Rice Research: Open Access

Aravind et al., J Rice Res 2015, 3:4
DOI: 10.4172/2375-4338.1000154

Research Article Open Access

Inter Specific *Indica-japonica* Drought Tolerant Rice Genotypes for Aerobic Condition

J Aravind, Farhad Kahani and Shailaja Hittalmani*

Marker Assisted Selection Laboratory, Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore 560065, India

Abstract

Rice is premier food crop of Asia and is cultivated in a variety of ecosystems. Twenty six medium duration *Indica/Japonica*, Recombinant Inbred Lines (RILs) of the cross IR50 × Moroberekan cross, their parents and popular rainfed aerobic rice varieties MAS 946-1, Rasi and Sahabhagi Dhan were evaluated under rain fed, drought and aerobic conditions with objective of identifying genotype for aerobic and stress situations. Observations were recorded for plant and yield traits. Field evaluation during wet season revealed significant differences among the means of genotypes except for panicle length, drought recovery score, relative grain yield and relative biomass yield under different stress levels during dry season of 2011. RILs IM036, IM095, IM090, IM014, IM167, IM039, IM192 and IM176 performed superior under aerobic condition in wet season while, IM192 and IM176 were superior under rain fed condition also. IM160, IM096, IM104, IM046 IM192, IM109, IM36, IM181, IM14, IM176, IM167 and IM95 were high yielding in aerobic condition in dry season 2011. IM 167 was superior for grain yield under both conditions except under moisture stress period of 60 to 70 Days after sowing (DAS). IM95 was superior for stress period of 100 to 115 DAS and aerobic condition, whereas IM176 for aerobic and stress period 60 to 70 DAS. IM181 was superior under all the conditions after 60 to 75 DAS. IM36 was superior under all the conditions except for stress period 100 to 110 DAS. Superior genotypes identified for both drought and aerobic situations will be recommended for water scarce situation in India.

Keywords: Drought; Aerobic; Rain fed; Indica-Japonica; Rice

Introduction

Rice (*Oryza sativa* L.) is one of the major staple food crops for about 65% of the world's population. It is one of the most economically important food crops in the world. It is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the human beings. The green revolution led to a tremendous increase in tropical rice production. Much of these yield increases were seen in the irrigated and stress free ecosystems. However, according to various estimates, we will have to produce 40% more rice by 2030 to fulfil the food grain demands of the growing population, from less land, with less water, less labor and fewer chemicals. The most pragmatic approach to meet this demand is to breed rice tolerant to biotic and abiotic stresses which hamper production. Drought is the most serious constraint that limit rice yields, especially in rain fed ecosystems, as it is a highly water intensive crop (2500 Lkg-1 of rough rice). In India the drought during 2009 had caused a significant drop in rice production as compared to previous years. In the present era of climate change, water scarcity is escalating and irrigation is becoming a costly input. Consequently development of high yielding lines of rice, tolerant for drought stress prone ecosystems is an essential and practical strategy to increase rice production and ensure livelihood security for farmers. Breeding for drought tolerance is widely perceived as a difficult task as it is a complex trait controlled by poly genes having varying effects, and is dependent on drought timing and severity. Moreover the different drought tolerance traits differ in their ease of screening, nature of inheritance and heritability. Low heritability under stress for yield per se has forced the breeders to turn to secondary traits for selection. However, broad-sense heritability of grain yield under reproductive-stage drought stress was observed to be high and comparable to that of grain yield estimated in non-stress conditions by several authors [11-15] indicating that selection for yield under drought stress is repeatable. Water is most limited and essential natural resource in agriculture. The dwindling water resources reveal a grim situation for low land puddled rice cultivation. Because of increasing water scarcity, there is a need to develop alternative systems that require less water there are examples of restriction of cultivation of rice and sugarcane to save water for other domestic purpose during scarcity. To keep up the rice production during irrigation water shortage, alternate methods of cultivation of rice is essential. One such strategy is cultivation of rice under aerobic situation. This method of cultivation involves direct seeding with surface irrigations when required and is characterized by aerated soil environment during the entire period of crop growth comparable to other cereals like maize and irrigated Ragi. Aerobic rice could be successfully cultivated with 600 to 700 mm of total water in summer and entirely on rainfall in wet season. New varieties specially bred for this situation are most suitable for such cultivation to achieved high yields. Varieties suitable for this type of cultivation also possess ability to withstand intermittent drought spells with minimum yield loss with maximum potential of 6 tons per hectare. Irrigation is given at an interval of 5 days up to 25 days; 5 to 7 days once up to 50 days and during grain filling stage irrigation is provided once in 3 days. Aerobic cultivation with suitable varieties saves about 50 to 60% of irrigation water. It is also reported that amount of methane emitted under aerobic situation is very low and contributes to lowering of greenhouse gas emission. Rains fed lowland rice ecosystems are highly variable and unpredictable in nature (Yoshida, 1977). Multiple abiotic

***Corresponding author:** Shailaja Hittalmani, Professor and University Head, Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore 560065, India, Tel: 91-8023624967; E-mail: shailajah_maslab@rediffmail.com

Received October 02, 2015; **Accepted** November 02, 2015; **Published** November 06, 2015

