Biological Forum – An International Journal 15(9): 330-339(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Evaluation of Rice Accessions for Anaerobic Germination, Yield and Attributing Parameters in Direct Seeded Rice condition

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(Received: 21 June 2023; Revised: 28 July 2023; Accepted: 25 August 2023; Published: 15 September 2023)
(Published by Research Trend)

ABSTRACT: Improving the tolerance against anaerobic germination has been the leading target domain in lowland areas, especially in Direct Seeded Rice (DSR) conditions. Flash flooding is a major issue in lowland rice cultivation. Direct seeded rice is affected by anaerobic stress. Most higher yielding modern rice varieties die within a week of complete submergence, making them unsuitable alternatives of traditional rice landraces. The present study was carried out to identify the elite genotypes for tolerance against anaerobic germination and yield parameters among twenty-five diverse rice genotypes under DSR. Traits namely germination percentage, seedling height, days to 50% flowering, early seedling vigour, leaf length, leaf width, number of productive tillers, panicle length, panicle weight, number of filled grains, spikelet fertility, 1000 grain weight and single plant yield were recorded.

Chitiraikar showed maximum germination percentage (100 %). The plant height was the highest in Garudan samba (124 cm). Chitiraikar showed the highest seedling vigour of 5185. Aanaikomban had 26 more productive tiller (26 Nos). Single plant yield was also greater in Aanaikomban (38.11 g). The genotypes Chitiraikar, Aanaikomban, Karunguruvai and CR1009 *sub-1* had better performance when compared to other genotypes. The highest PCV% and GCV% were found in the early seedling vigour (92.56 % and 70.97%) and the lowest (moderate) in spikelet fertility (9.53% and 9.51 %). The traits *viz.*, number of productive tillers (0.36), panicle weight (0.64**), number of filled grains (0.211**), and 1000 grain weight (0.81**) exhibited a significant positive association with single plant yield. The results of the PCA exhibited that PC1, PC2 and PC3 accounted for 23.97 %, 18.47% and 14.14% variation respectively. Cluster analysis showed that cluster III had the highest mean and encompassed the major influencing traits. Six clusters were formed and the genotypes were grouped based according to their performance. Cluster I and II contains seven genotypes. Thus, choosing the genotypes with these important traits mentioned above can increase the tolerance for anaerobic germination in DSR condition.**

Keywords: Rice, Abiotic stress, Anaerobic germination tolerance, Direct seeded rice, Screening.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal food crops and the main food source for more than one-third of the world's population. Over 90 per cent of the world's rice is produced and consumed in Asia (Bandumula, 2018). There exists a tremendous ecological diversity in Asian countries due to the various climatic conditions, soil, cultural practices and human selection. Rice occupies an area of about 46.38 million hectares with a production of 130.29 million tonnes and productivity of 2809 kg/ha during 2021-22 (4th advance estimates, E&S Division, DA&FW). Abiotic stresses like water deficit, absence of anaerobic respiration, submergence, salinity, and deficiencies of P and Zn greatly affect rice production worldwide. There is a 50% reduction in average yields of all major crops due to abiotic stresses and it is the main cause of crop failure worldwide (Varshney and Tuberosa 2013).

Direct-seeded rice (DSR) has emerged as a feasible alternative establishment method to deal with water and labour shortages (Sun *et al.*, 2015). The concept of direct seeding in rice cultivation involves the practice of planting rice by directly sowing seeds into the field. There are three primary methods of direct rice seeding: dry seeding, which involves sowing dry seeds into dry soil; wet seeding, which entails sowing pre-germinated seeds on wet puddled soil; and water seeding, where seeds are sown into standing water (Xu *et al.*, 2019. Due to its cost-effectiveness, direct seeding of rice is more readily embraced by rice farmers aiming to maximize their economic returns. By the early 21st century, direct seeding of rice covered 21% of the total rice cultivation area in Asia (Xu *et al.*, 2019). In recent years, this method has gained popularity among farmers in numerous traditional rice-growing regions (Sun *et al.*, 2015).

Direct-seeded rice is affected by anaerobic stress. Rice encounters anaerobic stress during the seed germination and seedling stage. Due to excessive flooding in the field, the seeds sown will experience stress and suffer from a lack of oxygen. Anaerobic germination tolerance rice genotypes showed seed germination and the emergence of seedlings above the surface of water (Chamara *et al.*, 2018). Improvement of rice genotypes for tolerance against anaerobic germination during the seedling stage is very important for direct seeded rice production (Septiningsih *et al.*, 2013). At the end of this experiment, elite genotypes are isolated which is tolerant towards anaerobic germination suitable in DSR conditions.

MATERIALS AND METHODS

Twenty-five diverse genotypes of rice (Table 1) were selected and used as the experimental materials which were collected from all over Tamil Nadu. DSR experiment was conducted at Karunya Institute of Technology and Sciences, South Farm.

A. Phenotyping for anaerobic germination

Ten seeds of all 25 genotypes were directly sown in the well-drained field. The water level was kept at a height of 5 cm until germination. Germination percentage was recorded on the 7^{th} to 10^{th} day and seedling height was recorded on the 25^{th} day while leaf length and width was calculated on 45^{th} day. This was because the seedling stage commences within 30 days and after that tillering phase will start. Usually tillering starts after 30 days. After germination, the field was flooded and the stress condition was induced. Anaerobic condition prevailed. The genotypes which continued to grow even after the stress was regarded as anaerobic germination tolerance lines. The experiment was replicated twice using Randomized Block Design (RBD) per genotype.

B. Statistical analysis

The difference among the genotypes were tested by Analysis of Variance (ANOVA) in RBD. Comparison of mean was done by the least significant difference test when the F value showed at least $p < 0.05$ level of significance. Genetic variability and heritability studies, correlation analysis between different traits, multi-variate analysis like cluster analysis and Principal Component Analysis (PCA) were done to group the genotypes based on performance and done with the help of STAR tool (Statistical Tool for Agricultural Research) and R software (https://cran.r-project.org/) version 4.2.2.

RESULTS AND DISCUSSION

A. Analysis of variance

The Analysis of Variance for thirteen traits showed a significant variation at $p < 0.05$ for all the traits among the 25 genotypes studied as mentioned in Table 2.

