Oryza Vol. 51 No.4, 2014 (267-272)

Identification of promising aerobic rice genotypes through Aerobic Response Index, stability analysis and participatory varietal selection

AK Mall*, SK Dash, SK Pradhan and ON Singh

Central Rice Research Institute, Cuttack-753 006, Orissa, India
**AICRP on Forage Crops, IGFRI, Jhansi-284003, U.P. India*
Email: ashutoshkumarmall@gmail.com

ABSTRACT

Twelve rice genotypes (including three checks) were evaluated under aerobic conditions using a randomized complete block design with three replications under farmers' field in four locations. GE interaction was analyzed using linear regression techniques. There was considerable variation for grain yield among both genotypes and environments. The regression coefficient of cultivar Pyari (CR 2624) was almost unity and had one of the lowest deviations from regressions with high coefficient of determination, confirming its stability. In contrast, genotypes IR 78875-53-2-2-2 and IR 78878-53-2-2-4 showed insensitivity to environmental changes for grain yield. Low and consistent Aerobic Response Index (ARI) also confirmed their stability. Genotypic variation in ARI was consistent for tested genotypes among all the farmers' field. The mean values of ARI for grain yield (GY) were less than 1, which indicated the relative tolerance of this character under this study. The significant and positive correlations were obtained between ARI and GY under favourable condition (irrigated), whereas, negative association in unfavourable (aerobic) condition. Three genotypes namely, Anjali, Lalat and IR 79906-B-5-3-3 were identified as inconsistent on the basis of performance of ARI, over the locations (farmers' field). The inconsistence of the estimates in ARI across farmers' field, reflects high G x E interactions for grain yield under aerobic condition. In this context, Pyari (CR 2624), IR 78875-53-2-2-2 and IR 78878-53-2-2-4 may be suggested as stable genotypes for target area during dry season. Involvement of the clients (farmers) in the breeding and selection process would be immensely helpful in selecting genotypes, that is expected to combine higher grain yield with other requisite parameters for the farmers, in irrigated/ lowland rice with water scarcity.

Key words: *Aerobic rice, Stability, ARI, Relative Yield, PVS*

Food security in India is challenged by increasing food demand and threatened by "physical water scarcity" at present and "economic water scarcity" in future. Rice consumes more than 50 per cent of the water used for irrigation in Asia (Barker *et al.*, 1999). Several strategies are being pursued to reduce rice water requirements, such as saturated soil culture (Borrel *et al.*, 1997), alternate wetting and drying (Li 2001, Tabbal *et al.*, 2002), ground cover systems (Lin Shan *et al.*, 2002), system of rice intensification (SRI, Stoop *et al.*, 2002), aerobic rice (Bouman *et al.*, 2002), and raised beds (Singh *et al.*, 2002). It is reported that SRI and AWD systems have high water productivity with some amount of saving (approx. 20 per cent) without any compromise on productivity. However, water requirement of these production systems is also very high as land preparation consists of soaking, followed by wet ploughing or puddling of saturated soil except Aerobic system.

To safeguard food security and preserve precious water resources, ways were explored to grow rice using less water, hence, shifting gradually from traditional rice production system to aerobic rice, can mitigate water scarcity considerably. In India, upland rice is already grown aerobically with minimal inputs but mostly as a low yielding subsistence crop to give stable yield under adverse conditions of the uplands. Alternatively, high yielding lowland rice varieties grown under aerobic soil conditions, but with supplemental irrigation, have been shown to save water, but at a severe yield penalty. Achieving high yield under irrigated but aerobic soil condition, requires new varieties of "aerobic rice" that combine the drought tolerant characteristics of upland varieties with the high yielding characteristics of lowland varieties. Yield penalty and yield stability of aerobic rice have to be considered before promoting this technology in subtropical India in general, and coastal Orissa in particular.

In this backdrop, a multi-location on-farm evaluation of promising aerobic rice genotypes was carried out under farmers' participatory mode in four different villages of Cuttack district adopted under "Asian Development Bank (ADB) funded collaborative research programme between IRRI, Philippines and ICAR-Central Rice Research Institute, Cuttack.