Citation: Aravind J, Kahani F, Hittalmani S (2015) Inter Specific *Indica-japonica* Drought Tolerant Rice Genotypes for Aerobic Condition. J Rice Res 3: 154. doi:10.4172/2375-4338.1000154

stresses such as unfavorable soil conditions, regional weather patterns, topography, pests and weeds all contribute to the complexity of the ecosystem. Asia is the biggest rice producer and consumer, accounting for 90 per cent of the world's production and consumption of rice. The worldwide harvested area of rain fed lowland rice is estimated to be 46 to 48 million hectares. Of this, 90% is in South and Southeast Asia. Rice farming in these rains fed areas is risk-prone. Yields remain low, about 1.5 to 2.5 t ha in most areas. The income of most farmers is low and they are challenged by erratic yields. In Asia, about 50% of all the rice land is rain fed and although rice yields in irrigated ecosystems have doubled and tripled over the past 30 years, only modest gains have occurred in rain fed rice systems. The water supply in rain fed areas principally comes from rainfall. Uncertainty in the timing of rainfall and variability in its intensity and its distribution cause either flood or drought stress in rain fed lowland rice production ecosystem. Recombinant inbred lines are stabilized breeding lines which are one of the widely used mapping populations derived from the F2 of a cross between parents differing for the trait of interest by repeated inbreeding and represents permanent mapping family, developed one such recombinant inbred (RI) population in rice derived from the cross between IR 50, an *indica* variety susceptible to drought stress and Moroberekan, a West African upland *japonica* variety that has substantial resistance to drought. Preliminary evaluation revealed wide variability for yield and drought response in the population. In the present study, an attempt was made to identify medium duration IR50/Moroberekan RILs for grain yield under aerobic, rainfed and stress conditions [1-24].

Materials and Methods

Experimental material

A set of twenty six selected medium duration IR50/Moroberekan recombinant inbred lines (RILs) developed by Girish et al. at marker assisted selection laboratory, along with the two parents and four checks (MAS 946-1, Rasi, Sahbhagi Dhan and OYR-128) were used for the study. The RILs were selected based on maturity duration. Earlier flowering is advantageous over late flowering in terms of higher spikelet fertility, higher harvest index and higher yield, as it helps to counter terminal drought stress [23-25] (Table 1).

Experimental site

The investigation was carried out in two experiments during wet season 2010 and dry season 2011 under aerobic, rain fed and drought conditions at 'K' block, GKVK, Bangalore, representing the eastern dry zone with a red sandy loam which is located at the latitude of 12° 58' North; longitude 77° 35' East and altitude of 930 m above mean sea level. The experiment was laid and in randomized complete block design (RCBD) during wet season 2010 and in split plot design (SPD) during dry season 2011.

Method of sampling and observations recorded

Two plants were selected at random in each genotype in each replication for recording observations. Data was collected for traits such as number of tillers per plant, panicle number, plant height (cm), panicle length (cm), panicle weight (g), grain yield (g), biomass yield (g), harvest index, total number of grains per panicle, percentage sterility, test weight (g) and days to 50% flowering under three conditions while data on visual drought scores such as days to leaf rolling, leaf rolling score, leaf drying score and drought recovery score, were recorded only in the stress treatments [26]. Traits such as relative grain yield, relative biomass yield and relative spikelet fertility were computed as ratio between the respective parameters under stressed and control (aerobic) plots. Mean values of the traits were used for statistical analysis.

Statistical analysis

The analysis of variance (ANOVA) for different characters was carried using the mean data for aerobic and rain fed condition separately for Experiment 1 and by split plot analysis for with stress treatments considered as main plot treatments for Experiment 2 according to the method given by [27]. The co-efficient of variability (CV) at phenotypic level for all the characters were analyzed by applying the formula suggested by [28]. Heritability in broad sense (h2) estimates was computed by the formula suggested by [29].The extent of genetic advance expected through selection for each of the character was calculated as per the formula suggested by [30] (Table 2).

Results and Discussion

Evaluation of rice genotypes under aerobic and rain fed situation in wet season 2010

The analysis of variance for twelve quantitative traits of the genotypes evaluated in Experiment 1 indicated significant difference among the means of different genotypes for all the traits except for test weight under aerobic condition and percentage sterility under rain fed condition, thus indicating the scope for selection. The differences in the mean performance of the genotypes under aerobic and rain fed conditions can be attributed mainly due to genotypic differences and interaction between genotypes and environment. All the RILs showed reduction in grain yield under rain fed condition as compared to irrigated. The reduction in grain mean values in yield and yield contributing traits is probably due to the long period of stress experienced during peak reproductive stage. A few RILs such as IM-82 and IM160 showed very low grain yield reduction under stress condition. Such lines can be used to study the mechanism of drought tolerance involved. On comparison with the high yielding checks, a few RILs showed better performance for grain yield than MAS 946-1 under aerobic and rain fed conditions. Sahbhagi Dhan, Rasi and OYR-128 checks and RILs like IM 14, IM36, IM90 IM95, IM176 and IM192 performed superior than the high yielding parent IR 50 under aerobic condition. The RILs IM176 and IM192 were found superior to IR50 with respect to grain yield under rain fed conditions. This may be due

Sl No.	Genotypes	Sl No.	Genotypes	Sl No.	Genotypes
RILs					
1	IM-010	10	IM-090	19	IM-160
2	IM-014	11	IM-095	20	IM-167
3	IM-016	12	IM-096	21	IM-172
4	IM-036	13	IM-104	22	IM-173
5	IM-039	14	IM-109	23	IM-176
6	IM-046	15	IM-110	24	IM-181
7	IM-064	16	IM-118	25	IM-183
8	IM-082	17	IM-125	26	IM-192
9	IM-086	18	IM-133		
Parents					
1	IR 50	2	Moroberekan		
Checks					
1	MAS 946-1	3	Rasi		
2	OYR-128	4	SahbhagiDhan		

Table 1: List of Genotypes used for evaluation under aerobic, rainfed and drought conditions.

