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Research Article

Genotype x environment interaction studies in promising early genotypes of rice

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Abstract
Twenty one early rice genotypes including four local check varieties (Gurjari, GR-3, GR-7 and GR-12) were evaluated for their stability parameters with respect to eighteen quantitative and qualitative traits in 3 environments (Nawagam, Dabhoi and Dahod) during *kharif* season of 2012. The genotypes x environments interaction and its G x E (linear) component were significant for all the characters except grain length, grain breadth, grain L:B ratio, test weight, kernel length, kernel breadth, kernel L:B ratio, kernel length after cooking, alkali spreading value and amylose content. The non-linear component of G x E interaction was also significant for all the characters except straw yield per plant, grain length, grain breadth, test weight, kernel breadth, kernel L : B ratio, hulling %, kernel length after cooking, alkali spreading value and amylose content when tested against pooled error suggested importance of both linear and non-linear components in building up total G x E interaction. Among twenty one genotypes, only one genotype NWGR-9147 was found stable with wide adaptability for grain yield per plant along with the stability for days to 50% flowering, plant height, straw yield per plant and milling percentage characters hence the cultivar could be used for cultivation over a range of environments.

Key words
Rice, G x E interaction, Stability, regression co-efficient, Eberhart and Russel model

Introduction:

Rice *(Oryza sativa* L.) is considered as one of the most important crop plants from Poaceae. Today, rice has special position as a source of providing over 75% of Asian population and more than three billion of world populations meal, which represents 50 to 80% of their daily calorie intake. The world population will increase to over 4.6 billion by 2050, which demands more than 50% of rice needs to be produced what is produced at present to cope with the growing population (Sreedhar *et al* 2011). Therefore, efforts to enhance rice productivity coupled with stability of performance under varying environments must receive top priority. India is largest rice growing country in the world; however its productivity per unit area is low. In India, rice is cultivated on 44.00 million hectares with a production and productivity of 103.00 million tons and 2.34 t/ha, respectively (Viraktamath *et al.*, 2012). In Gujarat, rice occupying about 5% of the gross cropped area, is cultivated on 0.75 million hectares with 1.69 t/ha productivity (Patel *et al.,* 2010). As stability testing of promising early genotypes of prime importance for increasing and stabilizing yield in crop plants, present investigation was undertaken to isolate stable genotypes in rice.

Material and method

Twenty one rice genotypes including four check varieties (Gurjari, GR-3, GR-7 and GR-12) were sown in an individual plot under suitable nursery condition at three locations *viz*., Nawagam, Dabhoi and Dahod of the experiments. After the development of seedling, selected healthy seedlings were transplanted in a plot consisting 11 rows of 4.2 m length with inter and intra row distance of 20 cm x 15 cm at the three locations. The experiment was laid out in a randomized block design with three replications, at three locations during *kharif* 2012. All the recommended agronomic practices and plant protection measures were followed. The observations were recorded on ten randomly taken plant for each genotype in each replication with respect to eighteen quantitative and qualitative characters *viz*., days to 50% flowering, plant height (cm), panicle length (cm), grain yield plant (g), straw yield per plant (g), grain length (mm), grain breadth (mm), grain length:grain breadth ratio, test weight (g), kernel length (mm), kernel breadth (mm), kernel length : kernel breadth ratio, hulling (%), milling (%), head rice recovery (%), kernel length after cooking (mm), alkali spreading value and amylase content (%). Pooled analysis of variance over three locations and stability parameters (mean, regression coefficient (b_i) and deviation from regression (S^2d_i) were estimated following Eberhart and Russel (1966) stability model.

Result and discussion

The data in Table 1 indicated the significance of G x E interaction for days to 50% flowering, plant height, panicle length, grain yield per plant, straw yield per plant, milling and head rice recovery traits. Partitioning of G x E interaction showed that pooled deviation effect was significant for days to 50% flowering, plant height, panicle length, grain yield per plant, grain length:breadth ratio, kernel length, milling and head rice recovery traits. Environment (linear) effects were significant for days to 50% flowering, plant height, panicle length, grain yield per plant, straw yield per plant, grain length:breadth ratio, kernel breadth, kernel length : breadth ratio, hulling, milling, head rice recovery and amylose content traits. Further, partitioning of variance *i.e.* Environment + (Genotype x Environment) interaction was observed to be significant for days to 50% flowering, plant height, panicle length, grain yield per plant, straw yield per plant, grain length : breadth ratio, hulling, milling and head rice recovery. The Magnitude of mean square due to Environment + (Genotype x Environment) was also recorded higher as compared to Genotype x Environment (linear) for all the eighteen characters. Genotype x Environment (linear) was significant for days to 50% flowering, plant height, panicle length, grain yield per plant, straw yield per plant, hulling, milling, head rice recovery. This suggested that the performance of genotypes over environments could be predicted reasonably for these traits only. For other characters the Genotype x Environment (linear) interaction was found non significant so further stability analysis was not carried out. Waghmode and Mehta (2011), Mahalingam *et al.* (2013), Ahamad and Torabi (2011) and Kumar *et al.* (2005) reported that both linear and non linear components of G x E were significant for some traits.

