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Genotype X Environment Interaction and Stability for Yield and Quality Characters in Rice (*Oryza sativa L.*)

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Genotype x environment interaction was studied for grain yield, its components and quality traits in 21 short duration varieties and hybrids of rice under three representative locations viz., Regional Agricultural Research Station (RARS), Jagtial, Karimnagar(Northern Telangana Zone); Rice section, Rajendranagar, Hyderabad(Southern Telangana Zone) and Agricultural Research Station (ARS), Kampasagar, (Southern Telangana Zone) of Andhra Pradesh during rabi (post rainy) season, 2009-10. Significant differences among the genotypes and environments for most of the characters suggested the presence of wide variability. Significant genotype x environment (GxE) interactions were observed for all the characters except spikelet fertility per cent and kernel length, indicating that the major portion of interaction was linear in nature, and prediction over the environments was possible. Significance of both linear and non-linear components for productive tillers per plant, filled grains per panicle, panicle density, grain yield per plant and milling per cent, indicated the importance of both the components in determining the stability of these traits and only part of variation could be predicted. Significant pooled deviations observed for days to 50 per cent flowering, plant height, panicle length, panicle density, head rice recovery per cent, kernel breadth and L/B ratio suggested that the performance of genotypes is entirely unpredictable in nature. Based on stability parameters, the genotypes RNR 2465 and WGL 32183 were identified as stable genotypes recording superior yield performance under different locations, while IR 64, Krishna hamsa, JGL 11118 and KRH 2 were suitable for poor environments and four promising entries JGL 3844, RNR 2354 (varieties), DRRH 44 and PA 6444 (hybrids) were found to be more suitable for favourable environments with respect to yield performance.

Key words: Rice, Stability parameters, G x E interaction, grain yield, grain quality

Rice (*Oryza sativa* L.) is one of the most ancient food crops being cultivated in 117 countries, hence called “Global Grain”. It is the staple food for more than half of the world’s population, cultivated annually in about 159 million ha with a production of over 428.7 million tonnes and the productivity of 4.1 tonnes/ha (2007–08). Most of the people in India (75%) meet their calorific and protein requirements through rice. Nearly 90 per cent of area cultivated under rice is in Asia. In India, it is cultivated in about 42.86 million ha with an annual production of 95.97 million tones, and the average productivity is 2.23 tonnes / ha. While, in Andhra Pradesh, rice is cultivated in an area of 4.51 million ha annually with an approximate production of 1.441 million tonnes and the average productivity is 3.03 tonnes / ha. Out of 3.03 million ha, area in rabi season will be about 1.40 million ha in the state.

To further augment the productivity level of rice, development of stable varieties with wider adaptability and high yielding potential is essential. Grafius (1959) suggested that there would be no separate gene system for yield per se and yield is an end product of multiplicative interaction between the yield components. Stability in performance of a genotype over a range of environments is a desirable attribute which depends upon the magnitude of G x E interactions (Ahmad *et al*., 1996). Information on G x E interaction and stability parameters provides an optimum measure of stable variety and the varietal adaptability.

Thus, the present investigation was undertaken to study the G x E interaction and stability of 21 selected entries comprising released and pre-release varieties in order to identify rice genotypes for their yield stability across three different locations.

Materials and Methods

The experimental materials comprised of 21 released varieties, six pre-release cultures and five hybrids of rice (Table 1) were evaluated in randomized complete block design with three replications at Regional Agricultural Research Station (RARS), Jagtial, Karimnagar; Rice section, Rajendranagar, Hyderabad and Agricultural Research Station (ARS), Kampasagar, Nalgonda during rabi, 2009-10. Thirty day old seedlings were transplanted in rows of 4.5 m at 15 cm apart. Recommended package of practices were adopted to raise a healthy crop and regular plant protection measures were undertaken. The observations were recorded on five randomly selected plants in each entry and replication on12

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yield and quality characters *viz*., days to 50 per cent flowering, plant height (cm), number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, panicle density (number of grains per centimeter, panicle length expressed as percentage), spikelet fertility per cent, 1000-grain weight (g), grain yield per plant (g), hulling recovery (per cent), milling recovery (per cent), head rice recovery (per cent), kernel length (mm), kernel breadth (mm) and L/B ratio. The mean values for all the traits across the environments were subjected to stability analysis (Eberhart and Russell, 1966).

