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Research Article

Stability analysis of different rice (*Oryza sativa* L.) genotypes for yield and yield attributing traits in paddy ecosystems of Northern Karnataka

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Abstract
The present investigation was conducted during *kharif* 2021 in paddy growing regions of Northern Karnataka. Pooled analysis of variance across locations, showed significant difference for all the traits selected except days to 50 percent flowering and grain length for GxE source of variation. Eberhart and Russel stability model was used to identify the stable performing genotypes for particular trait across the diverse environments. Out of 21 genotypes evaluated two genotypes (MAS-26 and MAS-946) were high performing but not consistent in their performance for yield and yield attributing traits across the diverse environments. The genotypes CR Dhan-201, Indrani, CR Dhan-206 were found to be the most stable genotypes across evaluated climatic conditions for grain yield in Northern parts of Karnataka.

Keywords: Aerobic rice, Eberhart and Russel model, Genotype × environment interactions, Stability

INTRODUCTION

Rice (*Oryza sativa L.*), belongs to the family poaceae and it is regarded as “Millennium Crop” since it contributes towards food security in the world and it is also one of the staple cereal crops of the world and a primary source of food for majority of the world’s population. Due to exponential increase in the human population, the demand for rice production will continue to rise in near future. As a result, rice breeders worldwide strive to increase rice grain output (Song *et al.*, 2007). This was achieved during green revolution through introduction of high yield varieties of rice to meet consumer demand in India. With reference to recent reports, worldwide rice has been cultivated in 167.2 million ha area producing 769.6 million tonnes per year with productivity of 4600 kg/ha. In India, rice is grown in 43.77 m hectares with annual productionof 117.47 mt and productivity of 2,570 kg/ha. In Karnataka, it occupies an area of 1.24 m ha with annual production of 3.54 million tonnes and productivity of 2,670 kg/ha (INDIA STAT, 2021- 2022). Since, rice has the ability to grow in a wide range of hydrologic environments, it is suitable for upland, rainfed lowland, flood-prone, and irrigated ecosystems. In Asia, majority of the total fresh water is used for irrigated agriculture and half of this is used to irrigate rice. Hence, research has been conducted by scientists on a variety of topics to increase supply of rice to ensure food security and to adopt modern irrigation techniques that conserves water and also to meet out water scarcity. Hence, aerobic method of cultivation could be of great advantage and can be adopted in limited water resource regions.

Yield being very complex trait, is influenced by diverse climatic conditions. Therefore, it is crucial to develop stable, high-yielding rice cultivars that can withstand conditions of moisture stress. In order to provide farmers with better economic benefits, it is crucial to identify rice varieties with a wide range of adaptability and stability (Blum, 1983). Hence multilocation trials are conducted in different locations/seasons/environments to test and to identify consistent performing genotypes across the seasons/locations and location specific high performing genotypes through stability analysis. So, information about the genotype × environment (G × E) interaction and stability parameters for each trait provides a better measure of stable performing genotype. Hence, several statistical procedures are proposed to deal with the genotype × environment (G × E) interaction in relation with stability for diverse environments. It is not only the genotype or environment that influences the performance but also various other climatic and edaphic factors which influences the adaptability. So, considering all these points the prime objective of present investigation was to identify the stable performing genotypes for grain yield among selected 21 rice cultivars for aerobic conditions in paddy ecosystems of Northern Karnataka.

Field experiments was conducted during *Kharif* 2021 at six locations in Northern partsof Karnataka *viz.,* Agricultural Research Station, Arbhavi, Agricultural Research Station, Sankeshwar, Agricultural Research Station, Bailahongal, Agricultural Research Station, Mugadh, Agricultural Research Station, Malagi and a farmer's field at Mukkunda in Sundhanoor of Raichur district (**Table 4**). Nineteen rice (*Oryza sativa* L.) genotypes were selected which were bred specially for aerobic condition and released fromrice research institutions *viz.,* National Rice Research Institute, Cuttack, Indian Rice Research Institute, Hyderabad and University of Agricultural Sciences, Bengaluru. Along with these cultivars, two check cultivars *viz.,* Belgaum Basmati and Indrani were evaluated at diverse environments under aerobic condition for grain yield (**Table 1**).