Experiment	Experiment 1		Experiment 2				
Treatment	**Aerobic**	**Rainfed**	**Control (Aerobic)**	**Stress1**	**Stress2**	**Stress3**	**Stress4**
Experimental Design	RCBD		Split Plot				
Season	Wet season 2010		Dry season 2011				
Period	Whole Season	17-10-2010 to 31-10-2010 (84 DAS - 99 DAS)	Whole Season	30-3-2011 to 7-4-2011 (60 DAS - 70 DAS)	30-3-2011 to 12-4-2011 (60 DAS - 75 DAS)	15-5-2011 to 24-5-2011 (100 DAS - 110 DAS)	15-5-2011 to 29-5-2011 (100 DAS - 115 DAS)
Crop Growth Stage	Throughout	Peak Reproductive Stage	Throughout	Early reproductive stage	Early reproductive stage	Late Reproductive stage	Late Reproductive stage
Duration (Days)	Whole Season	15	Whole Season	10	15	10	15
Drought induction	None - Aerobic Condition with irrigation once in 5 days	Natural dry spell	None - Aerobic Condition with irrigation once in 5 days	Withholding irrigation, avoiding seepage and rainfall	Withholding irrigation, avoiding seepage and rainfall	Withholding irrigation and avoiding seepage	Withholding irrigation and avoiding seepage

Table 2: Details of stress treatments used for evaluation of genotypes during Wet season 2010 and Dry season 2011.

Source	df	NT	PN	PH	PL	PW	GY	BM	HI	TG	PS	TW	DF
Replication	5	34.9	25.5	86.3	10.9	2.8	122.4	75.2	0.017	2483.4	214.5	3.35	19.4
Genotypes	31	128.2**	105.5**	1446.6**	21.6**	2.3**	142.5**	607.5**	0.01**	5160.5**	488.4**	0.671	628.3**
RILs	25	112.3**	99.4**	1469.8**	25.1**	2.2**	128.1**	606.1**	0.009**	5988.3**	487.3**	0.601	554.9**
Checks	5	78.3*	66.4*	1536.7**	5.5	1.4	113.2*	359.3**	0.013**	1975.03	285.8	1.13	1077.8**
RILs Vs Checks	1	778.2**	451.5**	416.9**	15.9	10.2**	657.3**	1899.4**	0.02	394.17	1528.6*	0.096	213.7**
Error	155	38.6	31.3	62.1	4.4	0.6	41.5	129.1	0.003	884.5	157.6	0.501	14.3
$SE_{(d)}$ (Genotypes)		3.59	3.23	4.55	1.21	0.46	3.72	6.56	0.03	17.17	7.25	0.41	2.18
$SE_{(d)}$ (RILs Vs Checks)		1.15	1.03	1.46	0.39	0.15	1.19	2.1	0.01	5.5	2.32	0.13	0.7
$CD_{5\%}$ (Genotypes)		7.08	6.38	8.98	2.39	0.91	7.35	12.96	0.06	33.92	14.32	0.81	4.31
$CD_{5\%}$ (RILs Vs Checks)		2.27	2.04	2.88	0.77	0.29	2.35	4.15	0.02	10.86	4.59	0.26	1.38

*. Significant at 5; *. Significant at 5%; **. Significant at 1%

NT: Number of Tillers per Plant; PN: Panicle number; PH: Plant Height (cm); PL: Panicle Length (cm); PW: Panicle Weight (g); GY: Grain Yield (g); BM: Biomass Yield (g); HI: Harvest Index; TG: Total Number of Grains per panicle; PS: Percentage Sterility; TW: Test Weight (g); DF: Days to 50% Flowering

Table 3: Analysis of variance for twelve quantitative traits among genotypes evaluated under aerobic condition during Wet season 2010.

to the fact that IR50 was developed for irrigated situation (Tables 3 and 4) (Figures 1 and 2).

Different genetic variability parameters were estimated using appropriate formulas and procedures. The range in the mean values reflects the extent of phenotypic variability present in the plant material (RILS). High range was noticed for plant height, number of tillers per plant, panicle number, and percentage sterility, total number of grains per plant, biomass yield and grain yield. High phenotypic coefficient of variability (PCV) was observed for number of tillers per plant, panicle number, percentage sterility, grain yield per plant, panicle weight and total number of grains per panicle whereas high genotypic coefficient of variability (GCV) was observed for number of panicle per plant, total number of grains per panicle and percent sterility under both aerobic and rain fed conditions. Moderate phenotypic coefficient of variability was observed for harvest index, panicle length, bio mass yield and plant height and for characters such as plant height, days to 50% flowering, and panicle number, moderate genotypic coefficient of variability was estimated. The GCV indicates the extent of genetic variability present for different characters and does not indicate heritable component of variability. To know the heritable component of the variability, heritability estimates were computed. Heritability values are important since their magnitude indicates the accuracy with which a genotype can be recognized by phenotypic expression. Though heritability estimates indicate the efficiency of selection system, its scope is restricted as they are prone to environmental effects. However, heritability values with genetic advance provide better response in selection program. High heritability was noticed for plant height and days to 50% flowering, moderate heritability recorded for number of tillers, number of panicles, panicle length, biomass yield, and total number of grains per panicle under both rain fed and aerobic conditions. Grain yield and harvest index showed low heritability under aerobic conditions and high heritability under rain fed condition. The remaining traits showed low heritability under aerobic and rain fed conditions. Comparable heritability's between the control and stress treatments have been reported by [15,16,31-33] have reported moderate to high heritability under stress for grain yield. Genetic advance as percent mean was high for plant height, days to flowering, total number of grains per panicle and percent sterility whereas that for number of tillers, panicle length, biomass yield, and harvest index were reported to be moderate. Grain yield showed moderate GA as percent of mean under aerobic situation and high GA as percent of mean under rain fed conditions. This indicates the feasibility of selection for yield under rain fed condition (Table 5).