The mean ($\bar{x}$), regression coefficient (b_i) and deviation from regression (s^2d_i) for different eight characters presented in Table 2. The general mean for days to 50 per cent flowering over three environments was 96.21 days. Out of the 21 genotypes seven genotypes *viz*., NWGR-9054, NWGR-9077, NWGR-9080, Gurjari, GR-3, GR-7 and GR-12 had lower mean values than overall mean. Earliness being a favourable character, low means are considered as desirable. Genotypes *viz*., NWGR-9007, NWGR-9019, NWGR-9081, NWGR-9091, NWGR-9147 and gurjari showed non-significant deviation from regression, which indicated that their performance for given environment may be predicted and hence they are considered to be stable. For the plant height genotypes NWGR-9013, NWGR-9019, NWGR-9054 had $b_i > 1$, whereas the genotypes NWGR-9108, NWGR-9083, NWGR-9077 had 'b_i' values near unity suggesting their adaptability respectively for unfavourable and wider environments. The genotypes NWGR-9007, NWGR-9013, NWGR-9019, NWGR-9023, NWGR-9047, NWGR-9054, NWGR-9077, NWGR-9108, NWGR-9147 and NWGR-9088 had non-significant deviation from regression hence their performance can be precisely predicted for plant height. For the panicle length genotypes NWGR-9013, NWGR-9047, NWGR-9108 and GR-3 had regression coefficient non-significantly deviation hence they would be considered as ideal genotypes for all environments. For the grain yield per plant genotypes NWGR-9007, NWGR-9013, NWGR-9019, NWGR-9023, NWGR-9039, NWGR-9046, NWGR-9054, NWGR-9077, NWGR-9083, NWGR-9088, NWGR-9091, NWGR-9147, gurjari and GR-7 showed non-significant which suggested that these genotypes should be better suited for all environments . The higher values of regression for straw yield per plant indicated that such genotypes might be recommended only for favourable environments (NWGR-9007, NWGR-9023 and NWGR-9039). For the hulling % genotypes NWGR-9007, NWGR-9046, NWGR-9080, NWGR-9088 and NWGR-9147 had mean performance at par with population mean, below one value of regression coefficient and non-significant deviation from regression, revealing above average stability and adaptation to unfavourable environment. While, a total of five genotypes *viz*., NWGR-9019, NWGR-9023, NWGR-9045, NWGR-9077 and GR-12 had above one estimates of regression coefficient leading to below average stability and specific adaptation to favourable environment. Out of a total of 21 genotypes, gurjari had the highest milling per cent (66.30%). For milling % the ten genotypes NWGR-9019, NWGR-9023, NWGR-9045, NWGR-9046, NWGR-9047, NWGR-9054, NWGR-9077, NWGR-9081, NWGR-9147 and gurjari had "b_i" > 1 indicating that they might stable for favourable environment, while the remaing genotypes had "b_i" < 1 suggesting their suitability for poor environments. Genotypes NWGR-9013, NWGR-9045 and NWGR-9081 were average stable and most adapted to wider/general environments among all other genotypes. For head rice recovery, the twelve genotypes *viz.*, NWGR-9013, NWGR-9039, NWGR-9045, NWGR-9047, NWGR-9080, NWGR-9081, NWGR-9083, NWGR-9091 and all check varieties Gurjari, GR-3, GR-7 and GR-12 showed high mean value as compared to overall mean. The cv. Gurjari (56.28%) had highest head rice recovery, whereas NWGR-9023 (35.37%) and NWGR-9108 (40.48%) registered lowest head rice recovery. NWGR-9083 and GR-3 were found with non-significant deviation from unit regression indicating their general adaptability. the non-significant values for deviations from regression in case of NWGR-9007, NWGR-9013, NWGR-9023, NWGR-9039, NWGR-9045, NWGR-9046, NWGR-9054, NWGR-9077, NWGR-9080, NWGR-9081, NWGR-9088, NWGR-9091, NWGR-9108, NWGR-9147, Gurjari, GR-7 and GR-12 displayed their stability for head rice recovery**.**