Table 1: List of rice genotypes used in the present study.

Sr. No.	Genotypes	Landraces/Variety	Area	Sr. No	Genotypes	Landraces/Variety	Area
1.	CO54	Variety	Tamil Nadu	13.	Karuppukavuni	Landrace	AC and RI, Madurai
2.	Sorna masuri	Landrace	Tamil Nadu	14.	Karunguruvai	Landrace	SSF, Kanyakumari
3.	Kalasar nel	Landrace	Kottaram	15.	Sivappukavuni	Landrace	Tamil Nadu
4.	Chitiraikar	Landrace	AC and RI, Madurai	16.	JCL nel	Landrace	Tamil Nadu
5.	Kullakar	Landrace	Tamil Nadu	17.	CO55	Variety	Tamil Nadu
6.	Seeraga samba	Landrace	Tamil Nadu	18.	TPS5	Variety	Tamil Nadu
7.	CR1009 *sub-1*	Variety	Tamil Nadu	19.	Kichili samba	Landrace	Tamil Nadu
8.	Kuzhiyadichan	Landrace	Tamil Nadu	20.	CO52	Variety	Tamil Nadu
9.	CO51	Variety	Tamil Nadu	21.	TPS3	Variety	Tamil Nadu
10.	Aanaikomban	Landrace	Tamil Nadu	22.	CO53	Variety	Tamil Nadu
11.	Thanga samba	Landrace	Thanjavur	23.	ASD16	Variety	Tamil Nadu
12.	ADT45	Variety	Tamil Nadu	24.	Milagu samba	Landrace	AC and RI, Madurai
				25	Garudan Samba	Landrace	Tamil Nadu

Table 2: Analysis of variance for the traits studied among 25 rice genotypes.

	Mean sum of squares		
Traits	Genotype	Replication	Error
Germination percentage (%)	1893**	0.44	2.71
Days to 50% flowering (days)	455.1**	7.33	2.87
Early seedling vigour	2749927.17**	813067.52	713648.02
Plant height (cm)	617.5**	4.18	3.02
Leaf length (cm)	460.1**	0.33	0.95
Leaf width (cm)	0.07**	0.00005	0.0004
No of productive tillers (nos)	109.76**	0.03	0.03
Panicle length (cm)	39.52**	1.69	1.1
Panicle weight (g)	1.80**	0.00005	0.0002
Number of filled grains (nos)	1122.06**	0.28	0.73
Spikelet fertility percentage (%)	207.52**	0.35	0.30
1000 grain weight (g)	109.59**	1.97	1.27
Single plant yield (g)	126.51**	0.28	0.59

Similar results for the analysis of variance were also found by Singh *et al*. (2019); Panda *et al*. (2020); Gautam *et al*. (2023).

B. Descriptive statistics

In the field experiment with the DSR condition, Thanga samba was recorded with minimum trait value (20 %) and Chitiraikar showed maximum germination percentage (100 %). Germination percentage is the successful trait to ensure the establishment of seedlings and subsequent seedling vigour (Miro and Ismail 2013). Among the twenty-five genotypes that were germinated under anaerobic conditions, the landraces have been recorded to have high germination percentage when compared with popular varieties. This was again confirmed by the research outcomes of Partheeban *et al.* (2017). Vergara *et al.* (2014) also reported that the performance of landraces when compared to cultivated varieties was better under flooding conditions. Chitiraikar had the best germination performance in DSR condition. The current study states that there is a broad genetic variation for anaerobic germination in rice. This was also presented by Vergara *et al.* (2014). Based on germination percentage under low oxygen stress the genotypes were grouped as highly tolerant, moderately tolerant and highly Susceptible (Partheeban *et al.*, 2017). Hence, the genotypes that exhibit a high level of tolerance can be utilized as contributors in programmes focused on enhancing crop improvement to anaerobic stress conditions. Vergara *et al.* (2014) also reported that variation in the tolerance of rice to long-term stagnant flooding that submerges most of the shoot will aid in breeding tolerant cultivars. According to Reddy and Redd (1997), plant height is a crucial growth factor for any crop because it determines or modifies traits that contribute to yield, which in turn affects grain production. The plant height ranged from 75.67 cm (Karunguruvai) to 124 cm (Garudan samba). In the case of early seedling vigour, JCL nel had the lowest trait value of 180 and Chitiraikar showed the highest trait value of 5185. Greater seedling vigour is a useful attribute in direct-seeded rice (Vu *et al*., 2016). Barua *et al.* (2018) reported that only 43 genotypes out of 243 rice genotypes showed germination under anaerobic conditions and were found to be variable among themselves for anaerobic germination, seedling vigour index, and seedling length. The leaf length ranged from 16.4 cm (ADT45) to 70.4 cm (Karuppukavuni). In the present study, genotypes like CO51 (82 days), CR 1009 *sub-1*, Karunguruvai and JCL nel (90 days) showed early flowering when compared to other genotypes. Therefore, these genotypes can be used for breeding for early flowering. In research conducted with 83 genotypes for different phenotype characteristics, the genotypes showed flowering between 80- 90 days. In another investigation, they found out ADT37 and CO51 showed early flowering (Deepika *et al*., 2019). Regarding leaf width, ADT45 had the lowest trait value of 0.5 cm and Kichili samba had the highest leaf width of 1.4 cm. The productive tillers ranged from 2.33 (Milagu samba) which had less productive tillers to 26 (Nos) (Aanaikomban) which exhibited more productive tillers. A study with 50 Indian genotypes had the number of productive tillers in the range of 8.5 to 42.5 nos (Gunasekaran *et al*., 2022). In another study, the line RNR 15048 showed highest mean for number of productive tillers (Deepika *et al*., 2019). Sorna masuri had the least panicle length of 16 cm while, Kalasar nel had the highest panicle length of 32.33 cm. The panicle weight ranged from 1.15 g (CO54) to 4 g (Sorna masuri, Kuzhiyadichan, CO51, Aanaikomban. TPS5, Kichili samba). The range of number of filled grains per panicle is between 91 Nos (Seeraga samba) to 183 Nos (Kalasar nel). Spikelet fertility percentage was recorded the least in Seeraga samba (70%) and the most inTPS5 (96%). In a study on quantitative characteristics, they observed the mean of 70.88 % for spikelet fertility (Pratap *et al*., 2018). 1000 grain weight had a range between 13.64 g (Thanga samba) to 36.20 g (JCL nel). Furthermore, single plant yield was lower in Thanga samba (10.48 g) and greater in Aanaikomban (38.11 g) (Table 3).