Evaluation under aerobic and drought situations in dry season 2011

The different RILs showed varying response to different drought stress treatments in Experiment2. Split-plot design was used for analysis of variance of different traits. Most of the RILs yielded better under aerobic condition. However, RILs like IM16, IM36, IM39, IM64, IM82, IM90, IM95, IM110, IM172 and IM173 showed higher yields under stress situations. Many RILs also out yielded the high yielding parent IR 50. These are ideal candidates to study the mechanism of drought tolerance involved. The split-plot design is as special type of design used

Source	df	NT	PN	PH	PL	PW	GY	BM	HI	TG	PS	TW	DF
Replication	3	23.2	26.9	12.3	5	0.26	21.6	68.648	0.002	3847.85	1045	1.13	77.79
Genotypes	31	76.5*	83.8**	718.3**	15.9**	1.43**	70.**	374.9**	0.007**	2211.93**	392.3	1.37**	567.93**
RILs	25	80.3*	88.85*	707.9**	18.1**	1.3**	54.9**	327.03**	0.007**	2282.4**	401.6	1.5**	437.2**
Checks	5	71.6	60.4	905.3**	6.6	1.5	43.9	233.2	0.004	1464.7	142.9	0.94	969.8**
RILs Vs Checks	1	6.6	75.2	43.1	5.9	4.3**	606.4**	2284.6**	0.02**	4187.33*	1405.25*	1.01	2.6
Error	93	37.6	25.9	49.9	3.8	0.56	15.8	125.443	0.002	715.28	286.9	0.44	11.83
$SE_{(d)}$ (Genotypes)		3.59	3.54	2.94	4.08	1.13	0.43	2.29	6.47	0.03	15.44	9.78	0.38
$SE_{(d)}$ (RILs Vs Checks)		1.15	1.13	0.94	1.31	0.36	0.14	0.73	2.07	0.01	4.95	3.13	0.12
$CD_{5\%}$ (Genotypes)		7.08	6.99	5.81	8.06	2.24	0.86	4.53	12.77	0.05	30.5	19.32	0.75
$CD_{5\%}$ (RILs Vs Checks)		2.27	2.24	1.86	2.58	0.72	0.27	1.45	4.09	0.02	9.77	6.19	0.24

*. Significant at 5%; **. Significant at 1%

NT: Number of Tillers per Plant; TW: Test Weight (g); DF: Days to 50% Flowering; PN: Panicle Number; PH: Plant Height (cm); PL: Panicle Length (cm); PW: Panicle Weight (g);GY: Grain Yield (g); BM: Biomass Yield (g); HI: Harvest Index; TG: Total Number of Grains per panicle; PS: Percentage Sterility

Table 4: Analysis of variance for twelve quantitative traits among genotypes evaluated under rainfed condition during Wet season 2010.

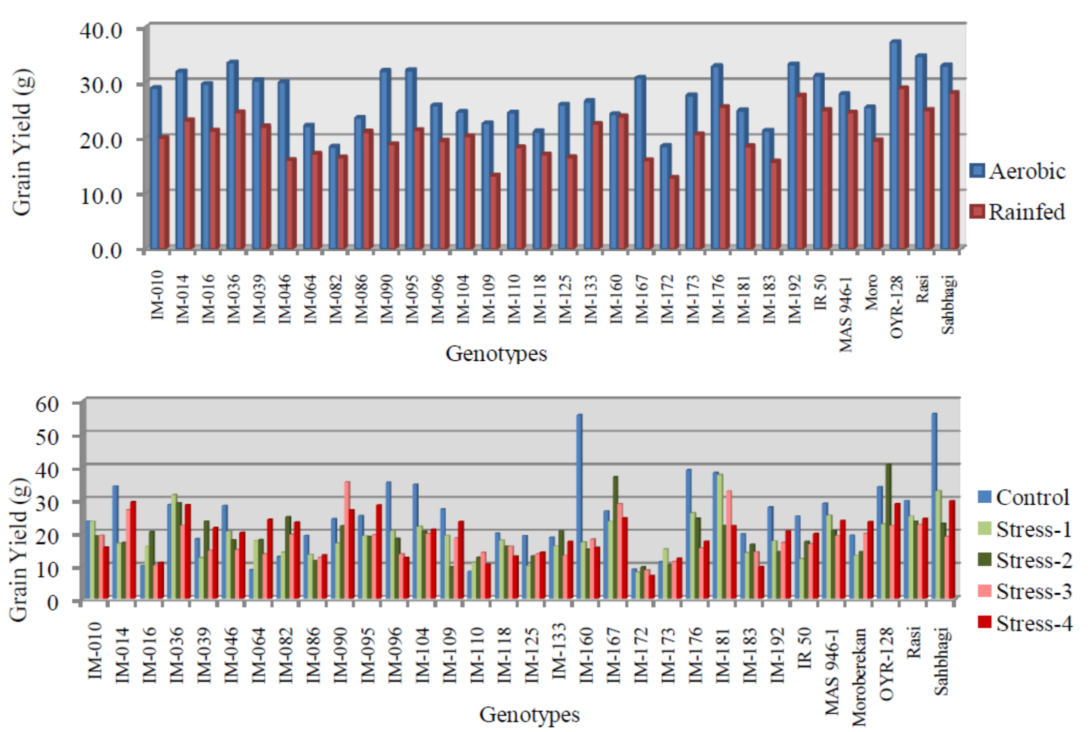


Figure 1: A. Comparison of genotypes evaluated under aerobic and rainfed conditions for grain yield (g) B. Comparison of genotypes evaluated under aerobic and drought conditions for grain yield (g).

for two factorial experiments, where the sub plot treatment effects and interaction effects can be determined with increased precision [34].The results of analysis of variance show that the effect of stress treatment on the variability was significant for all the traits except panicle length, drought recovery score, relative grain yield and relative biomass yield. Significant differences due to interaction between stress and genotypes were detected only for panicle length, days to 50% flowering, days to leaf rolling and leaf drying score. The genetic parameters estimated in the present population are due to additive effect as it is composed of stabilized RILs. The traits number of tillers, number of panicles, plant height grain yield, harvest index, percent sterility leaf drying score, leaf rolling score and relative grain yield showed high PCV and GCV values (Tables 6-8).