MATERIALS AND METHODS

On the basis of performance in advanced yield trials (AYT) over the years under aerobic and irrigated conditions, twelve selected promising genotypes including three checks were evaluated at four farmer's field *viz.*, Kochila Nuagaon (E_1): The village is partially irrigated from a perennial stream (*Damanijhar*) from the hills and a watershed (*Mahichua bandh*); Brahmanabasta (E_2): The village is partially irrigated from a lift irrigation point (LIP) from Mahanadi river (3 km away) and also from the local *Nala* (drainage channel) which passes near the village; Samian (E_3): the village is partially irrigated from a Minor Irrigation project called Kalakala Minor Irrigation Project (popularly known as *Gaapal Bandh*) and Ratanpur (E_4): The village is largely irrigated from government canal under participatory varietal selection trials to identify suitable genotypes under aerobic condition for target environments during dry season, 2011.

The experiments were conducted in Randomized Complete Block Design with three replications under two water regimes: (a) aerobic condition under non flooded and non puddled condition at on-farm and (b) irrigated condition at on-station. Rice varieties under aerobic condition were directly sown at 2-3 cm soil depth in dry and pulverized soil by hand plough with the seed rate of 50 Kg ha^{-1} to maintain 3-4 seeds hill^{-1}. Twenty one days old seedlings were transplanted under irrigated condition in same plot size used for aerobic condition. Peizometers (200 cm length and 5 cm diameter PVC pipe) were installed in all the treatments to monitor the ground water fluctuation to guide the timing of irrigation. Experimental plots under aerobic condition, were maintained at near saturation and re-watered only when soil water table reached below 15 cm whereas, irrigated condition was designed to maintain assured soil moisture by keeping 5 cm pounded water. Standard cultural practices were adopted and need based plant protection measures were taken. Phosphorus (@ 40 kg ha^{-1} P_2O_5) and potassium (@ 40 kg ha^{-1} K_2O) were applied as recommended before sowing/planting in aerobic and transplanted conditions. Nitrogen @ 80 kg ha^{-1} in the form of urea was used in three split doses. Pre-emergence herbicide Pretilachlor at 0.5 kg a.i. ha^{-1} was applied at 3 DAS followed by hand weeding at 20 DAS and 45 DAS.

The data were analyzed by appropriate statistical analysis (Gomez and Gomez, 1984) using CropStat 7.2 (2009) programme. Aerobic response index (ARI) was calculated on the basis of following modified formula (Mall *et al*., 2015) which was originally used for drought susceptibility index (DSI) by Fischer and Maurer (1978).

ARI= $(1-Y_A/Y_I)/(1-Y_A/Y_I)$, where Y = mean of a character; Y = experimental mean;

A = Aerobic condition and I =irrigated condition.

The relative yield under aerobic condition was calculated as the yield of a specific genotype under aerobic condition divided by that of the highest yielding genotype in the experiment. The stability analysis was done following Singh and Chaudhury (1985).

RESULTS AND DISCUSSION

The data were subjected to the analysis of variance to test the significance of genotype x environment interaction following Eberhart and Russell (1966) and Perkins and Jinks (1968) models. Highly significant variances due to genotype for grain yield (t ha^{-1}) indicated the presence of sufficient genetic variance in the cultures. Mean squares due to environment were found significant, indicating differences between environments and their influence on genotypes for expression of grain yield (t ha^{-1}). The G x E interaction mean squares were further partitioned into two components viz., G x E (linear) and pooled deviation (non linear) for grain yield (t ha^{-1}) (Table 1). Both of the above components were found to be significant. Similar findings of Panwar et al. (2008) and Mall et al. (2015) supports the present findings.

Table 1. Mean squares for phenotypic stability as per Eberhart and Russell for grain yield (t ha^{-1}) in rice

Source of Variation	df	Yield (t ha^{-1})
Genotypes	11	0.32**
Environments	3	0.16**
Genotypes x Environments	33	0.06**
Genotypes x Environments (Linear)	11	0.09**
Pooled Deviation	22	0.05**
Total	47	5.86

Four genotypes *viz*., IR 78875-131-B-1-4, IR 78875-53-2-2-2, IR 78878-53-2-2-4 and CR 2624 (Pyari) were recorded highest grain yield over the grand mean under aerobic conditions in four different farmers' field.