Results and Discussion

The analysis of variance pooled over three locations revealed significant interaction among the genotypes and environments. G X E interaction were significant for most of the characters (Table 2), indicating the presence of wide variability among the genotypes and environments. While pooling the data over three environments, Bartlett's test was performed to study the homogeneity of error variances. The Bartlett's χ^2 values were non-significant for days to 50 per cent flowering, productive tillers per plant, spikelet fertility per cent, 1000-grain weight, grain yield per plant, hulling per cent and milling per cent. So, the experimental errors over environments were homogenous for all these traits. However, further analysis was carried out for the remaining characters with respect to genotypes, environments and G x E interactions. The genotypes showed significant differences for all the characters except spikelet fertility per cent and milling per cent indicating the presence of genetic variability in the experimental material. Significant differences among genotypes for these traits were earlier reported by Shanmuganathan and Ibrahim (2005); Bhakta and Das (2008) and Sreedhar *et.al.*, (2011). Environments showed highly significant differences for all the characters except days to 50 per cent flowering, spikelet fertility per cent, kernel length, kernel breadth and L/B ratio indicating wide differences between environments selected. Significant mean sum of squares due to environments were in accordance with the findings of Satya Priya Lalitha and Sreedhar (2000); Swamy and Kumar (2003) and Ali *et al*., (2006).

Table 1. List of rice genotypes with their parentage and source

Genotypes	Parentage	Source/Origin
Released Varieties		
IR 64	IR 5657-33-2-1/IR 2061-465-1-5-5	IRRI , Philippines
MTU 1010	MTU 2077/IR 64	APRRI, Maruteru
Krishnahamsa	Rasi/Fine Gora	DRR, Hyderabad
Tellahamsa	HR 12/TN 1	Andhra Pradesh
Erramallelu	BC 5-55/W. 12708	RARS, Warangal
Rajendra	IJ 52/TN 1	Rice section, Rajendranagar
JGL 1798	BPT 5204/Kavya	RARS, Jagtial
JGL 3844	BPT5204/ARC 5984 // Kavya	RARS, Jagtial
NLR 34449	IR 72/BPT 5204	ARS, Nellore
Rasi	TN 1/CO.29	DRR, Hyderabad
Pre-release cultures		
RNR C 28	IR 64/IET 9994	Rice section, Rajendranagar
RNR 2465	RNR M7/RNR 19994	Rice section, Rajendranagar
RNR 2354	RNR M7/RNR 19994	Rice section, Rajendranagar
JGL 11118	IET 8585/JGL 1798	RARS, Jagtial
JGL 13595	MTU 4870/JGL 418	RARS, Jagtial
WGL 32183	Orugallu/BPT 5204	RARS, Warangal
Hybrids=		
DRRH 2	IR 68897 A/DR 714-1-2R	Public sector hybrid
KRH 2	IR 58025 A/KMR-3	Public sector hybrid
DRRH 44	APMS 6A/1005	DRR, Hyderabad
PA 6201	6 CO2/6 MO1	Private sector hybrid
PA 6444	6 CO2/6 MO5	Private sector hybrid

G x E interaction component was highly significant for all the characters except spikelet fertility per cent and kernel length indicating differential behaviour of genotypes in changing environments. Hegde and Vidyachandra (1998); Mc Laren and Wade (2000); Kishore *et al*., (2002); Nayak *et al*.,(2003); Arumugam *et al*., (2007); Panwar *et al*., (2008) and Sreedhar *et.al*.,(2011) also reported the differential response of varieties due to G x E interactions. Significance of environment (linear) component for all the characters except spikelet fertility per cent, kernel length, kernel breadth and L/B ratio indicated that the genotypes responded linearly for most of the characters. (Basavaraja *et al*., 1998 and Panwar *et al*., 2008).

Significance of both linear and non–linear components for productive tillers, filled grains, grain yield per plant and milling per cent indicated the importance of both the components in determining the stability of these traits in the present study; and only part of variation could be predicted (Hegde and Vidyachandra 1998; Kishore *et al*., 2002; Nayak *et al.,* 2003; Dushyanthakumar and Shadadshari 2007). The significance of only pooled deviations (non linear component of G x E interaction) for days to 50 per cent flowering, plant height, panicle length, panicle density, head rice recovery, kernel breadth and L/B ratio indicated that the performance of genotypes is entirely unpredictable in nature. Similar results were reported by Munisonnappa *et al*.,(2004), Shanmuganathan and Ibrahim (2005) and Dushyanthakumar and Shadadshari (2007).

