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Genetic diversity of rice under natural flash flood

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Abstract

Genetic divergence is an efficient tool for the selection of parents used in hybridization programme. The present investigation was carried out to evaluate genetic diversity for flash flood tolerance of twenty six rice genotypes. To study the field performance of the rice genotypes under natural flash flood, the experiments were conducted at two places *viz.,* a low lying field to screen the genotypes for flash flood tolerance (E2) and an elevated field (E1) representing normal condition which served as irrigated control. Pooled analysis was also carried out. The observations on eleven characters *viz.,* days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, 1000 grain weight, grain length, grain breadth, grain L/B ratio and grain yield per plant were studied. Genetic divergence based on Mahalanobis D^2 statistic grouped the rice genotypes into seven different clusters in E1 and six clusters in both E2 and pooled analysis. The maximum intracluster distance was observed by cluster IV in E1, E2 and pooled analysis. The maximum intercluster distance was observed between clusters IV, V, VI and VII. The six rice genotypes namely, JGL- 384, TN- 1, MTU- 1010, NDLR- 8 and Swarna *Sub* 1 from these clusters could be used to obtain superior progenies and hybrids for flash flood tolerance. The characters namely grain yield per plant along with grain length were the two major contributors in E1. In the flash flood environment E2, the traits grain yield, 1000 grain weight and number of grains per panicle were the major contributors. In pooled analysis, 1000 grain weight and number of grains per panicle remained as major contributors towards divergence. Therefore, these characters may be given importance during hybridization programme.

Keywords: Flash flood tolerance, genetic divergence, *Sub* 1, rice

Introduction

Rice (*Oryza sativa* L.) the, most essential food crop of the world, is cultivated round the year in India in an area of about 44.6 million hectares with a production of 90 million tonnes, and productivity level of 2.97 t ha^{-1} (Shekhawat *et al.* 2010). About 29% of India's total rice area, approximately 13 million hectares is rainfed lowland which contributes 19% of national rice production. Rainfed lowlands constitute fragile ecosystem being prone to flash flood with an average productivity of nearly 0.5t.ha^{-1} in case of complete submergence. The key factor limiting grain yield of lowland rice is temporary submergence due to flash floods. Out of the 42 biotic and abiotic stresses that prevail in the rainfed lowland rice areas, submergence stress ranks as the third most important one (Widawsky and O'Toole, 1995). Flash flood tolerance generally refers to the tolerance against temporal flash flooded condition where the water level rises quickly and covers the whole plant for a period not more than two weeks and then recedes (Kamolsukyunyong *et al.* 2001). Most of the existing rice cultivars are seriously damaged by flash flooding; however, few tolerant landraces can withstand inundation for up to two weeks (Mackill *et al.* 1993, Setter *et al.* 1997 and Ram *et al.* 2002).

The Indian rice cultivar FR 13A is the most widely studied and used source of submergence tolerance in rice breeding. A major QTL designated as *Sub* 1 was identified, fine mapped and cloned. The cultivar FR 13A also has additional QTLs that contribute to its tolerance (Toojinda *et al.* 2003). Recent studies reveal that new land races like Atiranga, Kusuma, Khuda *etc.,* have reasonably higher levels of submergence tolerance coupled with better agronomic traits than the most tolerant check FR13A, suggesting the possibility of identifying new genes or alleles for higher levels of tolerance (Sarkar *et al.* 2006).

Genetic diversity is one of the key factors in tailoring an effective breeding programme in any crop plant as it allows breeder in downsizing the core collections by elimination of some parents (Fuzzato *et al.,* 2002). Among the several methods to measure genetic diversity Mahalanobis' generalized distance (D^2) is most frequently used. D^2 analysis is a powerful tool in quantifying the degree of divergence between biological populations and to assess relative contribution of difference components to the total divergence. As identification of new donors through exploring genetic resource is highly desirable the present study was under taken to

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evaluate the genetic diversity for flash flood tolerance in rice.