Table 3: Descriptive statistics of anaerobic germination traits among 25 rice genotypes.

Variable	Mean	Min	Max	Std Dev	CV (%)	CD at 5%
Germination percentage (%)	43.2	20	100	25.12	58.14	2.70
Days to 50% flowering (days)	114.23	82	134	12.32	10.79	2.78
Early seedling vigour	1423.2	180	5185	1171.33	82.30	1743.53
Plant height (cm)	103.51	75.67	124	14.35	13.87	2.85
Leaf length (cm)	35.83	16.4	70.4	12.38	34.57	1.59
Leaf width (cm)	1.02	0.5	1.4	0.19	18.45	0.02
No of productive tillers (nos)	11.55	2.33	26	6.05	52.39	0.27
Panicle length (cm)	22.11	16	32.33	3.63	16.41	1.72
Panicle weight (g)	2.79	1.15	4	0.95	34.08	0.02
Number of filled grains (nos)	121.56	91	183.33	19.34	15.91	1.40
Spikelet fertility percentage (%)	87.40	70	96.78	8.32	9.52	0.90
1000 grain weight (g)	25.23	13.64	36.2	6.04	23.95	1.85
Single plant yield (g)	28.05	10.48	38.11	6.49	23.15	1.25

C. Variability

The results of genetic variability and heritability are given in Table 4. In the present study, the results revealed that the phenotypic variance (PV) is greater than the genotypic variance (GV) in all the studied parameters given in Table 4. Similarly, PCV is greater than GCV so, it implies that there is little environmental effect that influences the traits studied. The highest PCV% and GCV % were found in early seedling vigour (92.56 % and 70.97 %). Number of productive tillers had 52.39 % PCV and 52.37% GCV. These results were in conformity with the findings of Umadevi *et al*. (2009) for number of productive tillers per plant. An experiment aimed to know the relationship and effects between anaerobic germination tolerance traits showed the PCV is greater than GCV (Manivelan *et al*., 2022). In a study by Singh *et al*. (2021), it was found that the phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) with a minimal difference between the two. Moderate Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) were observed for the following biometric traits: days to 50% flowering, plant height, leaf width, panicle length, and the number of filled grains per panicle. This suggests that there is a reasonable degree of potential for phenotypic selection in these traits. These findings align with previous studies conducted by Sravan *et al*. (2012) and Jaiswal *et al*. (2015) regarding the time to reach 50% flowering, Sravan *et al*. (2012); Dhurai *et al*. (2014); Srujana *et al*. (2017); Dhanwani *et al*. (2013); Yadav *et al*. (2010) regarding plant height, Chouhan *et al*. (2014) regarding leaf width, Dhurai *et al*. (2014); Kahani and Hittalmani (2015) regarding panicle length, and Sala and Shanthi (2016) regarding the number of filled grains per panicle. All the traits showed high broad sense heritability. The highest heritability was found in Panicle weight (99.98 %) and the lowest was found in early seedling vigour (58.79%). The trait germination percentage show higher heritability (99.57 %) and genetic advance (51.60 %). The trait number of filled grains also show higher heritability (99.80 %) and genetic advance (39.78 %). This indicates most likely the heritability is due to additive gene effects. Hence, the selection based on these traits will be effective. The GAM % ranges between 19.54 %, the lowest in the case of spikelet fertility percentage and highest in early seedling vigour (112.11%). The results were in line with the findings of Saini *et al*. (2013) for days to 50% flowering; Srujana *et al*. (2017); Devi *et al*. (2017) for plant height; Chouhan *et al*. (2014); Shamim *et al*. (2017) for leaf length, leaf width; Srujana *et al*. (2017); Sravan *et al*. (2012); Lingaiah *et al*. (2015) for number of filled grains per panicle; Dhurai *et al*. (2014); Sala & Shanthi (2016) for thousand grain weight, number of productive tillers per plant, panicle length and single plant yield. Heritability and genetic advance are important concepts in plant breeding. Heritability provides insights into the genetic contribution to trait variation and helps breeders make decisions about selection strategies and parental selection. Genetic advance quantifies the potential improvement achievable through selection and aids in setting breeding goals and optimizing resource allocation. Together, these concepts play a crucial role in achieving genetic progress and developing improved cultivars in plant breeding programs.

Table 4: Genetic variability and heritability parameters for the traits studied among 25 rice genotypes.

Characters	PV	GV	EV	PCV%	GCV%	ECV%	H^2	GA	GAM
Germination percentage (%)	632.82	630.10	2.71	58.23	58.10	3.81	99.57	51.60	119.44
Days to 50% flowering (days)	153.62	150.75	2.87	10.84	10.74	1.48	98.13	25.05	21.93
Plant height (cm)	207.85	204.82	3.02	13.92	13.82	1.68	98.54	29.26	28.27
Early seedling vigour	1731787.59	1018139.57	713648.02	92.56	70.97	59.42	58.79	1593.77	112.11
Leaf length (cm)	154.01	153.06	0.94	34.63	34.53	2.71	99.38	25.40	70.91
Leaf width (cm)	0.35	0.35	0.00	18.48	18.40	1.70	99.15	0.38	37.75
No of productive tillers (nos)	36.60	36.58	0.02	52.39	52.37	1.45	99.92	12.45	107.86
Panicle length (cm)	13.90	12.80	1.10	16.86	16.18	4.74	92.08	7.07	31.98
Panicle weight (g)	0.90	0.90	0.00	34.07	34.07	0.50	99.98	1.95	70.19
No of filled grains (nos)	374.53	373.80	0.73	15.92	15.90	0.70	99.80	39.78	32.73
Spikelet fertility (%)	69.38	69.08	0.63	9.53	9.51	0.63	99.56	17.08	19.54
1000 grain weight (g)	37.38	36.11	1.27	24.22	23.81	4.47	96.59	12.16	48.21
Single plant yield (g)	42.56	41.97	0.58	23.26	23.09	2.73	98.62	13.25	47.25