According to Eberhart and Russell (1966), a stable genotype is one which has high mean with regression coefficient (b) near 'unity' and deviation from regression (s^2di) approaching 'zero'. The estimates of three stability parameters (i) mean performance (X), (ii) regression co-efficient (b) and (iii) deviation from regression (s^2di) for different traits are presented in Table 3. The genotypes with high mean, b more than unity and non-significant deviation from regression can perform well under favourable environments with predictable performance. The genotypes suited for poor environment recorded high mean, significantly less than unit regression and non-significant deviation from linearity. Genotypes, which are less influenced by changing environments for flowering duration are very much needed to ensure uniform harvesting time across a specific agro climatic zone especially in command areas. The genotypes *viz*., RNR C28, Rajendra, Tellahamsa and Erramallelu were identified as stable genotypes for days to 50 per cent flowering as they recorded low mean (earliness),non–significant regression co-efficient near unity and deviation from regression near to zero. The hybrid PA 6201 was found suitable for better environment with desirable mean, regression co-efficient greater than unity and non–significant deviation from regression.

For poor environment, the genotypes JGL 3844, RNR 2354 and PA 6444 were suitable, as they had regression co-efficient less than unity. In case of genotypes *viz*., MTU 1010 and Rasi, the performance

Table 3. Mean performance and stability parameters for yield and quality traits.

Genotypes	Days to 50per cent flowering			Plant height (cm)			Number of productive tillers per plant		
	Mean	Bi	s^2di	Mean (cm)	Bi	s^2di	Mean	bi	s^2di
1. IR 64	116.00	0.824	-1.536	78.93	1.339	31.337**	13.32	1.881	6.813**
2. MTU 1010	117.44	6.540	23.524**	80.57	1.638	1.630	9.04	0.933	-0.362
3.Krishnahamsa	115.22	0.214	-1.184	75.27	1.501	74.819**	10.31	4.669**	-0.320
4. Tellahamsa	112.22	3.685**	-1.428	87.9	1.946**	-2.416	9.95	1.429	1.430*
5. Erramallelu	111.88	-1.253*	-0.610	75.97	0.537**	-2.507	9.46	0.052	-0.119
6. Rajendra	109.55	-0.958	0.349	74.81	0.781	45.637**	7.96	-0.228	1.523*
7. JGL 1798	120.00	-0.529	-1.666	77.00	0.776**	-2.583	8.20	3.624	3.136**
8. JGL 3844	118.22	-2.432**	-1.375	81.03	1.359**	-2.446	8.54	2.450*	-0.012
9. NLR 34449	120.00	-1.762	0.103	71.18	-0.460	69.667**	8.38	0.088**	-0.352
10. Rasi	115.11	5.367	6.772*	78.80	2.252**	-2.604	10.34	2.564**	-0.364
11. RNR C 28	111.33	1.943	-0.426	87.14	2.074**	-0.435	7.46	0.418	-0.286
12. RNR 2465	118.88	1.749	2.659	80.23	1.069	-2.575	9.64	-0.753	0.467
13. RNR 2354	117.00	-0.824**	-1.536	76.04	2.169	40.976**	9.95	2.003	1.476*
14. JGL 11118	114.66	-0.643	2.673	79.47	-1.129**	3.177	7.35	1.169	-0.233
15. JGL 13595	115.33	1.709	0.695	75.65	0.375**	-2.347	8.18	0.694	-0.118
16. WGL 32183	115.88	2.218	-0.144	81.12	0.698	1.217	7.47	-0.131**	-0.358
17. DRRH 2	113.22	-1.313	-1.621	71.44	0.379	-1.140	8.74	-0.039**	-0.353
18. KRH 2	114.66	0.114	2.545	87.73	1.730**	-2.625	9.51	-0.349	0.823
19. DRRH 44	119.77	0.549	-1.609	87.50	0.220	0.592	9.51	2.210**	-0.197
20. PA 6201	118.44	5.783**	-0.886	80.95	2.267**	-1.306	9.72	1.977	0.672
21. PA 6444	120.11	0.020**	-1.593	88.05	-0.519	27.100**	12.63	-3.658*	3.789**