Materials and Methods

The present investigation was carried out to study the flash flood tolerance of 26 rice genotypes including ten modern varieties, seven traditional varieties, five rice cultures along with the submergence tolerant check variety Swarna *Sub* 1 during Samba (August-December), 2010 at the Plant Breeding Farm (11° 24' N latitude and 79° 44' E longitude, + 5.79 m MSL), Annamalai University, Tamilnadu (Table-1). Flash flooding due to heavy rain is a recurrent problem which is faced by the local farmers every year (Sabesan *et al*., 2010). The sowing date for our study was so planned that the flash flooding might coincide at active tillering phase and at the time of flowering. Weekly metorological data including rainfall were presented in Table-2. The field experiments were conducted at two places *viz,* a low lying field to screen the genotypes for flash flood tolerance (E2) and an elevated field (E1) representing normal condition which served as irrigated control. Pooled analysis was also carried out.

Seeds of twenty six genotypes were sown in raised nursery bed during Samba, 2010. The seedlings were transplanted to the main field at the rate of one seedling per hill, after 25 days, with a spacing of 20 cm x 15 cm. The experiment was arranged in a randomized complete-block design with two replications, in four-row plots of 3 m length. A uniform population of 20 plants in a row was maintained. Observations were recorded on five randomly selected plants in each replication from the two centre rows. The recommended agronomical practices and plant protection measures were followed to ensure a normal crop. The observations on eleven morphological and grain quality traits *viz.,* days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, 1000 grain weight, grain length, grain breadth, grain L/B ratio and grain yield per plant were analyzed to study using Mahalanobis D^2 statistic (Mahalanobis, 1963). Grouping of genotypes into clusters was carried out following Tocher's method (Rao, 1952).

Results and Discussion

The analysis of variance revealed significant difference among the rice genotypes for all the eleven traits in E1, E2 and pooled analysis. The mean value of 11 characters of the 26 rice genotypes were transformed into standardized uncorrelated values and D^2 values were computed. The 26 genotypes were grouped into seven different clusters in E1 and six clusters in both E2 and pooled analysis (Table-3).

In E1, cluster I with 15 genotypes was comprised of 13 genotypes origination from Tamil Nadu, one genotype from Puducherry and Philippines each. In E2, a total of 17 genotypes in cluster I had 13 genotypes representing Tamil Nadu, two from Philippines, one from Andhra Pradesh and Puducherry each. Cluster I in pooled analysis comprised of 18 genotypes, originating from Tamil Nadu (13 genotypes), Philippines (three genotypes), Puducherry (one genotype) and Andhra Pradesh (one genotype).

The clustering pattern in the present study revealed that the genotypes from different sources clustered together showing that there was no association between eco-geographical distribution of genotypes and genetic divergence. Similar results were also observed by Yogendra Singh *et al*., (2008) and Padmaja *et al.* (2010). This indicated that, in general, selections have been towards the same goal in the different centres of origin of these genotypes and yet, there is sufficient

genetic variability, that distinctly differentiates them into different clusters. Hence, the chosen genotypes used in the present study could be considered as a valid material.

The inter and intra cluster distance (Table-4) revealed that in E1, cluster IV recorded maximum intra cluster distance and minimum distance was recorded by cluster II. The maximum inter cluster distance was registered between clusters V and VII. Clusters V, VI and VII being monogenotypic in nature had zero intra cluster distance.

In E2, maximum and minimum intra cluster distance was recorded by cluster IV and cluster II respectively. Maximum inter cluster distance was registered between clusters IV and VI. The clusters III, V and VI were monogenotypic in nature.

In pooled analysis, maximum intra cluster distance was registered by cluster I and maximum by cluster II. Maximum inter cluster distance was registered between clusters IV and VI. The clusters IV, V and VI were monogenotypic in nature. Genotypes belonging to clusters separated by high genetic distance may be used in hybridization programme to obtain a wide spectrum of variation among the segregants (Subudhi, 2008). Therefore, selection of divergent genotypes from the clusters namely IV, V, VI and VII would produce a broad spectrum of variability for different traits studied, which may enable further selection and improvement of grain yield along with flash flood tolerance.