D. Trait associations

In this study, the traits *viz.*, number of productive tillers (0.36**), panicle weight (0.64**), number of filled grains (0.211**), and 1000 grain weight (0.81**) exhibited a significant positive association with single plant yield (Figure 1). The traits panicle length (0.58**) and number of productive tillers (0.42*) had a significant positive correlation with plant height. The number of filled grains per panicle (0.53**) is positively correlated with panicle length. Leaf width (0.48*) and leaf length had a positive association between them. Germination percentage had high significant positive correlation with early seedling vigour (0.86***). Similar findings were also reported by (Lakshmi *et al*., 2014; Saha *et al*., 2019). In a study with rice hybrids, the phenotypic correlation showed a number of productive tillers had a significant positive correlation with grain yield (Babu *et al*., 2012).

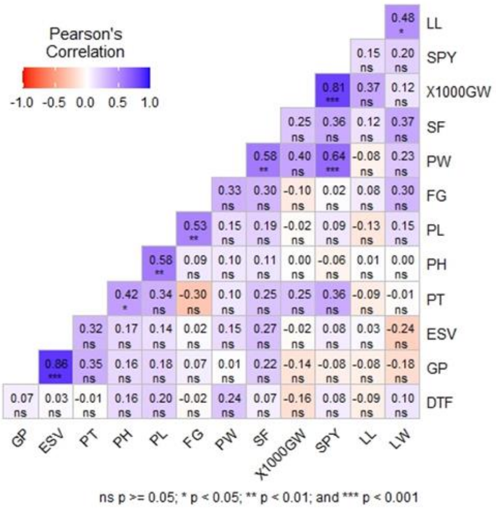

Fig. 1. Estimates of correlation coefficients between anaerobic germination traits.

E. Principal component analysis (PCA)

The first five components in the PCA with Eigen values greater than 1.25 contributed 76.90 per cent to the variability among the germplasm evaluated for all the studied traits. The three principal components (PC) exhibiting eigenvalues 3.11, 2.40 and 1.83, respectively among the traits studied in twenty-five genotypes (Table 5). The first principal component (PC1) with the eigenvalue of 3.11 accounted for 23.97 % variation to the total variability, whereby the traits. These characteristics contribute significantly to the difference and account for the majority of the variability. The PC2 expounds 18.47 % of the variation, the traits like germination percentage (0.49), leaf width (0.14), DTF (0.09), plant height (0.28), productive tillers (0.24) and panicle length (0.25) exhibiting positive factor loadings. The PC3 described a 14.14 % of variation to the total variability, where plant height (0.16), panicle length (0.38), panicle weight (0.05) and spikelet fertility (0.08) exhibited positive loadings. Hence, significant characteristics converge within distinct principal components, actively contributing to the explanation of variability. It is advisable to bear in mind their tendency to coexist when incorporating these traits into the breeding program. According to the biplot of PC1 and PC2 results the genotypes Aanaikomban and Sorna masuri performed better for the trait single plant yield (Fig. 2). In the case of plant height, the genotype, Kalasarnel performed better than other genotypes. Sorna masuri, Aanaikomban outperformed other cultivars in terms of spikelet fertility. For the traits, number of 1000 grain weight, leaf length and leaf width, Sorna masuri, Karuppukavuni, TPS3, JCL nel, CO52, CO51 and Milagu samba performed better. For the trait panicle weight, the genotype Kichili samba performed better. Overall, the study suggests that different genotypes perform better for different traits. In an experiment, PC1 exhibited the highest value (65.8%), followed by PC2 (13.7%) and PC3 (10.5%). The variations in PC1, PC2, and PC3 were mainly due to duration and plant height (Al-daej *et al*., 2023).

Table 5: Eigenvalues and per cent of the variation of principal component axes among 25 rice genotypes.

Principal Components	Eigen values	Percentage of variation	Cumulative percentage
PC1	3.12	23.97	23.97
PC2	2.40	18.47	42.44
PC3	1.84	14.14	57.58
PC4	1.38	10.60	67.17
PC5	1.26	9.72	76.90
PC6	1.01	7.75	84.65
PC7	0.72	5.57	90.22
PC8	0.52	4.06	94.27
PC9	0.31	2.39	96.67
PC10	0.17	1.38	98.05
PC11	0.14	1.10	99.15
PC12	0.08	0.06	99.81
PC13	0.02	0.00	100

Table 6: Eigenvectors for the first three principal components of anaerobic germination traits among 25 rice genotypes.

Characters	**PC1**	**PC2**	**PC3**
Germination Percentage (%)	-0.17	0.49	-0.14
Days to 50% flowering (days)	-0.11	0.09	0.19
Plant height (cm)	-0.21	0.28	0.17
Early seedling vigour	-0.22	0.43	-0.22
Leaf length (cm)	-0.11	-0.28	0.01
Leaf width (cm)	-0.21	-0.30	0.33
No of productive tillers (nos)	-0.29	0.24	-0.31
Panicle length (cm)	-0.28	0.25	0.38
Panicle weight (g)	-0.42	-0.15	0.05
Number of filled grains (nos)	-0.19	-0.01	0.55
Spikelet fertility percentage (%)	-0.41	-0.04	0.08
1000 Grain weight (g)	-0.31	-0.33	-0.36
Single plant yield (g)	-0.41	-0.28	-0.28