High values of broad sense heritability obtained can be attributed to lower differences between PCV and GCV values. However, phenotypic coefficient of variability is not very reliable since it includes both genetic and environmental effects and if the latter portion is large, selection will be inefficient. Thus, heritability values were estimated since its magnitude indicates the accuracy with which a genotype can be recognized by phenotypic expression. In present study heritability in broad sense was calculated. High heritability coupled with high GA observed for plant height, similar findings were reported for plant height by [35 and 36]. Moderate heritability and high genetic advance as percent of mean was observed for number of panicles, grain yield, harvest index, leaf rolling score, relative grain yield and relative biomass yield, indicating the suitability for improvement through selection. Moderate heritability and moderate GA as percent mean was observed for panicle length and days to leaf rolling, this was in conformity with the findings of [37]. Drought related traits like leaf rolling score and relative spikelet fertility showed low heritability and genetic advance.

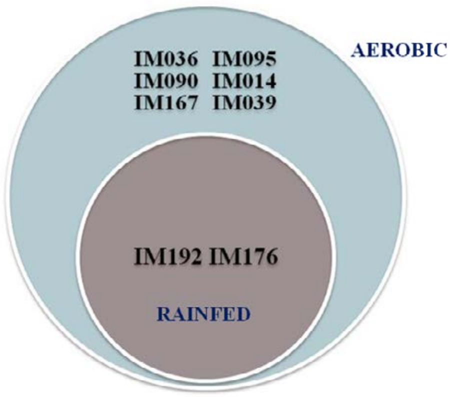


Figure 2: Venn diagram showing superior yielding RILs identified in Aerobic and Rainfed conditions.

Similar results were obtained by [38].

Identification of superior genotypes for grain yield under different situations

The genotypes were classified based on grain yield under various conditions and the RILs IM036, IM095,IM090, IM014, IM167, IM039, IM192 and IM176 were identified as superior under aerobic condition, IM192and IM176 were superior under rain fed condition during wet season 2010. In the evaluation under different drought treatments, IM160, IM096, IM104, IM046 IM192, IM109, IM36, IM181, IM14, IM176, IM167 and IM95 were be superior in aerobic condition IM90 was superior only under stress 3 (100-110DAS) and stress 4 (100-115DAS) IM 36 was superior under all the conditions except for stress 3 (100-110DAS), and IM I4 was superior under reproductive stage stresses stress 3 and 4; and under aerobic condition during dry season 2011. IM 167 was superior under all the conditions except stress 1(60-70DAS). IM 95 was superior for stress 4 and aerobic condition, whereas IM176 for aerobic and stress 1. IM181 was superior under all the conditions except stress 2 (60-75DAS). The high yielding RILs under different conditions are being tested in large scale for further selection suitable for target aerobic and drought conditions (Figure 3).

Acknowledgment

The financial assistance to Dr. Shailaja Hittalmani, from The Rockefeller Foundation USA, and ICAR- is gratefully acknowledged.

References

1. Kumar S, Dwivedi SK, Singh SS, Jha SK, Lekshmy S, et al. (2014) Identification of drought tolerant rice genotypes by analyzing drought tolerance indices and morpho-physiological traits. SABRAO Journal of Breeding and Genetics 46: 217-230.
2. Khush GS (2005) what it will take to feed five billion rice consumers by 2030. Pl. Mol. Bio. 59: 1 6.
3. Ricestat (2008) IRRI World rice statistics, International Rice Research Institute, LosBanos, Philippines.
4. O'Toole R, Von Hofsten J, Rosqvist R, Olsson PE, Wolf-Watz H (2004) Visualization of Zebrafish infection by GFP-labelled Vibrioanguillarum. MicrobPathog 37: 41-46.
5. Renuka Devi K, Siva Sankar A, Sudhakar P (2013) Identification of rice genotypes for drought tolerance based on root characters. IJABPT 4(4): 186-193.
6. Serraj R, Kumar A, Mcnally KL, Slamet-Loedin I, Bruskiewich R, et al. (2009) Improvement of drought resistance in rice. Adv Agron 103: 41-99.
7. Bouman BAM (2009) How much water does rice use? Rice Today. pp. 28-29.
8. Anonyomous (2010) Economic Survey of India - 2009-2010. Ministry of Finance, Government of India, New Delhi.
9. Bernier J, Kumar A, Ramaiah V, Spaner D, Atlin G (2007) A large-effect QTL for grain yield under reproductive-stage drought stress in upland rice. Crop Sci 47: 507-518.
10. Kamoshita AR, Chandra Babu N, ManikandaBoopathi, ShuFukai (2008) Phenotypic and genotypic analysis of drought-resistance traits for development of rice cultivars adapted to rainfed environments. Field Crops Res 109: 1-23.

Sl. No.	Character	Range				Mean		PCV		GCV		h^2_{bs}%		GA		GAM %	
		Min.		Max.													
		A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R
1	NT	6	4	44	42	19.72	16.78	37.09	41.00	19.60	18.59	27.92	20.55	4.21	2.91	21.33	17.36
2	PN	2	1	44	41	16.41	13.74	40.25	46.26	21.44	27.68	28.35	35.80	3.86	4.69	23.51	34.12
3	PH	47	45	120	111	86.15	76.25	19.86	19.32	17.63	16.95	78.81	77.01	27.78	23.37	32.25	30.65
4	PL	16	15	30	28.5	21.92	20.62	12.29	12.70	7.73	8.42	39.54	43.95	2.19	2.37	10.01	11.50
5	PW	1.1	1	5.9	4.5	2.95	2.24	32.37	39.44	17.86	20.77	30.46	27.74	0.60	0.50	20.31	22.54
6	BM	48.4	40.53	118.37	132.1	81.58	78.73	17.71	17.40	10.95	10.01	38.18	33.13	11.37	9.35	13.93	11.87
7	HI	0.16	0.13	0.48	0.38	0.34	0.26	18.99	21.93	10.05	13.60	28.00	38.46	0.04	0.05	10.95	17.37
8	TG	32	49	270	211	126.66	103.09	31.55	32.02	21.08	18.76	44.62	34.34	36.74	23.35	29.00	22.65
9	PS	1.02	3	88.89	91.38	22.25	24.36	65.55	72.65	33.37	21.08	25.91	8.42	7.79	3.07	34.99	12.59
10	TW	1.48	1.17	5.44	5.86	3.54	3.15	20.55	25.98	4.75	15.34	5.35	34.88	0.08	0.59	2.27	18.66
11	DF	69	72	116	120	85.75	88.42	12.59	13.89	11.80	13.34	87.73	92.16	19.52	23.32	22.76	26.37
12	GY	12.57	8.43	54.87	37.87	27.68	20.61	27.60	26.28	14.82	17.86	28.84	46.20	4.54	5.15	16.39	25.01