Genotypes	Filled grains/panicle			Panicle length			Panicle density per cent		
	Mean	bi	s2di	Mean (cm)	bi	s2di	Mean	bi	s2di
1. IR 64	100.94	-0.062**	-28.971	22.55	0.210**	-0.250	4.41	-0.153**	-0.089
2. MTU 1010	97.82	0.309**	-26.866	21.37	1.346**	-0.329	4.45	0.066	-0.047
3.Krishnahamsa	111.47	0.688	62.330	21.76	1.667	0.238	4.73	-0.766**	-0.032
4. Tellahamsa	108.75	0.458	-3.738	21.85	0.531**	-0.313	5.37	0.255	0.605**
5. Erramallelu	116.97	0.942	-31.242	21.92	0.625**	-0.367	4.87	0.979	-0.057
6. Rajendra	106.81	0.431**	-47.342	20.84	1.705	-0.367	5.21	-0.072**	-0.084
7. JGL 1798	208.47	1.278	233.057*	21.44	1.152	-0.188	8.55	3.026	1.415**
8. JGL 3844	185.50	0.614	81.765	22.47	1.210	1.065	7.33	2.132	0.604**
9. NLR 34449	107.76	-0.515**	-42.596	19.20	-0.187**	-0.330	6.31	-0.383	2.551**
10. Rasi	105.64	0.985	97.299	19.02	2.070	1.199*	6.11	0.395	0.753**
11. RNR C 28	96.56	0.589	243.734*	22.37	1.072	-0.218	4.29	0.427	0.429*
12. RNR 2465	113.48	0.499	-47.753	20.43	1.197	1.428*	6.18	1.548	1.513**
13. RNR 2354	137.46	2.431	929.107**	20.98	1.912**	-0.309	6.11	2.454	1.906**
14. JGL 11118	194.30	1.250	672.282**	22.85	-0.033	0.755	7.48	0.849	8.516**
15. JGL 13595	166.54	3.940	1397.241**	19.62	1.646**	-0.361	9.19	3.648*	1.032**
16. WGL 32183	144.23	1.560**	-41.674	23.82	0.753	-0.166	6.79	2.109	0.583**
17. DRRH 2	90.88	0.954	-24.716	22.43	0.726	0.098	4.93	1.246	2.072**
18. KRH 2	133.80	1.540	125.556	23.43	1.557**	-0.367	4.81	0.984	1.418**
19. DRRH 44	193.15	1.427	369.712**	23.46	1.033	-0.297	6.96	0.776	5.486**
20. PA 6201	125.91	1.293	-3.665	22.76	0.977	1.668*	6.64	1.095	8.046**
21. PA 6444	145.73	0.390**	-45.966	22.88	-0.169	1.136*	5.94	0.384	0.325*

Genotypes	1000 grain weight (g)			seed yield per plant (g)			Spike let fertility per cent		
	Mean	bi	s^2di	Mean (cm)	Bi	s^2di	Mean	Bi	s^2di
1. IR 64	21.96	1.874**	0.234	22.78	0.282**	-0.795	84.95	4.517	-10.700
2. MTU 1010	21.98	1.708	-0.123	12.53	0.423**	-0.973	85.65	0.439	-18.558
3.Krishnahamsa	21.75	1.565	-0.013	18.14	0.341*	-0.158	86.12	0.581	-13.120
4. Tellahamsa	22.65	0.575	1.281*	19.53	0.493	0.558	85.10	-0.906**	-19.274
5. Erramallelu	17.95	2.537*	0.253	16.69	0.072**	-0.123	83.96	0.282	-19.291
6. Rajendra	22.16	0.880	-0.075	17.62	-1.262	27.695**	82.93	-3.016	2.648
7. JGL 1798	13.53	0.286**	-0.206	16.17	1.282	3.561*	84.82	1.726	-17.845
8. JGL 3844	13.98	0.263**	-0.255	18.08	1.217**	-0.967	85.30	0.296	-19.134
9. NLR 34449	14.61	0.126**	-0.263	11.63	0.534*	-0.584	85.72	0.816	-17.272
10. Rasi	21.00	1.402	-0.051	15.79	2.659**	-0.782	84.88	-2.320	-17.124
11. RNR C 28	22.77	1.041	0.028	17.24	0.479	-0.307	83.85	2.282	-18.836
12. RNR 2465	12.40	0.728	0.184	22.27	0.905	-0.407	83.52	1.396	-17.487
13. RNR 2354	14.43	1.212	-0.139	20.94	2.574**	0.044	84.14	0.410	-18.791
14. JGL 11118	15.20	2.072*	0.148	21.27	0.830**	-0.978	84.53	0.546	-18.916
15. JGL 13595	12.77	0.442**	-0.267	15.80	0.834	2.504	85.05	1.251	-19.303
16.WGL 32183	16.53	0.682	-0.127	19.04	1.674	0.800	84.60	0.050**	-19.297
17. DRRH 2	20.18	0.802	0.538	16.76	0.684**	-0.957	84.55	0.579	-18.710
18. KRH 2	20.66	-0.019**	-0.260	22.80	0.110**	-0.015	84.71	4.904	-11.581
19. DRRH 44	16.60	0.899	-0.148	21.84	3.292**	-0.957	83.76	3.896	-13.184
20. PA 6201	19.87	0.861	0.097	14.41	1.036	-0.540	84.90	0.402	-12.296
21. PA 6444	21.08	1.064	-0.260	19.81	2.542**	0.391	85.03	2.869*	-19.034