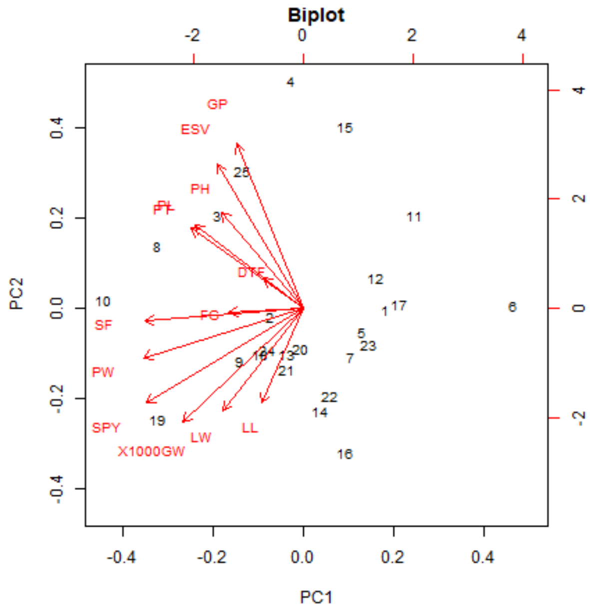

Fig. 2. Biplot of PC1 and PC2 of principal component analysis explaining the contribution of anaerobic germination traits towards divergence

Cluster analysis

Inter and intra cluster distance. The mean value of the inter and intra-cluster distance was evaluated for six clusters (Table 7). Cluster VI shows maximum intra-cluster distance (33.09), followed by cluster I (32.67), cluster II (32.20), cluster IV (29.53), cluster III (23.24), and cluster V (0.00) showed the lowest intra-cluster distance which means the genotypes were closely related. Likewise, the inter-cluster distance between cluster VI and cluster III was higher (42.74). Similarly, between cluster I and cluster VI (40.79) were found to be high and the lowest inter-cluster distance is observed between cluster II and cluster V (33.56). Genotype diversity increases with increasing inter-cluster and intra-cluster distances, and conversely.

Table 7: Average inter and intra-cluster values among six clusters based on Mahalanobis D^2 statistics

	C1	C2	C3	C4	C5	C6
C1	**32.67**	38.11	40.50	37.20	38.36	40.79
C2		**32.20**	36.54	35.29	33.56	39.20
C3			**23.24**	34.71	37.64	42.74
C4				**29.53**	37.94	37.30
C5					**0.00**	38.68
C6						**33.09**

Diagonal bolded values are intra-cluster values

Cluster means. Cluster means are important in plant breeding for grouping similar genotypes based on trait performance. They provide a concise summary of trait values within each cluster, facilitating trait evaluation and comparison. Cluster means help prioritize breeding objectives by identifying clusters with superior trait performance. They aid in selecting genotypes for further breeding advancement or specific purposes. Cluster means streamlining data analysis and assisting breeders in making informed decisions to achieve desired breeding goals.

The cluster means for different traits were estimated and presented in Table 8. The highest cluster means for various traits are: Cluster III contains the highest cluster means for five traits *viz.*, Germination percentage (60.00), leaf width (1.12), number of productive tillers (26.50), number of filled grains (155.67) and spikelet fertility (93.22) followed by Cluster I which encompasses of four high performing traits namely, plant height (113.00), leaf length (45.11), productive tillers (16.38) and 1000 grain weight (28.56) and cluster II have highest mean for days to 50% flowering (119.71), panicle weight (3.45) and single plant yield (31.79) and finally cluster IV have the highest mean for the early seedling vigour (2161.00). Thus, it shows that the genotype present in cluster III, Kalasar nel and Thanga samba had the majority of best performing traits. Cluster II consists of Sorna masuri, CO51, TPS5, Milagu samba, CO52, TPS3, CO53 had the majority of yield when subjected to stress conditions.

Percent contribution of characters towards divergence. The percentage contribution of twelve traits towards the divergence is presented in Table 9. It was observed that the character Germination percentage (17.11%) contributed maximum towards diversity followed by panicle weight (11.75%), plant height (11.07%), number of productive tillers (8.39%) and spikelet fertility (8.39%). The remaining characters *viz.*, days to 50 % flowering, leaf length, leaf width, panicle length, number of filled grains, 1000 grain weight and single plant yield did not contribute much to the diversity.

Table 8: Cluster mean values of anaerobic germination tolerance traits among 25 rice genotypes.

Characters	I	II	III	IV	V	VI
Germination Percentage (%)	48.57	41.43	60.00	48.00	20.00	23.33
Days to 50% flowering (days)	113.48	119.71	116.50	112.13	116.00	104.67
Plant height (cm)	113.00	94.38	108.17	111.00	85.67	93.00
Early seedling vigour	1425.14	1212.86	1402.50	2161.00	560.00	981.33
Leaf length (cm)	45.11	34.95	22.78	30.30	38.50	33.24
Leaf width (cm)	1.09	1.03	1.12	0.85	0.90	1.06
No of productive tillers (nos)	16.38	9.57	6.17	11.47	9.00	9.44
Panicle length (cm)	23.27	20.43	26.50	23.20	18.33	19.89
Panicle weight (g)	2.44	3.45	2.95	2.86	1.55	2.26
Number of filled grains (nos)	116.69	122.55	155.67	119.67	91.00	121.19
Spikelet fertility percentage (%)	88.39	91.77	93.22	80.41	70.00	88.42
1000 Grain weight (g)	28.56	26.99	15.22	26.04	14.64	22.24
Single plant yield (g)	28.81	31.79	16.94	28.55	16.00	28.14

Table 9: Percent contribution of characters towards divergence among 25 rice genotypes.

Characters	Rank	Percentage (%)
Germination Percentage (%)	51	17.11
Days to 50% flowering (days)	24	8.05
Plant height (cm)	33	11.07
Early seedling vigour	11	3.69
Leaf length (cm)	20	6.71
Leaf width (cm)	9	3.02
No of productive tillers (nos)	25	8.39
Panicle length (cm)	15	5.03
Panicle weight (g)	35	11.75
Number of filled grains (nos)	21	7.05
Spikelet fertility percentage (%)	25	8.39
1000 Grain weight (g)	21	7.05
Single plant yield (g)	8	2.69