A wide range of variation was observed in cluster means for all the eleven characters studied (Table-5). In E1, cluster II recorded the minimum plant height and maximum panicle length. Maximum grain yield per plant along with more number of grains per panicle was observed in cluster III. The maximum number of tillers per plant and productive tillers per plant was recorded in cluster IV. Earliness of flowering coupled with maximum grain length and 1000 grain weight was observed in cluster V, while minimum grain breadth was observed in cluster VI. In E1, Cluster I ranked first and recorded highest grain yield per plant along with high mean values for days to 50 % flowering, plant height, number of grains per panicle, 1000 grain weight, grain length and grain L/B ratio.

In E2, the flash flood environment, earliness in flowering along with more number of grains per panicle was observed in genotypes of cluster I. Cluster III had short statured plants with long panicles and more grains were noted in cluster V while higher yield was observed in cluster V and VI. In E2, cluster IV ranked first for grain yield per plant along with plant height, number of tillers per plant, number of productive tillers per plant, number of grains per panicle, 1000 grain weight, grain length and grain breadth. Late flowering was observed in clusters VI and II. Delayed flowering due to submergence caused by flash flooding was also reported by Setter *et al.* (1997) and Almeida *et al.* (2003) in rice.

In pooled analysis, cluster II recorded highest grain yield per plant by having long panicles with more grains. Cluster IV comprised of genotype with heavy long grains while slender grains were observed in cluster V. Cluster III ranked first and recorded higher cluster mean value than the general mean for eight characters namely plant height, number of tillers per plant, number of productive tillers per plant, 1000 grain weight, grain length, grain breadth, grain L/B ratio and grain yield per plant.

Comparison of cluster means revealed that there was a moderate shift of mean values because of flash flooding in E2 which has delayed flowering and induced plant height by means of stem elongation. These results are in agreement with the findings of Ito *et al.* (1999) and Sabesan *et al*., (2010).

The relative contribution of individual character towards the expression of genetic diversity estimated over character wise D2 value revealed that grain yield per plant with 42.77 per cent contribution and grain length with 31.38 per cent were the two major contributors in E1 (Table-5). Grain yield per plant with 29.54 per cent contribution, 1000 grain weight with 25.54 percent contribution and number of grains per panicle with 19.38 per cent contribution were the major forces of discrimination among the genotypes tested in the flash flood environment E2. In pooled analysis grain yield per plant followed by 1000 grain weight and number of grains per panicle were the major contributors. Similar findings were made by Banumathy *et al.* (2010) for number of grains per panicle and grain yield per plant and Yogendra Singh *et al.* (2008) for panicle length. The characters viz., 1000 grain weight, plant height and days to 50% flowering also contributed towards the genetic divergence. Similar results were reported by Subudhi *et al.* (2008) and Monika *et al.* (2008) for plant height, days to 50% flowering and 1000 grain weight in rice. Hence, these characters should be given importance during hybridization and selection in the segregating

population.

A perusal of our study revealed that the genotypes of different regions were clubbed together and little parallelism exists between clustering pattern and geographic distribution of genotypes (Ajmer Singh *et al.* 2011). Also most of the traditional cultivars are grouped together in cluster I. This indicate that the kind of genetic diversity found among the genotypes belonging to same geographic origin might be due to difference in adaption, selection criteria, selection pressure in environmental condition (Hilal Ahmed *et al.* 2010). The presence of Swarna *Sub* 1 (G22) in monogenotypic cluster not only in the flash flood environment (E2) but also in E1 and pooled analysis indicate the unique nature of the Swarna *Sub* 1 genome integrated in it that differentiates it in normal irrigated condition also. The data on intercluster distances and *per se* performance of genotypes may be used to select genetically diverse and superior genotypes for flash flood tolerance. The six rice genotypes namely, JGL- 384, TN- 1, MTU- 1010, NDLR- 8 and Swarna *Sub* 1 from clusters IV, V, VI and VII could be used to obtain heterotic combinations which may enable further selection and improvement of grain yield along with flash flood tolerance.