A: Aerobic; NT: Number of Tillers per Plant; TG: Total Number of Grains per panicle; R: Rainfed PN Panicle number; PS: Percentage Sterility; PCV: Phenotypic Coefficient of Variation; PH: Plant Height (cm); TW: Test Weight (g); GCV: Genotypic Coefficient of Variation; PL: Panicle Length (cm); DF: Days to 50% Flowering; h2bs Broad Sense Heritability; PW: Panicle Weight (g); GY: Grain Yield (g); GA: Genetic Advance; BM: Biomass Yield (g); GAM: Genetic Advance as Percentage of Mean; HI: Harvest Index

Table 5: Estimates of genetic parameters for twelve quantitative traits among genotypes evaluated in Wet season 2010 under aerobic condition and rainfed condition.

Source	df	NT	PN	PH	PL	PW	GY	BM	HI	TG	PS	TW	DF	DM
Replication	1	583.2	39.9	21.5	4.9	6.2	565.2	4630.9	7.03E-05	9990.5	7516.5	1.9	66.6	42.1
Stress	4	538.1**	236**	936.2**	8.9	3.2*	552.1**	1663.9**	0.02*	3458.6**	865.9*	1.7**	329.9**	516.1**
Error (a)	4	1121.3	276	957.8	13.8	9.4	1117.3	6294.8	0.024	13449.02	8382.4	3.6	396.5	558.1
Genotypes	31	102.6**	66.7**	2084.4**	38.4**	2.5**	348.6**	568.8**	0.05**	2734.1**	469.4*	0.6**	341.2**	297.1**
Stress Vs Genotypes	124	37.3	20.6	107.3	9.5**	0.8	69.7	341.3	0.008	769.6	215.8	0.3	21.5**	24.4*
Error (b)	155	36.6	18	112.2	4.2	0.8	60.4	314.7	0.01	837.5	226.2	0.2	13.2	17.5
$SE_{(d)}1$		5.92	2.94	5.47	0.66	0.54	5.91	14.03	0.03	20.50	16.18	0.34	3.52	4.18
$SE_{(d)}2$		2.71	1.90	4.74	0.92	0.41	3.47	7.93	0.04	12.94	6.73	0.22	1.62	1.87
$SE_{(d)}3$		8.40	5.11	11.78	2.13	1.04	9.66	22.40	0.10	35.09	21.93	0.59	5.02	5.87
$SE_{(d)}4$		6.05	4.24	10.59	2.06	0.91	7.77	17.74	0.10	28.94	15.04	0.49	3.63	4.19
$CD_{5\%}$ 1		16.44	8.15	15.19	1.82	1.50	16.41	38.94	0.08	56.92	44.94	0.93	9.77	11.60
$CD_{5\%}$ 2		5.35	3.75	9.36	1.82	0.80	6.86	15.67	0.09	25.57	13.29	0.44	3.21	3.70
$CD_{5\%}$ 3		16.59	10.08	23.26	4.20	2.06	19.09	44.24	0.20	69.33	43.33	1.17	9.91	11.59
$CD_{5\%}$ 4		11.96	8.38	20.93	4.06	1.79	15.35	35.04	0.20	57.17	29.71	0.98	7.17	8.27

*. Significant at 5%; **. Significant at 1%

$SE_{(d)}1$ - Standard error of difference between two main plot treatment means; $SE_{(d)}2$ - Standard error of difference between two sub-plot treatment means; $SE_{(d)}3$ - Standard error of difference between two main plot treatments means at the same or different levels of subplot treatment means; $SE_{(d)}4$ - Standard error of difference between two sub-plot treatment means at the same level of main plot treatment; $CD_{5\%}1$, $CD_{5\%}2$, $CD_{5\%}3$ and $CD_{5\%}4$ - The corresponding critical differences.

NT: Number of Tillers per Plant; PN: Panicle number; PH: Plant Height (cm); PL: Panicle Length (cm); PW: Panicle Weight (g); GY: Grain Yield (g); BM: Biomass Yield (g); HI: Harvest Index; TG: Total Number of Grains; PS: Percentage Sterility; TW: Test Weight (g); DF: Days to 50% Flowering

Table 6: Analysis of variance for twelve quantitative traits among genotypes evaluated under aerobic and drought conditions during Dry season 2011.

Source	df	DLR	LRS	LDR	DRS	RGY	RBY	RSF
Replication	1	4.5	3.3	5.6	39.1	2.8	2.2	0.10
Stress	3	**67.7****	**89.4****	**82.6****	4.3	0.2	0.3	**0.20***
Error (a)	3	72.2	92.7	88.3	43.3	3.0	2.5	0.30
Genotypes	31	**8.5****	**13.2****	2.5	4.6	**1.5****	**1.0****	0.11
Stress Vs Genotypes	93	**2.9***	2.6	**2.7***	2.7	0.3	0.2	0.06
Error (b)	124	2.0	2.0	1.8	3.1	0.4	0.2	0.07
$SE_{(d)}1$		1.50	1.70	1.66	1.16	0.30	0.28	0.10
$SE_{(d)}2$		0.62	0.63	0.60	0.78	0.29	0.22	0.12
$SE_{(d)}3$		2.04	2.20	2.12	2.08	0.70	0.56	0.28
$SE_{(d)}4$		1.40	1.41	1.34	1.75	0.64	0.49	0.27
$CD_{5\%}$ 1		4.17	4.72	4.61	3.23	0.85	0.78	0.27
$CD_{5\%}$ 2		1.23	1.25	1.19	1.54	0.56	0.43	0.24
$CD_{5\%}$ 3		4.02	4.34	4.19	4.10	1.38	1.10	0.56
$CD_{5\%}$ 4		2.76	2.79	2.65	3.45	1.26	0.97	0.54