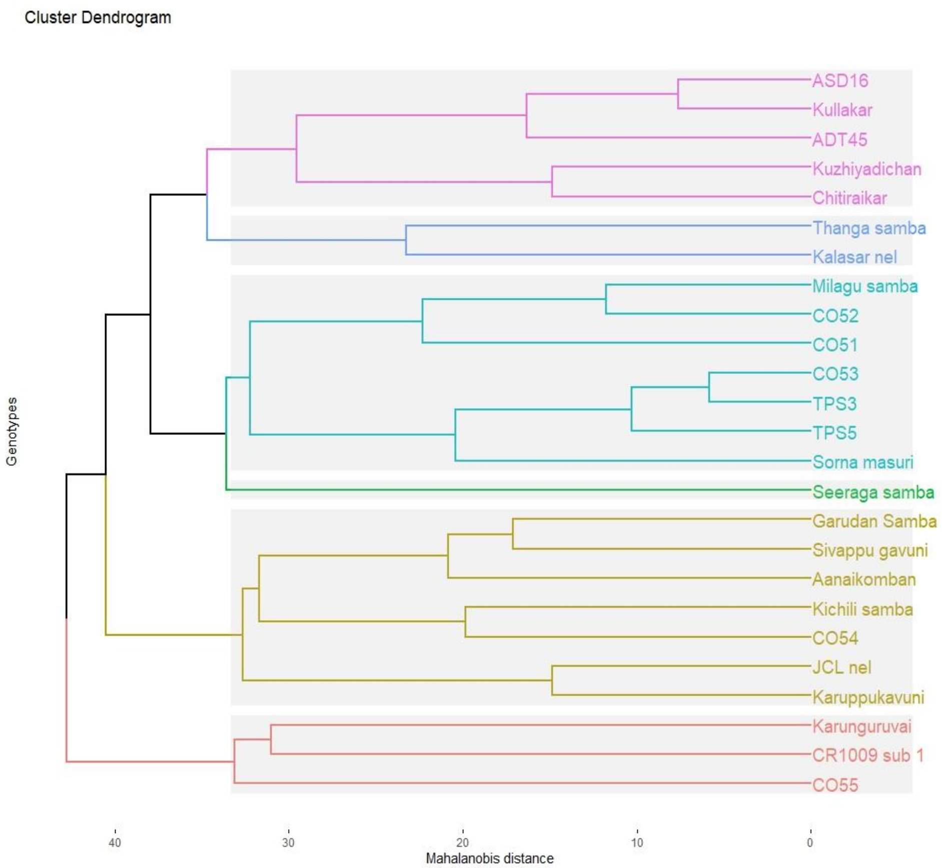

Fig. 3. Dendrogram explains the phylogenetic relationship of twenty-five genotypes using Mahalanobis D^2 statistics.

Supplementary Table: Mean performance of traits studied among 25 rice genotypes under DSR condition.

	Genotype	GP	DTF	PH	ESV	LL	LW	PT	PL	PW	FG	SF	1000GW	SPY
1	CO54	60	106.00	90.00	1540	39.63	1.17	14.33	20.00	1.15	92.00	75.41	27.22	25.98
2	Sorna masuri	80	116.00	90.67	2396	35.90	1.00	10.00	16.00	4.00	110.00	90.00	27.20	33.11
3	Kalasar nel	60	116.33	113.00	1836	25.13	1.20	7.33	32.33	3.65	183.33	95.00	16.80	23.40
4	Chitiraikar	100	116.00	117.00	5185	35.46	0.70	12.00	23.00	2.34	111.66	89.00	20.00	23.00
5	Kullakar	20	116.00	101.33	520	35.60	0.97	8.33	25.00	2.45	140.00	73.68	23.20	27.06
6	Seeraga samba	20	116.00	85.67	560	38.50	0.90	9.00	18.33	1.55	91.00	70.00	14.64	16.00
7	CR1009 *sub 1*	20	90.00	91.00	620	29.03	0.97	13.00	23.67	1.43	112.23	89.00	27.45	31.22
8	Kuzhiyadichan	70	106.00	115.00	3640	33.73	1.03	20.33	23.67	4.00	110.00	95.67	32.00	35.00
9	CO51	20	82.00	92.67	570	22.57	0.80	14.67	23.33	4.00	110.00	95.67	31.23	36.86
10	Aanaikomban	60	116.00	121.67	2510	54.40	1.20	26.00	25.33	4.00	130.23	95.67	32.00	38.11
11	Thanga samba	20	116.67	103.33	969	20.43	1.03	5.00	20.67	2.24	128.00	91.43	13.64	10.48
12	ADT45	30	106.33	110.67	1200	16.40	0.50	8.00	21.67	2.96	120.00	71.86	30.60	29.38
13	Karuppukavuni	30	116.33	119.33	1372	70.40	1.17	6.33	24.33	2.18	134.00	91.16	26.56	22.54
14	Karunguruvai	30	90.00	75.67	1644	37.65	1.12	8.00	16.67	3.47	141.33	92.94	23.80	30.08
15	Sivappu kavuni	70	116.00	116.33	2114	19.07	0.70	24.00	21.67	1.65	94.59	88.00	19.65	22.00
16	JCL nel	20	90.00	105.00	180	59.10	1.00	6.33	18.00	2.01	119.00	87.50	36.20	27.27
17	CO55	20	134.00	112.33	680	33.03	1.10	7.33	19.33	1.89	110.00	83.32	15.46	23.12
18	TPS5	20	106.00	110.67	390	23.40	1.10	13.33	22.67	4.00	120.00	96.78	25.26	29.45
19	Kichili samba	20	134.00	114.67	580	40.60	1.40	16.67	24.67	4.00	110.00	95.67	34.63	38.00
20	CO52	60	116.00	77.00	1674	44.17	1.10	11.00	20.33	2.18	134.00	91.16	27.00	30.34
21	TPS3	30	116.00	111.00	740	39.03	1.13	7.67	20.33	3.49	134.00	89.33	25.20	29.28
22	CO53	20	116.00	97.33	360	39.53	1.07	8.00	19.33	3.00	115.87	90.12	24.33	29.46
23	ASD16	20	116.33	111.00	260	30.30	1.07	8.67	22.67	2.57	116.67	71.86	24.40	28.31
24	Milagu samba	60	134.00	81.33	2360	40.07	1.00	2.33	21.00	3.49	134.00	89.33	28.73	34.00
25	Garudan Samba	80	116.00	124.00	1680	32.57	1.00	21.00	28.87	2.10	137.00	85.35	23.66	27.76

Distribution of genotypes in cluster. The characteristics that contributed significantly to overall variance were chosen for clustering, as determined by the principal component analysis. Six clusters were formed from the twenty-five genotypes using the Mahalanobis D^2 statistics. Among the six clusters, cluster I have seven genotypes, cluster II encompasses seven genotypes, cluster III groups two genotypes, cluster IV consists of five genotypes, cluster V had one genotype and cluster VI have three genotypes. Cluster III has the highest mean value for five traits. This indicates that cluster III is the largest, followed by cluster I, cluster IV and cluster V and VI. A study examined 77 native rice landraces and 3 hybrid varieties. Utilizing cluster analysis, the rice landraces were categorized into two primary clusters with subgroups based on variations in quantity traits. The larger cluster consisted of 76 landraces showing a similarity of more than 75%, while the second exhibited a similarity of over 80%. Additionally, a smaller cluster with 91% similarity was identified (Panda *et al*., 2020).