Grain yield under aerobic condition is a function of yield potential and aerobic response. Therefore, the use of the aerobic response index (ARI) can help to distinguish suitable genotypes for aerobic adaptation from the angle of phenology and yield potential (Mall et al., 2015). The ARI is a yield stability parameter which is based on grain yield reduction under stress. Grain yield reduction ranged from 12.83% (Annada) to 29.70 % (Lalat) under aerobic condition. Large ARI values indicate greater drought susceptibility (Chatham *et al*., 2007). The mean values of ARI for grain yield (GY) were less than 1, indicated that the relative tolerance to water scarcity of these genotypes of this character was high in general (Table 2). The significant and positive correlations were obtained between ARI and GY under irrigated condition (r=0.333**, 0.551**, 0.465** and 0.424**), whereas negative association (r= -0.720**, -0.556**, -0.506** and -0.464**) was recorded in aerobic condition in on station trials. This result is in agreement with Pantuwan *et al*. (2002) under reproductive stage drought stress. Desirable correlation between yield and ARI indicated that there is scope of choosing ARI as one of the selection criteria under aerobic condition. Therefore, it would allow breeders to identify genotypes with high yield potential under aerobic condition for water limiting areas in tropics. All the genotypes under study recorded low ARI (ARI<1) over the locations and among them, CR 2624, IR 78878-53-2-2-4 and IR 78875-53-2-2-2 were recorded with lowest ARI for seed yield over the environments (farmers fields), thereby indicating that the genotypes were tolerant to water limiting conditions. Furthermore, only CR 2624 (Pyari) had a grain yield above 4 t ha^{-1} under both the situations and was found with lowest ARI over the locations.

It is not necessary that a stress tolerant genotype should have also higher yield potential. In this context, the mean relative grain yields values under aerobic condition were compared and the values were found to be 0.86 in E_1, 0.87 in E_2, 0.89 in E_3 and 0.86 in E_4. The genotypes CR 2624 (Pyari) and IR 78878-53-

Table 2. Genotypic mean performance under aerobic and irrigated conditions and their aerobic response index (ARI) for grain yield (t ha^{-1}) at farmer's field (E_1, E_2, E_3, E_4)

Genotypes	ARI over the locations					Relative Yield under Aerobic				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
IR 78875-53-2-2-2	0.69	0.96	0.92	0.82	0.90	0.91	0.87	0.89	0.90	0.90
IR 74371-3-1-1	0.81	0.83	1.22	0.86	0.98	0.84	0.84	0.79	0.84	0.83
IR 80312-6-B-3-2-B	1.53	0.76	0.09	0.99	0.96	0.70	0.88	1.00	0.83	0.86
IR 78875-131-B-1-4	0.46	1.13	0.97	0.97	0.93	0.96	0.83	0.88	0.86	0.89
IR 79906-B-5-3-3	1.20	0.87	0.24	1.04	0.94	0.69	0.77	0.87	0.73	0.77
IR 79906-B-192-2-1	0.80	0.85	0.50	1.28	0.94	0.87	0.87	0.94	0.77	0.87
IR 55419-04	0.76	0.69	1.15	0.92	0.93	0.80	0.82	0.75	0.77	0.79
CR 2624	0.71	0.75	0.95	0.75	0.83	1.00	1.00	0.97	1.00	1.00
IR 78878-53-2-2-4	0.57	0.94	1.04	0.85	0.89	0.97	0.90	0.90	0.92	0.93
Lalat	1.75	1.14	1.73	1.56	1.65	0.80	0.99	0.90	0.86	0.89
Annada	0.52	0.75	1.16	0.37	0.71	0.88	0.84	0.79	0.92	0.86
Anjali	1.10	1.12	0.66	0.96	1.04	0.85	0.87	0.97	0.90	0.91
Mean	0.91	0.90	0.88	0.95	0.98	0.86	0.87	0.89	0.86	0.87

2-2-4 were relatively high yielding (RY> mean RY) along with check varieties, while rest of the genotypes in all the environments were relatively low yielding (RY< mean RY) in this study, except IR 79906-B-192-2-1, IR 78875-131-B-1-4 and IR 78875-53-2-2-2. Similar finding was reported by Ahmad *et al*. (2003).

There was sufficient variation for mean grain yield among environments and had a range from 3.02 t ha^{-1} for E_4 to 4.32 t ha-1 for E_3 (Table 3). The presence of genotype x location interactions indicates that particular genotypes tended to rank differently in grain yields at different locations. The broad sense heritability (h_b) was 54.0 for grain yield, indicating that grain yield is a complex character and is greatly affected by different farmer's field. An analysis of variance for stability, revealed that there was significant differences for grain yield among genotypes and environments (farmers' fields). This reveals not only the amount of variability that existed among environments but also among the genotypes. The mean square for G x E interaction was significant for grain yield. Significant F values were found for GE interaction (linear) for grain yield, indicating differences among the regression coefficients. The mean grain yield of the 12 rice genotypes ranged from 3.13 t ha^{-1} to 4.18 t ha^{-1} and the higher grain yield was obtained from genotypes IR 78875-131-B-1-4, IR 78875-53-2-2-2, IR 78878-53-2-2-4 and CR 2624 (Table 3). It was emphasized that both linear (bi) and non-linear (S^2 di) components of GE interactions are necessary for judging the stability of a genotype (Eberhart and Russell, 1966). The regression coefficients (bi values) ranged from 0.40 to 1.78. This large variation in regression coefficients indicates different responses of genotypes to environmental changes.