*. Significant at 5%

**. Significant at 1%

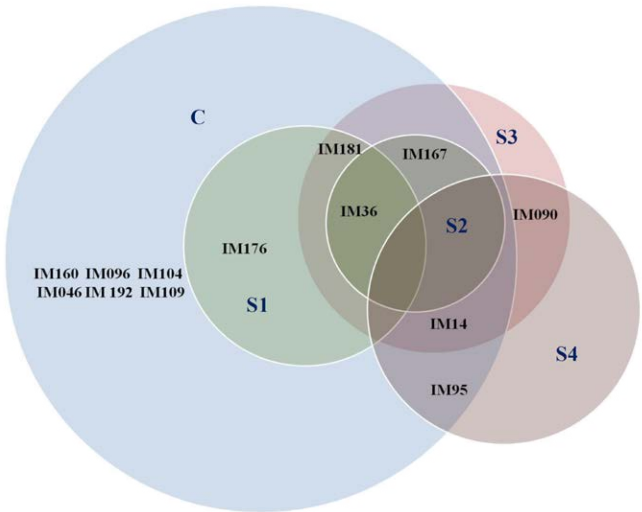
$SE_{(d)}1$ - Standard error of difference between two main plot treatment means; $SE_{(d)}2$ - Standard error of difference between two sub-plot treatment means; $SE_{(d)}3$ - Standard error of difference between two main plot treatments means at the same or different levels of subplot treatment means; $SE_{(d)}4$ - Standard error of difference between two sub-plot treatment means at the same level of main plot treatment; $CD_{5\%}1$, $CD_{5\%}2$, $CD_{5\%}3$ and $CD_{5\%}4$ - The corresponding critical differences.

Table 7: Analysis of variance for seven quantitative traits among genotypes evaluated under drought conditions during Dry season 2011.

Sl. No.	Character	Range		Mean	PCV	GCV	h^2_{bs}%	GA	GAM %
		Min.	Max.						
1	NT	4	54	16.8062	41.07	19.73	23.08	3.28	19.53
2	PN	1	31	10.7156	47.69	26.59	31.08	3.27	30.53
3	PH	21	126	78.5281	26.74	23.09	74.55	32.25	41.06
4	PL	15	30	20.9609	15.03	11.39	57.41	3.73	17.77
5	PW	5.03	12.25	8.0894	12.98	6.54	25.35	0.55	6.78
6	BM	23.02	131.95	58.322	32.40	11.16	11.86	4.62	7.92
7	HI	0.07	0.73	0.3491	36.98	23.39	40.00	0.11	30.47
8	TG	23	214	94.875	35.80	18.74	27.40	19.17	20.21
9	PS	0	96.7	21.2928	76.70	29.90	15.19	5.11	24.01
10	TW	1.53	5.05	2.9709	18.54	8.20	19.56	0.22	7.47
11	DF	82	115	101.7062	8.10	7.27	80.57	13.67	13.44
12	DLR	5	15	7.66	22.79	13.64	35.86	1.29	16.83
13	LRS	1	9	6.00	32.78	22.79	48.32	1.96	32.63
14	LDR	0	9	1.84	74.93	17.88	5.69	0.16	8.79
15	DRS	1	9	2.08	87.62	24.65	7.91	0.30	14.28
16	RGY	0.14	6.68	0.94	82.11	45.55	30.78	0.49	52.06
17	RBY	0.22	4.86	0.97	62.67	36.84	34.55	0.43	44.60
18	RSF	0.04	2.61	0.92	30.54	8.03	6.92	0.04	4.35
19	GY	5.42	64.38	20.2489	51.42	34.23	44.31	9.50	46.94

PCV: Phenotypic Coefficient of Variation; PL: Panicle Length (cm); DLR: Days to Leaf Rolling; GCV: Genotypic Coefficient of Variation; PW: PanicleWeight (g); LRS: Leaf rolling score; h^2_{bs} Broad Sense Heritability; BM: Biomass Yield (g); LDR: Leaf drying score; GA: Genetic Advance; HI: Harvest Index; DRS: Drought recovery score; GAM Genetic Advance as Percentage of Mean TG Total Number of Grains RGY: Relative grain yield; NT: Number of Tillers per Plant; PS: Percentage Sterility; RBM: Relative biomass yield; PN: Panicle number; TW: Test Weight (g); RSF: Relative spikelet fertility; PH: Plant Height (cm); DF: Days to 50% Flowering; GY: Grain Yield (g);

Table 8: Estimates of genetic parameters for nineteen quantitative traits among genotypes evaluated in Dry season 2011 under aerobic and drought conditions.



C Control
S1 Stress1 – 10 days (60 DAS - 70 DAS)
S2 Stress2 – 15 days (60 DAS - 75 DAS)
S3 Stress3 – 10 days (100 DAS - 110 DAS)
S4 Stress 4 – (100 DAS - 115 DAS)

Figure 3: Venn diagrams showing superior yielding RILs identified in Aerobic and Drought conditions.

11. Blum A, Zhang JX, Nguyen HT (1999) Consistent differences among wheat cultivars in osmotic adjustment and their relationship to plant production. Field Crops Res. 64: 287 291.

12. Atlin GN, Lafitte HR (2002) Developing and testing rice varieties for water-saving systems in the tropics. In: Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK (Eds.), Water-Wise Rice Production. Proceedings of the International Workshop on Water Wise Rice Production, Los Ban˜os, Philippines, 8-11 April.

13. Babu RC, Nguyen BD, Chamarerk V, Shanmugasundaram P, Chezhian P, et al. (2002) Genetic analysis of drought resistance in rice by molecular markers: Association between secondary traits and field performance. Crop Sci 43: 1457-1469.