Table 1: List of genotypes selected for D^2 analysis

Genotype Code	Varieties/ Cultures	Origin/ Source
G 1	AURC 1	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 2	AURC 12	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 3	AURC 11	Plant Breeding Farm, Annamalai University, Tamil Nadu
G4	AURC 3	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 5	Kavuni	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 6	IR 42	International Rice Research Institute (IRRI), Philippines.
G 7	IR 36	International Rice Research Institute (IRRI), Philippines.
G 8	CO 43	Paddy Breeding Station, TNAU, Coimbatore, Tamil Nadu
G 9	Vettaikaraniruppu Kulivedichan	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 10	AUR 4	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 11	ADT 43	Tamil Nadu Rice Research Institute (TRRI),Tamil Nadu,
G 12	ADT 39	Tamil Nadu Rice Research Institute (TRRI), Tamil Nadu
G 13	PY 5	Krishi Vigyan Kendra, Pondicherry, India.
G 14	IR-55408-01	International Rice Research Institute (IRRI), Philippines.
G 15	AURC 6	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 16	Sivappu Kurivikar	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 17	Maapillai Samba	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 18	Karung Kuruvai	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 19	Jeeraga Samba	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 20	Sembili Priyani	Plant Breeding Farm, Annamalai University, Tamil Nadu
G 21	Kurnool Sona	Agricultural College, Bapatla, Andhra Pradesh, India.
G 22	Swarna *Sub*- 1	International Rice Research Institute (IRRI), Philippines.
G 23	MTU- 1010	Rice Research Station, Marteru, Andhra Pradesh
G 24	NDLR- 8	Rice Research Station, Nandyala, Andhra Pradesh
G 25	JGL- 384	Rice Research Station, Jagityala, Andhra Pradesh
G 26	TN- 1	Directorate of Rice Research, Hyderabad, Andhra Pradesh

Table 2: Weekly meteorological mean data from July to December 2010

Week No.	Period	Temperature (ºC)		Relative Humidity (%)	Rainfall (mm)	Rainy Days
		Maximum	Minimum			
1	July 30- August 5	31.3	25.2	80	023.8	1
2	August 6-12	35.5	25.9	83	013.0	3
3	August 13-19	33.9	27.6	85	053.0	3
4	August 20-26	27.5	24.4	92	064.9	5
5	August 27- Sep 2	29.8	24.2	86	045.6	3
6	September 3-9	33.5	25.4	81	004.8	1
7	September 10-16	33.8	24.1	88	026.4	3
8	September 17-23	32.6	25.6	83	000.4	-
9	September 24-30	33.3	25.0	87	034.6	3
10	October 1-7	31.8	25.0	85	032.4	1
11	October 8-14	31.4	24.9	82	017.8	1

12	October 15-21	33.0	24.7	81	-	-
13	October 22-28	33.9	25.4	84	018.2	2
14	October 29- Nov 4	33.2	23.8	92	125.0	4
15	November 5-11	30.1	23.4	81	058.2	5
16	November 12-18	29.5	24.2	80	022.6	2
17	November 19-25	29.9	23.6	87	128.6	5
18	Nov 26- Dec 3	29.0	22.8	91	405.8	6
19	December 4-9	27.0	22.5	91	118.8	5
20	December 10-16	27.0	23.5	88	006.7	1
21	December 17-23	30.6	21.4	89	069.2	3
22	December 24-31	27.7	21.3	87	028.0	1

Table 3: Composition of D^2 clusters for 26 rice genotypes in Normal (E1), Flash flood (E2) and Pooled analysis