Field experiments was carried out using Randomised Block Design with three replications with two-three seeds per hill. The seeds were direct seeded maintaining spacing of 30 × 20 cms between rows and plants and plot size of 3 ×1.5 meters containing three rows. Aerobic condition was maintained with supplementary irrigation and other management practices without allowing for stagnation of water. Five plants in all the genotypes were selected at random from each treatment for recording the observations as mentioned in **table 2**. The average of observations recorded on these five plants were considered for statistical analysis. Similarly, plant morphological characters of each genotype were recorded by selecting a single or group of plants on all the characters at different stages of crop growth.

Table 1. List of 21 genotypes used under present investigation

S.No.	Genotypes	Pedigree	Developed/ Released from
1	CR DHAN – 200	UPLRI5 × IR-12979-24-1	National Rice Research Institute, Cuttack
2	CR DHAN – 201	IRRI 105 × IR-72022-46-2-3-2	
3	CR DHAN – 202	IRRI 148 × IR-78877-208-B-1-1	
4	CR DHAN – 203	IR 78877 × IRRI 132	
5	CR DHAN – 204	IRR 76569-259-1-2-1 × CT6510-24-1-2	
6	CR DHAN – 205	N22 × SWARNA	
7	CR DHAN – 206	BRAHMANAYAKI × NDR 9930077	
8	CR DHAN – 207	IR 71700-247-1-1-1-2 × IR 57514-5-B-1-2	
9	CR DHAN – 209	IR 72022-46-2-3-2 × IRRI 105	
10	CR DHAN – 210	IRB717002-247-1-1-2 × IR 77080B-34-1-1	
11	DRR DHAN- 41	RP 5311 -PR 26703-3B-PJ7	Indian Institute of Rice Research, IHyderabad
12	DRR DHAN – 54	RP 5124-11-4-3-2-1 ×IR 78877-208-B-1-1.	
13	DRR DHAN – 55	MTU 1010/ × IR79915-B-83-4-3	
14	PAUSTIC – 1	BPT 5204 × HPR 14	University of Agricultural Sciences, Bangalore
15	PAUSTIC – 7	BPT 5204 × HPR 14	
16	PAUSTIC – 9	BPT 5204 × HPR 14	
17	MAS – 26	IR 64 × AZUCENA	
18	MAS- 946-1	IR 64 × AZUCENA	
19	BPT- 5204	GEB 24 × TN1 × Mahsuri	
20	BELGAUM BASMATI (c)	Check cultivar	Check cultivars in Belgaum region
21	INDRANI (c)	Check cultivar	

Table 2. Location of experiments conducted to evaluate rice genotypes for stability analysis

S.No.	Particulars	Environments					
1	Locations	ARS Arabhavi	ARS Sankeshwar	ARS Bailahongal	ARS Mugadh	ARS Malagi	Farmersfield Sindhanur
2	Latitude	16° 13' N	16° 23' N	15° 82' N	15° 43' N	14° 75' N	15° 77' N
3	Longitude	74° 49' E	74° 62' E	74° 83' E	74° 89' E	75° 28' E	76° 75' E
4	Elevation	625 meters	638 meters	664 meters	730 meters	634 meters	358 meters
5	Average Temperature	28° C	33° C	30° C	27° C	28° C	34 C
6	Total rainfall	981 mm	788 mm	832 mm	992 mm	1872.2 mm	609 mm

