM – Genetic Advance as Percentage of Mean; P1 – Susceptible Parents in the crosses; P2 – Resistant parent

Table 3: Mean Values and Coefficients of Variation for Internode Length, Days to Flowering and Plant Height assessed among Six Generations of the Two Rice Crosses

	Internode Length (cm)				Days to 50% Flowering				Plant Height (cm)			
	Cross I		Cross II		Cross I		Cross II		Cross I		Cross II	
Generations	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged
P1	15.52	0.00	13.40	0.00	67.95	0.00	67.95	0.00	97.19	0.00	113.38	0.00
P2	12.32	11.56	10.91	11.11	87.73	117.59	88.50	94.96	79.21	96.08	94.66	92.89
F1	13.99	15.37	12.18	12.74	68.36	98.36	69.09	73.01	80.76	98.72	94.33	96.96
F2	22.77	21.32	19.88	19.28	81.83	118.64	82.44	84.52	87.61	103.78	105.05	99.56
BC1	12.45	12.34	11.07	10.61	70.13	90.39	70.13	71.10	86.65	110.26	98.80	102.95
BC2	15.30	18.14	13.59	15.13	89.50	117.99	89.50	91.22	82.41	102.04	94.02	91.11
Mean	15.37	15.75	13.51	11.48	79.51	108.59	77.94	69.14	83.33	101.78	100.04	79.58
Minimum	12.45	11.56	10.91	10.61	67.95	90.39	67.95	71.10	79.21	96.08	94.02	90.96
Maximum	15.52	21.32	19.88	19.28	89.50	118.64	89.50	94.96	97.19	110.26	113.38	102.95
LSD	3.01	3.13	2.64	2.54	5.23	7.16	3.48	4.16	12.23	14.65	10.32	12.14
PCV (%)	22.37	39.42	40.04	25.81	10.69	34.78	37.02	12.24	13.54	34.33	32.63	19.09
GCV (%)	20.53	38.19	38.98	23.60	10.16	34.50	36.80	11.78	10.60	31.55	30.01	16.58
H^2	0.84	0.94	0.95	0.84	0.90	0.98	0.99	0.93	0.52	0.96	0.96	0.52
GAM (%)	33.17	65.12	66.80	37.98	16.99	60.21	64.38	19.94	9.64	17.70	15.27	8.38

LSD – Least significance Difference, PCV – phenotypic coefficient of variation, GCV - genotypic coefficient of variation, GAM – Genetic Advance as Percentage of Mean; P1 – Susceptible Parents in the crosses; P2 – Resistant parent

Table 4: Mean Values and Coefficients of Variation for Number of Panicle, Number of Tiller and Panicle Length assessed among Six Generations of the Two Rice Crosses

	Number of Panicle				Number of Tiller				Panicle Length (cm)			
	Cross I		Cross II		Cross I		Cross II		Cross I		Cross II	
Generations	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged	Normal	Submerged
P1	14.40	0.00	12.10	0.00	28.55	0.00	24.15	0.00	32.51	0.00	28.17	0.00
P2	14.66	14.34	12.38	12.29	37.01	33.50	30.97	31.48	26.68	24.18	23.03	24.29
F1	24.00	21.17	19.91	19.64	26.87	25.65	23.32	22.84	27.92	22.19	24.11	21.80
F2	12.40	11.12	10.35	9.82	31.68	28.86	26.88	25.89	29.87	30.00	25.84	26.48
BC1	13.55	14.41	11.45	10.84	27.47	30.05	22.85	21.74	32.28	28.80	28.05	27.11
BC2	13.91	12.81	11.69	12.58	32.25	31.02	26.76	29.30	25.72	28.16	22.27	24.37
Mean	15.70	14.77	12.98	10.86	31.06	29.82	25.82	21.88	28.49	26.67	25.25	24.18
Minimum	12.40	11.12	10.35	9.82	26.87	25.65	22.85	21.74	25.72	22.19	22.27	21.29
Maximum	14.66	14.41	19.91	19.64	32.25	33.50	30.97	31.48	32.51	32.19	28.17	27.11
LSD	1.26	2.14	1.05	1.80	4.60	6.64	3.89	3.89	4.61	3.22	3.93	5.62
PCV (%)	22.43	38.92	40.46	26.45	21.88	35.78	36.61	13.98	21.03	34.63	35.32	22.83
GCV (%)	22.05	38.30	29.87	21.05	19.68	34.21	25.79	11.32	18.24	24.12	23.71	19.73
H^2	0.97	0.97	0.97	0.97	0.66	0.91	0.96	0.66	0.56	0.97	0.91	0.57
GAM (%)	38.16	66.34	69.14	45.16	13.87	57.59	61.58	16.13	10.83	19.17	16.61	12.97