Clusters	Grouping of Genotypes		
	Normal - E1 (seven clusters)	Flash flood - E2 (six clusters)	Pooled analysis (six clusters)
I	G3 (AURC 11), G10 (AURC 4), G17(Maapillai Samba), G8(CO 43), G15(AURC 6), G1 (AURC 1), G18 (Karung Kuruvai), G4(AURC 3), G11 (ADT 43), G13 (PY 5), G20 (Sembili Priyani), G6(IR 42), G16 (Sivappu Kurivikar), G9 (Vettaikaraniruppu Kulivedichan), G2 (AURC 12)	G3 (AURC 11), G10 (AURC 4), G17 (Maapillai Samba), G8 (CO 43), G15 (AURC 6), G1 (AURC 1), G18 (Karung Kuruvai), G4 (AURC 3), G11 (ADT 43), G13 (PY 5), G20 (Sembili Priyani), G6 (IR 42), G16 (Sivappu Kurivikar), G9 (Vettaikaraniruppu Kulivedichan), G2 (AURC 12), G14 (IR-55408-01), G21 (Kurnool Sona)	G3 (AURC 11), G10 (AURC 4), G17 (Maapillai Samba), G8 (CO 43), G15 (AURC 6), G1 (AURC 1), G18 (Karung Kuruvai), G4 (AURC 3), G11 (ADT 43), G13 (PY 5), G20 (Sembili Priyani), G6 (IR 42), G16 (Sivappu Kurivikar), G9 (Vettaikaraniruppu Kulivedichan), G2 (AURC 12), G14 (IR-55408-01), G21 (Kurnool Sona), G7 (IR-36).
II	G7 (IR 36), G14 (IR-55408-01), G21 (Kurnool Sona).	G5 (Kavuni), G12 (ADT 39), G19 (Jeeraga Samba)	G5 (Kavuni), G12 (ADT 39), G19 (Jeeraga Samba)
III	G5 (Kavuni), G12 (ADT 39), G19 (Jeeraga Samba)	G7 (IR 36)	G25 (JGL-384), G26 (TN- 1)
IV	G25 (JGL- 384), G26 (TN- 1).	G25 (JGL- 384), G26 (TN- 1), G23 (MTU- 1010)	G23 (MTU- 1010).
V	G23 (MTU- 1010).	G24 (NDLR- 8)	G24 (NDLR- 8)
VI	G24 (NDLR- 8)	G22 (Swarna *Sub*- 1)	G22 (Swarna *Sub*- 1)
VII	G22 (Swarna *Sub*- 1).	NIL	NIL

Table 4: Average intraclusters and intercluster distances (D^2 values)

Cluster Number	Environment	I	II	III	IV	V	VI	VII
I	Normal	228.01	395.61	1272.35	3595.20	3462.15	2807.94	2313.61
	Flash flood	256	648.72	428.49	5599.53	3527.17	1911.44	-
	Pooled	254.72	991.62	3395.39	3294.76	2571.50	2116.92	-
II	Normal		5.81	2162.25	3258.13	2788.90	2795.24	2261.00
	Flash flood		30.58	1039.42	6430.44	3479.82	1746.40	-
	Pooled		19.01	3821.71	4338.86	2051.18	2066.61	-
III	Normal			6.40	4545.46	5234.52	2700.88	2632.72
	Flash flood			0.00	3756.46	2355.16	1877.49	-
	Pooled			242.11	405.21	816.24	6799.65	-
IV	Normal				292.07	424.36	742.56	7857.05
	Flash flood				334.16	1022.08	8643.42	-
	Pooled				0.00	1273.06	7609.07	-
V	Normal					0.00	1169.64	8342.99
	Flash flood					0.00	5478.96	-
	Pooled					0.00	5019.72	-
VI	Normal						0.00	5930.54
	Flash flood						0.00	-
	Pooled						0.00	-