CONCLUSIONS

Recently, there has been a notable increase in interest surrounding the development and application of rice varieties that exhibit anaerobic germination tolerance in DSR condition. These particular lines have the capacity to enhance food production and provide resilience to the uncertainties brought about by climate change and global warming. The discoveries from this research pave the way for the enhancement of rice cultivars with anaerobic germination tolerance, given that these genetic resources encompass a wider spectrum of genetic diversity associated with anaerobic germination capabilities.

FUTURE SCOPE

The promising genotypes with the traits which are tolerant towards anaerobic germination in DSR conditions evaluated in this research can be used in places where flooding is a major concern. The present study identifies new sources of tolerance to anaerobic germination within the landraces and genotypes which could serve as valuable contributors to future breeding programs. This in turn, may pave the way for a deeper understanding of the genetic mechanisms underlying anaerobic germination.

Acknowledgement. We wish to express our sincere gratitude of the Karunya Institute of Technology and Sciences' laboratory and South Farm for providing access to all the essential facilities.

Conflict of Interest. None.

REFERENCES

Al-daej, M. I., Rezk, A. A., El-Malky, M. M., Shalaby, T. A., & Ismail, M. (2023). Comparative Genetic Diversity Assessment and Marker–Trait Association Using Two DNA Marker Systems in Rice (*Oryza sativa* L.). *Agronomy*, *13*(2), 329.

Azarin, K. V., Usatov, A. V., & Kostylev, P. I. (2017). Molecular breeding of submergence-tolerant rice. *Annual Research & Review in Biology*, 1-10.

Babu, V. R., Shreya, K., Dangi, K. S., Usharani, G., & Shankar, A. S. (2012). Correlation and path analysis studies in popular rice hybrids of India. *International Journal of Scientific and Research Publications*, *2*(3), 1-5.

Bandumula, N. (2018). Rice production in Asia: Key to global food security. Proceedings of the National Academy of Sciences, India Section B: *Biological Sciences*, *88*, 1323-1328.

Das, S., Das, S. S., Chakraborty, I., Roy, N., Nath, M. K., & Sarma, D. (2017). Principal component analysis in plant breeding. *Biomolecule Reports*, *3*, 1-3

Dhurai, S. Y., Bhati, P. K., & Saroj, S. K. (2014). Studies on genetic variability for yield and quality characters in rice (*Oryza sativa* L.) under integrated fertilizer management. *The Bioscan*, *9*(2), 745-748.

Doley, D., Barua, M., Sarma, D., & Barua, P. K. (2018). Screening and enhancement of anaerobic germination of rice genotypes by pre-sowing seed treatments. *Current Science*, *115*(6), 1185-1190.

Chamara, B. S., Marambe, B., Kumar, V., Ismail, A. M., Septiningsih, E. M., & Chauhan, B. S. (2018). Optimizing sowing and flooding depth for anaerobic germination-tolerant genotypes to enhance crop establishment, early growth, and weed management in dry-seeded rice (*Oryza sativa* L.). *Frontiers in Plant Science*, *9*, 1654.

Chouhan, S. K., Singh, A. K., Singh, A., Singh, N. K., Yadav, S. K., & Singh, P. K. (2014). Genetic variability and association analysis in wild rice (*Oryza nivara* and *Oryza rufipogon*). *Annals of Plant and Soil Research*, *16*(3), 219-223.

Dar, M. H., Chakravorty, R., Waza, S. A., Sharma, M., Zaidi, N. W., Singh, A. N., & Ismail, A. M. (2017). Transforming rice cultivation in flood prone coastal Odisha to ensure food and economic security. *Food Security*, *9*, 711-722.

Das, K. K., D. Panda, R. K. Sarkar, J. N. Reddy, and Ismail, A. M. (2009). Submergence Tolerance in Relation to Variable Floodwater Conditions in Rice. *Environmental and Experimental Botany*, *66* (3), 425–434.

Deepika, C., Gnanamalar, R. P., Thangaraj, K., & Revathy, N. (2019). Combining ability analysis for yield and yield contributing traits in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, *10*(2), 440-445.

Dhanwani, R. K., Sarawgi, A. K., Solanki, A., & Tiwari, J. K. (2013). Genetic variability analysis for various yield attributing and quality traits in rice (*Oryza sativa* L.). *The bioscan*, *8*(4), 1403-1407.

Ghosal, S., F. A. Quilloy, C. Casal, E. M. Septiningsih, M. S. Mendioro, and S. Dixit, S. (2020). Trait-based Mapping to Identify the Genetic Factors Underlying Anaerobic Germination of Rice: Phenotyping, GXE, and QTL Mapping. *BMC Genetics*, *21*(1), 6.

Gunasekaran, A., Seshadri, G., Ramasamy, S., Muthurajan, R., & Karuppasamy, K. S. (2023). Identification of Newer Stable Genetic Sources for High Grain Number per Panicle and Understanding the Gene Action for Important Panicle Traits in Rice. *Plants*, *12*(2), 250.

Lakshmi, R. R., Padma, S. V., Naidu, L. N., & Umajyothi, K. (2014). Correlation and path analysis studies of yield and yield components in brinjal. *Plant Archives*, *14*(1), 583-591.