LSD – Least significance Difference, PCV – phenotypic coefficient of variation, GCV - genotypic coefficient of variation, GAM – Genetic Advance as Percentage of Mean; P1 – Susceptible Parents in the crosses; P2 – Resistant parent

Table 5: Mean Values and Coefficients of Variation for Grain Yield, Grain Weight, Grain Width and Grain Length assessed among Six Generations of the Two Rice Crosses

	Grain Yield (g/plant)				100 Grain Weight (g)				Grain Width (mm)				Grain Length (mm)			
	Cross I		Cross II		Cross I		Cross II		Cross I		Cross II		Cross I		Cross II	
Generations	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
P1	38.26	0.00	31.68	0.00	3.01	0.00	2.88	0.00	2.70	0.00	2.36	0.00	11.36	0.00	9.71	0.00
P2	26.40	18.90	21.07	16.07	2.32	2.33	2.01	2.06	2.63	2.65	2.26	2.40	9.66	8.05	8.07	7.49
F1	57.66	36.44	47.28	30.60	3.02	2.27	2.77	2.87	2.89	2.65	2.44	2.48	11.43	13.52	9.94	9.37
F2	30.55	19.88	24.80	16.13	3.00	2.93	2.81	2.72	2.79	2.59	2.41	2.35	11.02	11.48	9.59	8.87
BC1	32.63	21.13	27.61	15.69	3.09	2.85	2.80	2.71	2.76	2.92	2.35	2.18	11.77	10.12	9.78	9.64
BC2	23.66	17.26	19.78	14.67	2.36	2.56	2.15	2.28	2.87	2.55	2.40	2.60	10.78	11.46	9.21	10.27
Mean	34.18	22.72	28.70	15.53	2.76	2.59	2.57	2.11	2.79	2.67	2.37	2.00	10.93	10.93	9.38	7.61
Minimum	23.66	17.26	21.07	14.67	2.32	2.27	2.01	2.06	2.63	2.55	2.26	2.18	9.66	8.05	8.07	7.49
Maximum	57.66	36.44	47.28	30.07	3.09	2.93	2.88	2.87	2.89	2.92	2.44	2.60	11.77	13.52	9.94	10.27
LSD	5.75	3.93	2.68	3.33	0.13	0.23	0.07	0.22	0.17	0.29	0.09	0.28	0.78	1.00	0.30	1.49
PCV (%)	30.67	42.49	28.11	53.95	13.54	38.15	34.43	15.81	4.31	14.01	13.62	3.65	7.26	16.28	14.26	7.89
GCV (%)	29.32	41.67	27.55	52.83	13.33	37.02	34.16	15.67	3.00	13.48	11.08	2.04	5.88	15.89	13.09	7.18
H^2	0.91	0.96	0.96	0.96	0.97	0.94	0.98	0.98	0.48	0.97	0.97	0.31	0.66	0.98	0.95	0.83
GAM (%)	49.32	71.91	47.50	91.07	23.09	63.23	59.66	27.33	3.68	8.00	9.04	2.01	8.39	12.48	17.26	11.51

LSD – Least significance Difference, PCV – phenotypic coefficient of variation, GCV - genotypic coefficient of variation, GAM – Genetic Advance as Percentage of Mean; P1 – Susceptible Parents in the crosses; P2 – Resistant parent

Table 6: Survival rate of the two crosses in the two evaluation years

Crosses	Generations	Year 2019				Year 2020			
		No. of Seedlings planted	Number of plants survived	Observed % survival	% Shoot elongation (cm)	Number of individuals planted	Number of plants survived	Observed % survival	% Shoot elongation (cm)
	P1	21.00	0.00	0.00	0.00	21.00	2.00	9.52	1.29
Cross I	P2	21.00	20.00	95.24	5.54	21.00	20.00	95.24	5.81
	F1	21.00	21.00	100.00	6.41	21.00	21.00	100.00	6.89
	F2	402.00	310.00	77.11	5.47	402.00	303.00	75.37	7.45
	BC1	15.00	8.00	53.33	5.18	15.00	8.00	53.33	8.79
	BC2	15.00	14.00	83.33	10.82	15.00	13.00	86.67	12.87
Cross II	P1	21.00	1.00	0.00	0.00	21.00	0.00	0.00	0.00
	P2	21.00	19.00	90.48	6.75	21.00	21.00	100.00	7.08
	F1	21.00	19.00	90.48	6.24	21.00	20.00	95.24	7.33
	F2	402.00	298.00	74.12	4.53	402.00	295.00	73.38	6.62
	BC1	15.00	7.00	46.67	1.56	15.00	8.00	53.33	1.72
	BC2	15.00	13.00	86.67	11.22	15.00	12.00	80.00	9.37