Intra cluster – Diagonal Bold Values; Inter cluster – Off-diagonal Values

Table 5: Cluster means of rice genotypes for various characters under normal and flash flooded condition

S. No	Characters	Environments	Clusters							Characters' contribution
			I	II	III	IV	V	VI	VII	
1.	DFF	Normal	84.47	88.33	85.00	95.00	83.50	105.00	128.00	0.31
		Flash flood	89.96	90.10	94.34	96.64	111.30	135.68	-	1.54
		Pooled	87.66	87.55	97.85	86.01	108.15	131.84	-	0.62
2.	PH (cm)	Normal	91.00	83.67	110.67	90.00	94.00	95.00	94.50	0.92
		Flash flood	99.06	121.73	93.50	100.47	104.50	103.95	-	0.62
		Pooled	94.27	116.20	94.50	98.70	99.75	99.23	-	0.62
3.	NT	Normal	16.40	12.67	23.33	27.00	14.00	24.50	23.50	0.31

#	Trait	Condition								
		Flash flood	14.35	21.17	13.00	21.00	23.00	22.50	-	1.23
		Pooled	15.03	22.25	26.13	13.25	23.75	23.30	-	0.31
4.	NPT	Normal	14.07	9.33	19.33	24.28	12.40	22.27	22.00	1.54
		Flash flood	9.38	15.00	6.50	14.50	18.26	17.00	-	0.31
		Pooled	11.25	17.17	20.91	10.40	20.26	19.50	-	0.31
5.	PL (cm)	Normal	23.53	28.00	27.33	21.54	21.80	19.50	20.75	1.23
		Flash flood	24.03	27.33	28.35	21.63	19.40	20.50	-	2.15
		Pooled	24.28	27.33	21.54	21.55	19.45	20.63	-	1.85
6.	GPP	Normal	167.87	112.00	201.33	130.00	99.50	130.50	239.00	6.15
		Flash flood	34.41	37.67	45.26	50.67	58.75	66.76	-	19.38
		Pooled	96.78	119.50	90.50	80.04	94.63	152.88	-	10.77
7.	TGW (g)	Normal	19.95	23.43	11.70	21.40	26.70	17.50	29.65	6.77
		Flash flood	20.36	11.70	23.41	23.17	17.48	19.51	-	25.54
		Pooled	21.03	11.70	21.40	26.69	17.49	19.53	-	24.62
8.	GL (mm)	Normal	6.61	5.93	5.80	7.00	8.70	7.42	6.86	31.38
		Flash flood	6.50	5.80	5.78	7.57	7.38	6.82	-	13.23
		Pooled	6.32	6.43	7.07	8.68	7.40	6.84	-	12.31
9.	GB (mm)	Normal	1.53	1.70	1.97	1.24	2.35	1.10	2.69	7.08
		Flash flood	1.55	1.97	1.62	1.61	1.07	2.65	-	5.23
		Pooled	1.56	1.97	1.23	2.34	1.09	2.67	-	7.08
10.	GLBR	Normal	4.33	3.50	2.97	5.78	3.70	6.75	2.55	1.54
		Flash flood	4.24	2.97	3.57	2.60	6.90	2.57	-	1.23
		Pooled	4.19	2.97	5.78	3.72	6.82	2.56	-	0.62
11.	GYD (g)	Normal	22.65	13.63	26.97	19.92	27.36	25.51	29.65	42.77
		Flash flood	4.42	5.06	7.25	6.25	8.48	19.57	-	29.54
		Pooled	12.87	16.01	14.64	17.25	16.99	24.61	-	40.92

DFF- Days to 50% flowering, PHT- Plant height, NT- Number of tillers per plant, NPT- Number of productive tillers per plant, PL- Panicle length, GPP- Number of grains per panicle, TGW- Thousand grain weight, GL- Grain length, GB- Grain breadth, GLBR- Grain L/B ratio, GYD- Grain yield per plant.

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