The pooled mean values of all the traits across the environments were subjected to statistical analysis. Analysis of variance (ANOVA) was performed as per Panse and Sukhatme (1967). The stability analysis was conducted using the Eberhart and Russel (1966) model using Windostat version 9.2 statistical software from Indostat services, Hyderabad. Among various stability analysis models proposed, Eberhart and Russell (1966) model is widely used and the best method to determine adaptability and stability of genotypes based on its three stability parameters. According to this model a stable genotype is one with high mean value for particular trait, regression coefficient near to unity and less deviating from regression. It considers not only the regression factor that is predictable performance but also deviation from regression line that is unpredictable performance which makes it more accurate to identify stable performing genotypes. It also identifies the genotypes suitable for rich and poor environments **(Table 3)**. Hence, a stable genotype is one which shows consistency in its performance without much environmental effect.

RESULTS AND DISCUSSION

Bartletts test was conducted to check the homogeneity or heterogeneity of varianceamong the genotypes selected before subjecting to statistical analysis which assumes there is homogeneity of variance among the genotypes used. Similar test was performed by Dewi *et al.* (2014), Panwar *et al.* (2008)

To understand G x E interaction better two components, linear and non-linear, which had significant and non-significant variation in expression of trait with influence of environments were considered. The linear components were highly significant for most ofyield and its attributing traits except days to flowering. It was maximum for biomass, number of panicles per m^2, number of tillers $panicle^{-1}$ and plant height (**Table 3**). Similar results were reported by Panwar *et al.* (2008) and Das *et al.* (2005) indicating that these components could be responsible for high adaptation in relation to grain yield and other traits.

The non-linear components were also highly significant for

Table 3. Analysis of variance for stability for fourteen yield and yield contributing characters across six environments in 21 rice(*Oryza sativa* L.) under aerobic condition

Source of variation	df	Mean sum of squares													
		Days to 50% flowering	Days to maturity	Plant height8 (cm)	Panicle length (cm)	Number of tillers $panicle^{-1}$	Number of panicles sqm^2	Number of productive panicles	Grain yield $plant^{-1}$ (gm)	Grain length (mm)	Grain breadth (mm)	L/B ratio	TW (gm)	BM (gm)	SFR
Genotypes	20	0.401*	0.08**	1.8**	0.089**	0.77**	21.7**	1.059**	1.22**	0.12**	0.106**	0.023**	0.0318**	4.40**	0.17**
Environment	5	0.0002	0.0006**	0.28**	0.20**	0.038**	3.71**	0.056**	0.79**	0.0102**	0.0045**	0.0032**	0.0010**	28.72**	0.13**
Environment + (Genotype × Environment)	105	0.0004	0.0027*	0.059**	0.028**	0.028	0.95**	0.044**	0.102**	0.026**	0.0079**	0.0005**	0.0003**	0.370**	0.02**
Environment (Linear)	1	0.0009	0.0003*	1.39**	1.005**	0.192**	18.5**	0.283**	3.97**	0.0512**	0.0225	0.0163**	0.0050**	21.34**	0.69**
Pooled deviation	84	0.0004	0.0021	0.045**	0.018**	0.025**	0.58**	0.039**	0.047**	0.014	0.0050	0.0003	0.0002	0.15**	0.01**
Pooled error	240	0.0009	0.00028	0.0042	0.0031	0.005	0.03	0.0074	0.0081	0.0019	0.0019	0.0015	0.0002	0.020	0.003

*:significant at 5% level

** significant at 1% level

yield and its attributingtraits except days to flowering and days to maturity. The magnitude of non-linear component was maximum for number of panicles per m^2 and biomass which indicated the differential and non- consistent response of the genotypes for these characters. Both linear and non-linear components were significant for productive tillers per plant, plant height, panicle length and grain yield plant^{-1} indicating the importance of both the components in determining the stabilityof these traits (**Table 3**). Similar findings were reported by Krishnappa *et al*. (2009), Dushyanthakumar *et al*. (2010).