Genotypes NWGR-9147, NWGR-9007, NWGR-9108, NWGR-9047, NWGR-9013, NWGR-9054, NWGR-9081 and GR-3 were found stable for different agro-morphological, grain yield component and grain quality characters. It was revealed that the genotype NWGR-9147 showed stability for maximum number of component traits compared to the checks because of the wider genetic base (three way cross (GR-103 x IET-16900 x IR-72)). It is clear from the present investigation that the genotypes do not perform consistently across locations and they exhibit variable performance due to high proportion of G x E interaction.

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Table 1. ANOVA for phenotypic stability in rice.

Source of Variation	d.f.	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Grain yield per plant	Straw yield per plant	Grain length	Grain breadth	Grain L:B ratio	Test weight
Genotype	20	96.240**	220.000**	15.710**	7.910**	8.950**	1.360**	0.110**	0.460**	40.510**
Environment	2	1473.360**	264.710**	35.630**	9.670*	362.020**	0.020	0.001	0.001	0.130
Geno. X Env.	40	10.150**	78.800**	1.260**	2.880**	4.590*	0.0150	0.001	0.008	0.310
Environment (Linear)	1	2946.720**	529.430**	71.270**	19.350**	724.050**	0.040	0.002	0.030**	0.250
Geno. X Env. (Linear)	20	10.950**	76.240**	1.550**	2.000**	8.140**	0.010	0.001	0.004	0.270
Pooled deviation	21	8.910**	77.490**	0.910**	3.580**	1.000	0.020	0.001	0.009**	0.330
Pooled error	120	0.230	8.260	0.270	0.530	0.900	0.010	0.001	0.005	0.230

Table: 1 contd….

Source of Variation	d.f.	Kernel length	Kernel breadth	Kernel L:B ratio	Hulling	Milling	Head rice recovery	KLAC	ASV	Amylose content
Genotype	20	0.840**	0.090**	0.620**	8.730**	93.590**	78.760**	0.560**	3.710**	13.680**
Environment	2	0.001	0.006**	0.050*	90.940**	486.460**	363.080**	0.020	0.005	3.040*
Geno. X Env.	40	0.008	0.001	0.010	4.190	18.630**	13.990**	0.050	0.009	0.720
Environment (Linear)	1	0.002	0.012**	0.100*	181.880**	972.910**	726.160**	0.050	0.010	6.080*
Geno. X Env. (Linear)	20	0.004	0.001	0.010	6.550**	33.670**	24.050**	0.070	0.010	0.330
Pooled deviation	21	0.010*	0.001	0.009	1.740	3.410**	3.730*	0.030	0.010	1.060
Pooled error	120	0.006	0.002	0.020	1.620	1.190	1.940	0.034	0.009	1.270

*, ** Significant at 5 and 1 per cent levels, respectively.

Table 2. Stability parameters for quantitative and qualitative characters in rice.