Lingaiah, N., Venkanna, V., & Cheralu, C. (2015). Genetic vairability, heritability and genetic advance in rice (*Oryza sativa* L.). *Asian Journal of Environmental Sciences*, *46*(4), 917-919.

Loreti, E., van Veen, H., & Perata, P. (2016). Plant responses to flooding stress. *Current opinion in plant biology*, *33*, 64-71.

Luo, F. L., Nagel, K. A., Scharr, H., Zeng, B., Schurr, U., & Matsubara, S. (2011). Recovery dynamics of growth, photosynthesis and carbohydrate accumulation after de-submergence: a comparison between two wetland plants showing escape and quiescence strategies. *Annals of Botany*, *107*(1), 49-63.

Manivelan, K., Juliet Hepziba, S., Suresh, R., Theradimani, M., Renuka, R., & Gnanamalar, R. P. (2022). Inherent variability, correlation and path analysis in lowland rice (*Oryza sativa* L.). *Biological Forum–An International Journal*, *14*(2), 771-778.

Miro, B. & Ismail, A. M. (2013) Tolerance of anaerobic conditions caused by flooding during germination and early growth in rice (*Oryza sativa* L.). *Frontiersin Plant Science*, *4*(269), 1-18.

Panda, D., Sahu, N., Behera, P. K., & Lenka, K. (2020). Genetic variability of panicle architecture in indigenous rice landraces of Koraput region of Eastern Ghats of India for crop improvement. *Physiology and Molecular Biology of Plants*, *26*(10), 1961-1971.

Partheeban, C., Chandrasekhar, C. N., Jeyakumar, P., Ravikesavan, R., & Gnanam, R. (2017). Effect of PEG induced drought stress on seed germination and seedling characters of maize (*Zea mays* L.) genotypes. *International Journal of Current Microbiology and Applied Sciences*, *6*(5), 1095-1104.

Gunasekaran, A., Seshadri, G., Ramasamy, S., Muthurajan, R., & Karuppasamy, K. S. (2023). Identification of Newer Stable Genetic Sources for High Grain Number per Panicle and Understanding the Gene Action for Important Panicle Traits in Rice. *Plants*, *12*(2), 250.

Saha, S. R., Lutful, H., Haque, M. A., Islam, M. M., & Rasel, M. (2019). Genetic variability, heritability, correlation and path analyses of yield components in traditional rice (*Oryza sativa* L.) landraces. *Journal of the Bangladesh Agricultural University*, *17*(1), 26-32.

Sala, M., & Shanthi, P. (2016). Variability, heritability and genetic advance studies in F2 population of rice (*Oryza sativa* L.). *International Journal of Forestry and Crop Improvement*, *7*(1), 57-60.

Sarma, M. K., Ahmed, A. N., Saharia, D. D., Nath, M. P., Talukdar, J., Devi, N. S., & Bhuyan, J. (2022). Pattern of genetic diversity in indigenous Ahu rice germplasm of Assam. *Electronic Journal of Plant Breeding*, *13*(1), 21-27.

Septiningsih, E. M., J. C. I. Ignacio, P. M. D. Sendon, D. L. Sanchez, A. M. Ismail, and Mackill, D. J. (2013). QTL Mapping and Confirmation for Tolerance of Anaerobic Conditions during Germination Derived from the Rice Landrace Ma-Zhan Red. *Theoretical and Applied Genetics*, *126* (5), 1357–1366.

Singh, A., Septiningsih, E. M., Balyan, H. S., Singh, N. K., & Rai, V. (2017). Genetics, physiological mechanisms and breeding of flood-tolerant rice (*Oryza sativa* L.). *Plant and Cell Physiology*, *58*(2), 185-197.

Sravan, T., Rangare, N. R., Suresh, B. G., & Kumar, S. R. (2012). Genetic variability and character association in rainfed upland rice (*Oryza sativa* L.). *Journal of Rice Research*, *5*(1), 2.

Srujana, G., Suresh, B. G., Lavanya, G. R., Ram, B. J., & Sumanth, V. (2017). Studies on genetic variability, heritability and genetic advance for yield and quality components in rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry*, *6*(4), 564-566.

Sun, L., Hussain, S., Liu, H., Peng, S., Huang, J., Cui, K., & Nie, L. (2015). Implications of low sowing rate for hybrid rice varieties under dry direct-seeded rice system in Central China. *Field Crops Research*, *175*, 87-95.

Umadevi, M., Veerabadhiran, P., & Manonmani, S. (2009). Stability analysis for grain yield and its component traits in rice (*Oryza sativa* L.). *Journal of Rice Research*, *3*(1), 10-12.

Varshney, R. K., & Tuberosa, R. (2013). Translational genomics in crop breeding for biotic stress resistance: an introduction. Translational genomics for crop breeding: *biotic stress*, *1*, 1-9.

Vergara, G. V., Nugraha, Y., Esguerra, M. Q., Mackill, D. J., & Ismail, A. M. (2014). Variation in tolerance of rice to long-term stagnant flooding that submerges most of the shoot will aid in breeding tolerant cultivars. *AoB PLANTS*, *6*, plu055.

Vu H. T. T., Nguyen H. T. T., Tran K. D., Khuat T. H. and Nakamura C. (2016). Genetic diversity of Vietnamese lowland rice germplasms as revealed by SSR markers in relation to seedling vigour under submergence. *Biotechnology and Biotechnological Equipment*, *30*(1), 17-25.

Xu, L., Li, X., Wang, X., Xiong, D., & Wang, F. (2019). Comparing the grain yields of direct-seeded and transplanted rice: A meta-analysis. *Agronomy*, *9*(11), 767.

Yadav, S. K., Suresh, B. G., Pandey, P., & Kumar, B. (2010). Assessment of genetic variability, correlation and path association in rice (*Oryza sativa* L.). *Journal of Biological Science*, *18*(0), 1-8.

How to cite this article: Godwin Gilbert J., Agalya Jasmin S., Ramchander S., Indira Petchiammal K., Samundeswari R. and Dinesh Kumar P. (2023). Evaluation of Rice Accessions for Anaerobic Germination, Yield and Attributing Parameters in Direct Seeded Rice condition. *Biological Forum – An International Journal, 15*(9): 330-339.