Primary requirement for sustainable crop production is the performance of a genotypewith high grain yield and stable performance across different locations. The estimates on the three stability parameters *viz*., mean performance of genotype, regression co-efficient (bi) and mean deviation from regression (S^2 di) for yield and some selected yield attributes are presented in **Tables 4a and 4b**.

For days to 50 percent flowering, the linear and non-linear component of genotype × environment was non-significant indicating that diverse environment has less influence on expression of this character. Among the genotypes, Indrani recorded highest mean values 100 days which is late flowering type and MAS-26 recorded lowest mean value of 79 days to 50% flowering but they are not consistent in their performance across the diverse environments and do not meet the required values of stability parameter. They are suitable for rich environments where as the cultivar DRR Dhan-54 had mean value of 86 days with regression value of 0.71 near to unity and has less deviation of 0.0004 from S^2di (**Table 4a**) which is rankedfirst from the analysis and is stable across evaluated environments for days to 50% flowering (**Table 4a**).

Similar results was reported by Singh *et al.*(2020) and Koli *et al.* (2015). Non-significant correlation between deviation from regression and mean performance or regression indicated that the stability parameter might be under the control of different genes located on different chromosomes (Reddy *et. al.*, 1991).

For number of tillers panicle^{-1} the values are ranging from 9.15 to 20.90. MAS-26 recorded highest mean values for

Table 4a. Stability parameters of 21 rice (*Oryza sativa* L.) genotypes for yield attributing traits across six locations

S. No.	Genotype	Number of productive tillers/ panicle				Grain yield/plant (g)				Number of tillers/panicles			
		Mean	bi	S^2di	Rank	Mean	bi	S^2di	Rank	Mean	bi	S^2di	Rank
1	CR DHAN 200	11.02	4.24	0.011*	19	14.85	1.83	0.046***	14	13.67	-0.27	0.007	12
2	CR DHAN 201	11.79	0.22	0.015*	10	18.53*	1.11	0.029	1	13.72	-0.03	0.026***	9
3	CR DHAN 202	11.36	3.63	0.022**	17	14.91	2.49*	0.017*	20	13.13	2.20	0.029***	11
4	CR DHAN 203	13.13	1.09	0.017	1	20.36*	1.82*	0.009	13	14.38	0.30	0.028***	6
5	CR DHAN 204	11.67	1.72	0.009	9	17.10	1.55	0.105	10	13.81	0.74	0.002	3
6	CR DHAN 205	12.97	2.11	0.002	13	14.37	1.33	-0.013	7	14.46	1.06	0.029	1
7	CR DHAN 206	12.70	1.94	0.007	12	16.26	1.12	0.009	3	14.45	0.46	0.008	5
8	CR DHAN 207	11.95	6.25*	0.012*	21	15.45	1.97	0.0626***	16	13.78	2.09	0.032***	10
9	CR DHAN 209	13.61	-0.19	0.008	15	19.76*	1.44*	-0.0041	8	15.03	0.91	0.007	2
10	CR DHAN 210	17.36	0.09	0.069***	11	16.73	0.67	0.054***	6	18.45	-0.28	0.028***	13
11	DRR DHAN 41	15.23	0.42	0.005	7	24.85*	-0.16**	-0.005	17	17.19	2.38	0.004	14
12	DRR DHAN 54	16.17	1.12	0.033***	2	25.95*	1.51	0.039***	9	17.21	-1.33	0.009*	18
13	DRR DHAN 55	14.83	0.68	0.015*	5	26.50*	-0.89**	0.012*	21	16.55	0.07	0.002	8
14	Paustic-1	12.55	-0.15	0.085***	14	18.44*	1.85	0.249***	15	13.78	5.73*	0.021***	21
15	Paustic-7	9.98	-2.43	0.066***	20	17.89*	0.86	0.035***	4	11.96	0.47	0.031***	4
16	Paustic-9	11.73	-1.82	0.020**	18	21.09*	-0.28	0.035***	18	13.51	-0.59	0.049***	17
17	MAS-26	20.08	0.69	0.006	4	36.86*	0.33	0.004**	12	20.90	2.56	0.017	15
18	MAS-946-1	18.38	-1.22	0.002	16	33.20*	0.42*	-0.004	11	19.48	1.76	0.005	7
19	BPT-5204	7.72	1.51	0.069***	6	11.17	-0.34	0.074***	19	9.15	-0.56	0.033***	16
20	Indrani (c)	8.60	0.77	0.147***	3	15.92	1.11	0.095***	2	11.02	-1.71	0.045***	19
21	Belgaum Basmathi (c)	13.45	0.31	0.054***	8	20.36*	1.282	0.051***	5	15.08	5.02	0.019**	20