Genotypes	Days to 50 % flowering			Plant height (cm)			Panicle length (cm)			Grain yield per plant (g)		
	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}
NWGR-9007	98.78	1.155**++	-0.206	125.90	1.381	4.89	27.69	0.005++	0.053	13.17	-0.816	9.653**
NWGR-9013	96.89	1.161**	1.208*	113.22	3.504**++	4.863	26.04	0.758**	-0.18	15.66	-0.653	1.234
NWGR-9019	99.00	1.156**++	-0.218	119.59	2.133**	8.615	27.42	0.308	0.299	15.92	-1.115	15.139**
NWGR-9023	98.00	1.008**	6.821**	126.03	1.888**++	-8.09	23.29	2.409**	2.085**	11.94	2.006	7.804**
NWGR-9039	99.67	1.398**	27.64**	129.13	2.142	52.295**	28.33	1.828**	1.055*	13.63	-0.691	1.097
NWGR-9045	100.56	1.294**	19.029**	120.71	3.557	160.806**	27.31	1.256**	0.634	16.93	0.607**++	-0.515
NWGR-9046	100.56	0.752*	11.968**	115.91	1.842	49.116**	22.07	1.462**	1.075*	14.98	2.377	7.92**
NWGR-9047	104.78	0.942**	1.202*	128.76	-1.123++	18.308	28.89	0.773	0.275	16.00	-0.048++	-0.504
NWGR-9054	93.78	1.278**	15.085**	122.40	3.347**++	2.537	25.93	0.723**	-0.196	14.46	0.589	3.946**
NWGR-9077	95.11	1.166**	4.653**	131.03	1.187	10.543	25.24	-0.208++	0.777	16.42	2.194	1.104
NWGR-9080	94.44	1.097**	17.512**	113.29	0.281	339.56**	24.53	0.37**++	-0.165	17.12	2.859**++	-0.44
NWGR-9081	97.89	0.818**++	-0.198	115.16	0.811	87.701**	25.93	1.89**++	-0.007	14.30	2.906**++	-0.274
NWGR-9083	97.89	0.922**	1.578**	132.52	0.795	195.871**	26.20	0.392**++	-0.231	16.22	-0.058	0.247
NWGR-9088	100.67	1.384**++	3.84**	124.93	0.197++	-4.295	27.36	1.15**	0.419	15.05	0.28	1.233
NWGR-9091	96.44	1.177**++	-0.175	122.21	0.53	44.455*	27.33	1.747**	0.261	13.98	2.273	0.877
NWGR-9108	99.67	1.012*	30.27**	119.54	1.04	5.036	22.84	0.47	3.037**	15.39	4.347**++	-0.401
NWGR-9147	99.33	0.939**	0.196	120.54	1.211	6.984	25.24	1.29**	0.233	15.81	1.011	-0.267
Gurjari(c)	87.00	0.535**++	0.309	106.31	-0.549	60.81**	22.11	1.238**	-0.008	15.62	2.03	2.268*
GR-3(c)	82.00	0.792	33.376**	100.86	-4.398++	171.93**	21.44	0.443	2.568**	10.48	0.722**++	-0.525
GR-7(c)	83.89	0.728**	4.676**	106.23	0.45	232.267**	22.93	1.424**	0.871*	14.55	0.313	15.019**
GR-12(c)	94.11	0.288++	3.788**	112.63	0.775	9.762	22.82	1.273**	0.722	15.75	-0.131++	-0.51
Mean	96.21			119.38			25.28			14.92		
S. Em. ±	2.11			6.22			0.68			1.34		

*, ** =significant at 5% and 1% level respectively, ** = significant at 5% level when $H_o : b_i = 0$, ++ = significant at 5% level when $H_o : b_i = 1$

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Table: 2. contd…

Genotypes	Straw yield per plant (g)			Hulling %			Milling %			Head rice ricovery %		
	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}	Mean	b_i	S^2_{di}
NWGR-9007	20.68	2.184**++	6.191**	77.72	0.945**	-0.891	58.33	0.812**++	-0.772	48.18	1.223**	0.436
NWGR-9013	18.41	0.679**++	-0.743	75.70	0.945	0.619	61.57	0.993**	0.983	50.70	0.97**	-0.825
NWGR-9019	20.94	1.029**	0.469	76.04	2.242**++	-0.389	55.43	1.702**++	1.502	45.78	1.332**	6.085*
NWGR-9023	16.09	1.56**++	-0.418	75.42	2.614**++	-1.468	43.75	1.783**++	-0.707	35.37	1.845**++	1.135
NWGR-9039	21.06	2.091**++	0.865	77.23	0.781**	-1.217	64.32	0.516**++	-1.086	52.91	0.352**++	-1.94
NWGR-9045	20.90	1.096**	-0.508	77.83	1.384**++	-1.622	63.45	1.16**	-0.579	53.26	1.308**++	-1.109
NWGR-9046	17.05	1.309**++	-0.643	77.17	0.942**	-1.008	52.21	2.469**++	-1.122	43.33	1.737**	5.058
NWGR-9047	19.27	1.211**	-0.148	78.77	0.754	1.434	62.82	1.282**	1.027	51.75	1.576**	6.07*
NWGR-9054	19.05	1.067**	0.25	76.62	3.3**++	1.865	56.58	3.055**++	19.106**	46.99	3.311**++	1.481
NWGR-9077	18.96	0.834**++	-0.745	75.59	1.364**++	-1.536	55.69	1.352**++	-1.069	46.24	1.242**++	-1.475
NWGR-9080	17.87	0.683**++	-0.589	76.87	0.862**	-0.747	59.46	0.247**++	-1.173	49.80	0.193++	0.89
NWGR-9081	18.52	0.64**++	-0.887	78.17	0.947**	-1.556	60.83	1.108**	-0.513	50.75	1.009**	-1.44
NWGR-9083	17.82	1.036**	-0.786	74.12	-0.059	8.819*	63.07	0.929**++	-1.185	50.94	0.791	7.21*
NWGR-9088	21.63	0.466**++	-0.235	76.86	0.662**	-0.989	55.71	0.557**++	0.224	44.77	0.522**++	-1.258
NWGR-9091	19.36	1.143**++	-0.73	79.26	0.736**	-1.164	63.15	0.68**++	-1.048	52.32	0.415**++	-1.405
NWGR-9108	17.63	0.561**++	-0.723	74.98	-0.146++	-0.619	50.32	-0.9++	14.345**	40.48	-0.924*++	3.54
NWGR-9147	18.83	0.935**	0.266	80.09	0.512**++	-1.246	58.50	1.091**	-0.884	47.49	1.106**	-1.091
Gurjari(c)	17.28	0.5	1.416	79.64	0.366++	-0.987	66.30	1.478**	1.542	56.28	1.608**	4.895
GR-3(c)	15.95	0.998**	-0.039	73.87	0.051	4.717*	61.05	0.083	20.169**	52.36	0.326	14.476**
GR-7(c)	15.85	0.605**++	0.274	76.18	0.163	1.446	63.86	0.257**++	-1.068	54.22	0.51**++	-1.801
GR-12(c)	17.75	0.374**++	-0.434	77.84	1.635**++	-0.927	65.43	0.345**++	-0.988	55.16	0.549**++	-1.263
Mean	18.61			76.95			59.13			49.00		
S. Em. ±	0.71			0.93			1.31			1.37		