Genotypes with high mean yield, a regression coefficient equal to the unity (bi = 1) and small deviations from regression (S^2di=0) are considered stable (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). Accordingly, genotypes CR 2624 (Pyari) was found to be the most stable genotype for grain yield because their regression coefficients were almost equal to unity and they had lower deviations from regression with high R_i (88%) values (Pinthus, 1973), conforming their stability. In contrast, genotype IR 78875-131-B-1-4 had regression coefficients greater than one, and so was regarded as sensitive to environmental changes, with respect to grain yield.

Genotypes IR 78875-53-2-2-2 and IR 78878-53-2-2-4 had regression coefficients less than unity (bi<1.0), but they had high grain yields. These genotypes are, therefore, insensitive to environmental changes and have adapted to the poor environments. Furthermore, IR 78875-131-B-1-4 had regression coefficients significantly greater than unity for grain yields over mean grain yield. Therefore, this genotype is sensitive to environmental changes and can be recommended for cultivation under favourable conditions. Similar inferences were reported for genotype x environment interaction for grain yield in rice (Kishore *et al.*, 2002, Subudhi *et al.*, 2008 and Subudhi *et al.*, 2012).

During maturity stage of the crop, farmers

Table 3. Estimates of stability and adaptability parameters of grain yield (t ha^{-1}) for twelve rice genotypes at four farmers field (E_1, E_2, E_3, E_4)

Genotypes	Mean grain yield (t ha^{-1})	Regression coefficient (b_i)	Deviation from regression (S^2_{di})	Coefficient of determination (R_i^2)
IR 78875-53-2-2-2	3.76	0.51	0.01	60
IR 74371-3-1-1	3.49	0.40	0.01	81
IR 80312-6-B-3-2-B	3.61	1.78	0.13	61
IR 78875-131-B-1-4	3.71	1.47	0.09	25
IR 79906-B-5-3-3	3.13	0.51	0.01	47
IR 79906-B-192-2-1	3.63	0.89	0.03	62
IR 55419-04	3.22	1.01	0.04	21
CR 2624	4.18	0.99	0.00	88
IR 78878-53-2-2-4	3.89	0.77	0.02	58
Lalat	3.64	1.59	0.09	20
Annada	3.51	0.90	0.03	52
Anjali	3.34	0.88	0.03	8

were taken around the trials and participated in varietal selection. Farmers were asked to rank three best varieties as first, second and third as per their perceived criteria. Thirty per cent farmers have choosen CR 2624 (Pyari) as first followed by IR 78878-53-2-2-4 (23%) and Annada (17%). The other varieties which were given first preference each by 7 per cent farmers were IR 55419-04 and Lalat (Table 3). The second rank was given mainly to four varieties *viz.,* CR 2624 (Pyari), Annada, IR 78878-53-2-2-4 and IR 55419-04 (30 %, 20 %, 20 % and 13 %, respectively). The third rank was given mainly to three varieties namely, CR 2624 (25%) followed by Annada (17%) and IR 74371-3-1-1 (13%). On the whole, CR 2624(Pyari) was preferred by most of the farmers followed by IR 78878-53-2-2-4, IR 74371-3-1-1 and IR-55419-04. The reasons specified by the farmers for preferring the varieties were i) higher panicle length and weight, ii) good grain type, iii) higher number of tillers per hill and iv) more straw.

Yield penalty and stability of aerobic rice are the two key criteria that need consideration before promotion in tropics. Testing of aerobic genotypes across farmers' field, indicated that cultivar Pyari showed stability in performance over locations and was also preferred by the farmers through participatory varietal selection. As grain yield is the most important breeding objective, direct selection for grain yield under aerobic is supposed to be effective, hence, the genotypes with a grain yield of 4.2 t ha^{-1} under both water regimes(Pyari), needs some morpho-physiological adjustments for yield contributing traits to develop new aerobic rice varieties with minimum yield gap. The cultivar superiority based on quantitative data (breeders' criteria) and qualitative preference scores (farmers' criteria) often showed synergies, however, there were differences as well. This indicates farmers' ability to choose superior cultivars based on qualitative observation compared to tedious quantitative data recording in the on-station testing.