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number of tillers panicle^{-1} 20.90 and cultivar BPT-5204 recorded lowest mean value of 9.15 and these are not much influenced by the environment. But the genotype CR Dhan 205 was not affected from diverse environment with mean value of 14.15 with regression value of 1.056 and S^{2}di with value of 0.028 (**Table 4a**). Similar results was reported by Biswas *et al.* (2012), Umadevi *et al.* (2008), Das *et. al* (2010) and Pande *et. al* (2006) and Santoshkumar *et. al* (2020). For number of productive tillers panicle^{-1} MAS-26 recorded highest mean (20.08) and BPT-5204 recorded the lowest value (7.72). The genotype CR Dhan 203 was ranked first for stability with mean value of 13.12 with regression value of 1.098 and less deviating from S^2 di with value of 0.017 and it was stable at all locations.

For grain yield plant^{-1} the genotype MAS-26 recorded highest mean (36.86 g) and the cultivar BPT-5204 recorded lowest mean value of 16.7g and are not consistent in performance across the locations, while the genotype CR Dhan 201 was consistent in its performance with high mean value of 18.8 g with regression value of 1.112 andnon-significantly deviating from S^{2}di (0.028) and it is stable over locations evaluated.The highest grain yield was observed in Malagi (E5) which indicated favorable environmental condition that supported genotype to express without affecting the growth and development of plant. Grain yield was found to be maximum at this location due to good moisture availability during anthesis stage and also high temperature during grain filling stage and GE interaction effects.Similar findings were reported by Raju *et al*. (2013) and Sivakrishna (2015) indicating that environment has greater influence on phenotypic expression. (**Table 4b**)

Local cultivar Belgaum basmati recorded highest mean values for test weight and seed fertility ratio and it was due to high photosynthetic product accumulation, proper endosperm development and remaining genotypes differed in its values due to variation caused by genotype × environment effects. The genotype Paustic-1 was ranked first in stability for test weight and the genotype CR Dhan 201 was ranked consistent in its performance for seed fertility ratio. Similar results were observed by Chaudhari *et.al* (2002), Deshpande *et al.* (2003) and Shadakashari *et al.* (2001). This indicated that variable

Table 4b. Stability parameters of 21 rice (*Oryza sativa* L.) genotypes for yield and its attributing traits across six locations