*, ** =significant at 5% and 1% level respectively, ** = significant at 5% level when $H_o : b_i = 0$, ++ = significant at 5% level when $H_o : b_i = 1$

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Table 3. Classification of genotypes for various characters the basis of mean performance and stability parameters.

Group-I	Group-II		Group-III	Group-IV
Ideal genotypes with general adaptability	**Specific adaptability for** **Favourable environment**	**Unfavourable environment.**	**Unstable /Unpredictable behavior**	
Days to 50 % flowering				
NWGR-9147	NWGR-9007, NWGR-9019,NWGR-9091	Gurjari, NWGR-9081,NWGR-9047,NWGR-9083	NWGR-9039,NWGR-9045, NWGR-9046,NWGR-9088	NWGR-9023, NWGR-9108, NWGR-9013
Plant height (cm)				
NWGR-9007, NWGR-9108	NWGR-9019, NWGR-9147, NWGR-9077	NWGR-9088	GR-3	NWGR-9083, NWGR-9091, NWGR-9081
Panicle length (cm)				
NWGR-9047	NWGR-9045,NWGR-9081,NWGR-9088,NWGR-9091	NWGR-9013, NWGR-9007,NWGR-9019, MWGR-9054,NWGR-9083	NWGR-9039	None
Grain yield per plant (g)				
NWGR-9147	NWGR-9080,NWGR-9081,NWGR-9108,Gurjari	NWGR-9045,NWGR-9047,NWGR-9083,NWGR-9013.GR-12	None	NWGR-9019,NWGR-9054
Straw yield per plant (g)				
NWGR-9054, NWGR-9147, GR-3	NWGR-9019, NWGR-9023, NWGR-9045, NWGR-9046, NWGR-9047, NWGR-9083, NWGR-9039, NWGR-9091	NWGR-9013, NWGR-9077, NWGR-9081, NWGR-9088,GR-12	NWGR-9007	None
Hulling (%)				
NWGR-9013	GR-12	NWGR-9007, NWGR-9046, NWGR-9080, NWGR-9081, NWGR-9088, NWGR-9091, NWGR-9047, NWGR-9147,Gurjari	None	None
Milling (%)				
NWGR-9013, NWGR-9081, NWGR-9147	NWGR-9023, NWGR-9045, NWGR-9046, NWGR-9047, NWGR-9077,GUrjari	NWGR-9039, NWGR-9083, NWGR-9091,GR-7,GR-12	NWGR-9054	None
Head rice recovery (%)				
NWGR-9013	NWGR-9045, NWGR-9081,Gurjari	NWGR-9039, NWGR-9080, NWGR-9091,GR-3,GR-7,GR-12	NWGR-9047	NWGR-9083