REFERENCES

Ahmad R, Quadir S, Ahmad N and Shah KH 2003.Yield Potential and Stability of Nine Wheat Varieties under Water Stress Conditions. International Journal of Agriculture and Biology. 5 (1): 7-9.

Barker R, Dawe D, Tuong TP, Bhuiyan SI and Guerra LC 1999. The outlook of water resources in the year 2020: Challenges for research on water management in rice production. In: Assessment and Orientation towards the 21st century. Proceedings of 19th session of the International Rice Commission, Cario, Egypt. 7-9 September, 1998. pp. 96-109. FAO, Rome (Italy).

Borell A, Garside A and Shu FK 1997. Improving efficiency of water for irrigated rice in a semi-arid tropical environment. Field Crops Research. 52: 231–248.

Bouman BAM, Wang Hua Qi, Yang Xiao Guang, Zhao Jun Fang and Wang Chang Gui 2002. Aerobic rice (Han Dao): a new way of growing rice in water-short areas. In: Proceedings of the 12th International Soil Conservation Organization Conference, 26–31 May 2002, Beijing, China. Tsinghua University Press, p. 175–181.Eberhart SA and Russell WA 1966. Stability parameters for comparing varieties. Crop Science. 6: 36-40.

Chatham JS, Tyagi MK, Kumar A, Nashaat NI, Singh M, Singh NB, Jakhar ML and Welham, SJ 2007. Drought effects on yield and its components in Indian mustard (*Brassica juncea* L.). Plant Breeding. 126: 399-402.

Finlay KW and Wilkinson GN 1963. The analysis of adaptation in a plant-breeding programme. Australian Journal of Agricultural Research. 14: 742-754.

Fischer RA and Maurer R 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian Journal of Agricultural Research. 29: 897-912.

Gomez KA and Gomez AA 1984. Statistical Procedures for Agricultural Research (2nd Edition). John Wiley & Sons. Inc. 680 p.

IRRI 2009. CropStat 7.2 for Windows. Crop Research Informatics Laboratory, International Rice Research Institute, Los Banos, Philippines.

Kishore K, Singh NK, Niraj Kumar and Thakur R 2002. Genotype x Environment interaction and stability analysis for grain yield and some associated traits in boro rice. Oryza. 39: 12-14.

Li YH 2001. Research and practice of water-saving irrigation for rice in China. In: Barker, R. Li, Y. and Tuong T. P., Water-saving irrigation for rice. Proceedings of an International Workshop, 23–25 Mar 2001, Wuhan, China. Colombo (Sri Lanka): International Water Management Institute. p. 135–144.

Lin Shan, Dittert K and Sattelmacher B 2002. The ground cover rice production system (GCRPS) - a successful new approach to save water and increase nitrogen fertilizer efficiency? In: Water-Wise Rice Production. (eds. Bouman, Hengsdijk, Hardy, Bindraban, Tuong, Lafitte and Ladha). Los Baños (Philippines): IRRI.

Mall AK, Swain P, Pradhan SK, Dash SK and Singh ON 2015. Development of aerobic rice cultivars with reference to G x E interaction and aerobic response index. Electronic Journal of Plant Breeding. 6 (1): 1-7.

Pantuwan G, Fukai S, Cooper M, Rajatasereekul, S, and O'Toole JC 2002. Yield response of rice (*Oryza sativa* L.) genotypes to different types of drought under rainfed lowlands Part 1 Grain yield and yield components. Field Crops Research. 73: 153-168.

Pinthus MJ 1973. Estimates of genotypic value: a proposed method. Euphytica. 22: 345-351.

Singh AK, Choudury BU and Bouman BAM 2002. The effect of rice establishment techniques and water management on crop-water relations. In "Water-Wise Rice Production". (Eds. Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK). Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute, pp. 237-246.

Singh RK and Chaudhury BD 1985. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi, India.

Stoop W, Uphoff N and Kassam A 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. Agricultural Systems. 71: 249–274.

Subudhi HN, Bose LK, Singh ON and Rao GJN 2012. Genotype x Environment interaction for grain yield and its component traits in irrigated Rice. The Madras Agricultural Journal. 99 (4-6): 178-180.

Subudhi HN, Meher J and Bose LK 2008. Stability analysis for grain yield in some rice varieties. Environment and Ecology. 26: 2199-2201.

Tabbal DF, Bouman BAM, Bhuiyan SI, Sibayan EB and Sattar MA 2002. On-farm strategies for reducing water input in irrigated rice; case studies in the Philippines. Agricultural Water anagement. 56(2): 93–112.