S. No.	Genotypes	Days to fifty percent flowering				Test weight				Spikelet fertility			
		Mean	bi	S^{2}di	Rank	Mean	bi	S^{2}di	Rank	Mean	bi	S^{2}di	Rank
1	CR DHAN 200	86.11	4.35	0.0003	16	23.84	0.04	-0.002	14	84.29	2.47	0.027***	17
2	CR DHAN 201	89.38	2.47	-0.0004	10	23.80	-0.45*	-0.002	18	82.21	0.92	0.002	1
3	CR DHAN 202	85.83	-1.67	-0.0008	15	24.05	-0.08*	-0.002	15	86.54	1.25	-0.001	3
4	CR DHAN 203	87.55	4.59	-0.0007	17	23.60	0.23	-0.002	9	88.07	-0.01	0.0256***	14
5	CR DHAN 204	87.16	3.64	-0.0005	14	23.67	0.09	-0.002	12	87.23	1.27	0.029***	5
6	CR DHAN 205	85.83	8.88	-0.0004	21	23.51	0.08	-0.002	13	88.32	2.47	0.013**	16
7	CR DHAN 206	85.05	5.64	-0.0005	20	24.16	3.97**	-0.002	19	86.90	1.72*	-0.001	10
8	CR DHAN 207	91.33	-0.62	-0.0008	11	24.21	0.20	-0.002	11	83.40	1.80	0.012**	12
9	CR DHAN 209	91.61	0.00	-0.0009	6	22.27	1.35	0.002	4	91.26	0.51	0.005*	6
10	CR DHAN 210	89.05	-3.50	-0.0008	19	23.98	0.24	-0.002	8	93.35	0.05	0.002	13
11	DRR DHAN 41	91.22	0.00	-0.0009	7	24.41	0.52	-0.001	6	92.46	0.35	0.001	9
12	DRR DHAN 54	86.38	0.71	-0.0004	1	24.33	0.79	-0.003	2	90.96	0.45	0.006*	7
13	DRR DHAN 55	90.72	0.00	-0.0009	8	24.35	1.51*	-0.003	7	90.84	0.73	0.001	4
14	Paustic-1	90.66	0.69	-0.0005	2	22.47	5.36*	0.003	21	85.89	-0.89*	0.010**	20
15	Paustic-7	89.22	-3.30	0.0007	18	22.36	0.85	-0.003	1	86.08	2.71	0.017***	18
16	P-austic-9	90.50	-1.38	0.0009	13	23.31	4.07	0.012***	20	85.06	3.31	0.029***	21
17	MAS-26	79.22	0.36	-0.0008	4	24.51	1.23	0.0000	3	92.33	0.25	0.009**	11
18	MAS-946-1	81.61	-0.73	-0.0004	12	24.43	0.23	-0.002	10	91.73	-0.28**	-0.003	15
19	BPT-5204	99.94	0.56	-0.0004	3	24.26	-0.34	-0.002	16	90.04	1.15	0.008*	2
20	Indrani (c)	100.16	0.33	-0.0008	5	24.13	-0.35	-0.002	17	85.96	-0.85**	-0.002	19
21	Belgaum Basmathi (c)	91.11	0.00	-0.0009	9	24.70	1.44	-0.0001	5	89.05	1.62	0.011**	8

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Table 5. Top performing genotypes identified across six locations based on stability parameters for yield and its important attributingtraits

Genotypes	GY (kg/ha)	DF	NTP	NPM	TW(g)	SFR(%)
CR Dhan-201	2780	89.39	13.73	280.22	23.81	82.21
Indrani	2388	100.17	11.02	284.33	24.14	85.96
CR Dhan 206	2439	85.00	14.15	284.28	24.17	86.90
P-7	2684	89.22	11.97	249.61	22.36	86.09
Belgaum Basmati	3003	91.11	15.09	341.72	24.70	89.05
CR Dhan- 210	2510	89.06	18.45	350.56	23.99	93.36

GY = Grain yield /ha, DF = Days to fifty percent flowering, NTP = number of tillers panicle^{-1}, NPM = number of panicles sqm^{-1}, TW= testweight, SFR = seed fertility ratio.

expression and accumulation of grains are less influenced from biotic factors across all the six environments.

From the present study it is concluded that genotypes, CR Dhan-201, Indrani and CR Dhan-206 are identified as most stable performing genotypes across six locations in Northern Karnataka and these genotypes can also be used as a donor parent for generating new breeding material for development of variety with good drought tolerant capacity and also stability for aerobic condition (**Table 5**). However, more information regarding genotype × environment interaction across environments and among genotypes for specific location can be obtained when they are subjected to further analysis using AMMI and GGE biplot.

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