14. Lanceras JC, Pantuwan G, Jongdee B, Toojinda T (2004) Quantitative trait loci associated with drought tolerance at reproductive stage in rice. Plant Physiol 135: 384-399.

15. Venkataramana P, Hittalmani S (2003) Factors determining grain yield in early generation of Rice (Oryza sativa L.) under non-submergence condition. Mysore J Agric Sci 37: 38-44.

16. Verulkar SB, Mandal NP, Dwivedi JL, Singh BN, Sinha PK, et al. (2010) Breeding resilient and productive rice genotypes adapted to drought-prone rain fed ecosystems of India. Field Crops Res 117: 197-208.

17. Bouman BAM, Yang Xiaoguang, Wang H, Wang Z, Zhao J, et al. (2002) Aerobic rice (Han Dao): A new way of growing rice in water-short areas, International Soil Conservation Organization Conference, Beijing, China. Tsinghua University Press. pp. 175-181.

18. Hittalmani S (1986) Genetical studies quantitative traits in rice (Oryzasativa L.) under three sub-optimal environments. Ph D Thesissubmitted to the Univ. Agric. Sci. GKVK, Bangalore.

19. Venkatesh Gandhi R, Rudresh NS, Shivamurthy M, Hittalmani S (2012) Performance and adoption of new aerobic rice variety MAS 946-1(Sharada) in southern Karnatak. Karnataka J Agric Sci 25: 5-8.

20. Sala M, Ananda Kumar CR, Geetha S (2015) Variability Studies for Quality Traits in Rice with High Iron and Zinc Content in Segregating Population. Rice Genomics and Genetics, 6: 1-5.

21. Fischer KS, Lafitte R, Fukai S, Atlin G, Hardy B (2003) Breeding rice for drought-prone environments International Rice Research Institute, Los Baños, Philippines.

22. Collard BCY, Jahufer MZZ, Brouwer JB, Pang ECK (2005) An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts. Euphytica 142: 169-196.

23. Girish TN, Gireesha TM, Vaishali MG, Hanamareddy BG, Hittalmani S (2006) Response of a new IR50/Moroberekan recombinant inbred population of rice (Oryza sativa L) from an indica × japonica cross for growth and yield traits under aerobic conditions, Euphytica. 152: 149-161.

24. Shivapriya M (2004) Evaluation of IR50 x Moroberekan RIL for drought and blast resistance Parental polymorphism using DNA markers inrice (Oryza sativa. L) Ph.D Thesis, University of Agricultural Sciences Bangalore, India P 152.

25. Lafitte R, Courtois B (2002) Interpreting cultivar x environment interactions for yield in upland rice: assigning value to drought-adaptive traits. Crop Sci 42: 1409-1420.

26. Anonyomous (2002) Standard Evaluation System for Rice, IRRI, Los Banos, Philippines.

27. Panse VG, Sukhatme PV (1964) Statistical methods for Agricultural Workers. ICAR, New Delhi, 381.

28. Burton GW, DeVane EW (1953) Estimating heritability in tall Fescue (Festucaarundinacea) from replicated clonal material. Agron J 45: 478-81.

29. Hanson CH, Robinson HF, Comstock RE (1956) Biometrical studies in yield in segregating populations of Korean Laspedez, Agron, J 48: 267-282.

30. Johnson HW, Robinson HF, Comstock RE (1955) Genotypic and phenotypic correlations in Soybean and their application in selection, Agron. J 47: 477-483.

31. Kumar R, Venuprasad R, Atlin GN (2007) Genetic analysis of rainfed lowland rice drought tolerance under naturally-occurring stress in eastern India: heritability and QTL effects. Field Crops Res. 103: 42-52.

32. Venkataravana P (1991) Studies on genetic variability, character association and path co-efficient analysis in F_2segregants of rice (*Oryza sativa* L) under Irrigated and Aerobic conditions MSc Thesis submitted to the Univ. Agric. Sci. GKVK, Bangalore, India P178.

33. Dixit S, Huang BE, Sta Cruz MT, Maturan PT, Ontoy JCE, et al. (2014) QTLs for Tolerance of Drought and Breeding for Tolerance of Abiotic and Biotic Stress: An Integrated Approach. PLoS ONE 9(10): e109574. doi: 10.1371/journal.pone.0109574.

34. Rangaswamy R (2010) A textbook of Agricultural Statistics (2ndedn), New Age International Publishers, New Delhi.

35. Krishna TV, Hittalmani S (2009) Response of yield and related traits in a recombinant inbred line population at reproductive stage moisture stress in rice. Bull. Biol. Sci 7: 165-177.

36. Rakhi Soman, Naveen kumar Gande, Rajeswari Ambati, Pavan J Kundur, Ashwathanarayana R, et al. (2014) Studies for grain iron concentration and yield related traits in recombinant inbred lines of rice (*Oryza sativa*. L) Grown under aerobic condition. International Journal of Current Research 6: 5869-5874.

37. Vanitha J, Usha Kumari R, Amudha K, Robin S (2015) Genetic evaluation of rice genotypes for zinc deficiency tolerance and yield traits under aerobic condition in rice. Electronic Journal of Plant Breeding 6: 191-195.

38. Subashri M, Robin S, Vinod KK, Rajeswari S, Mohanasundaram K, et al. (2009) Trait identification and QTL validation forreproductive stage drought resistance in rice using selective genotyping of near flowering RILs. Euphytica 166: 291-305.

39. International Rice Research Institute (IRRI), Los Ban˜os, Philippines, pp. 275-283.

40. Lafitte HR, Courtois B (2000) Genetic variation in performance under reproductive stage water deficit in a doubled-haploid rice population in upland fields. In: Ribaut JM, Poland D (eds) Molecular approaches for the genetic improvement of cereals for stable production in water- limited environments. A strategic planning workshop held on 21-25.