Genotypes	Hulling per cent			Milling per cent			Head Rice Recovery per cent		
	Mean	bi	s^2di	Mean (cm)	Bi	s^2di	Mean	Bi	s^2di
1. IR 64	81.14	1.064	-0.020	70.90	0.988	-0.515	64.54	0.412	1.909
2. MTU 1010	80.97	1.368	-0.467	69.96	1.400**	-0.393	60.29	1.427**	-0.592
3.Krishnahamsa	81.51	1.681	0.298	70.64	1.251	2.681*	61.32	2.392**	-0.552
4. Tellahamsa	82.58	1.267	-0.159	70.35	0.321	1.318	61.98	0.359	7.111**
5. Erramallelu	83.09	0.512**	-0.466	71.09	-0.338**	-0.520	61.59	0.732	14.459**
6. Rajendra	82.35	1.461	-0.270	69.93	0.653**	-0.514	57.30	0.865*	-0.790
7. JGL 1798	79.88	0.119**	-0.148	71.24	0.097	1.401	63.12	0.541	21.773**
8. JGL 3844	80.32	0.543**	-0.466	70.56	0.125**	0.041	65.06	0.870	0.248
9. NLR 34449	82.57	3.905**	1.700*	64.24	3.149**	0.112	55.33	2.005*	3.062*
10. Rasi	80.99	1.406	-0.316	71.45	0.777	-0.153	64.67	0.934	-0.827
11. RNR C 28	83.03	1.481	-0.152	69.85	-0.005**	-0.520	59.02	0.028**	-0.878
12. RNR 2465	77.93	0.199	4.544**	70.04	1.001	3.154**	64.30	2.098*	3.912*
13. RNR 2354	80.24	0.932	-0.423	72.06	0.417	0.501	65.01	0.977	1.308
14. JGL 11118	81.32	0.809**	-0.469	70.89	0.699	3.418**	62.49	-0.168	7.642**
15. JGL 13595	79.79	-0.566**	0.398	70.92	1.033	0.826	61.56	1.608	5.507**
16.WGL 32183	81.80	1.207	0.811	69.58	2.598**	-0.522	61.90	1.432	11.619**
17. DRRH 2	82.06	1.753**	-0.329	70.19	0.359	10.216**	62.06	0.569	23.252**
18. KRH 2	81.78	0.746**	-0.468	66.72	-0.353	12.186**	56.61	-0.366**	2.319
19. DRRH 44	81.97	0.559**	-0.458	71.68	0.425**	-0.455	64.56	0.779	14.542**
20. PA 6201	81.75	0.971	-0.461	68.71	3.566**	0.594	59.90	1.800**	-0.792
21. PA 6444	83.65	-0.418**	-0.432	68.28	2.836**	0.256	58.77	1.704	2.506

Genotypes	Kernel length			Kernel breadth			L/B ratio		
	Mean (mm)	bi	s^2di	Mean (mm)	Bi	s^2di	Mean	bi	s^2di
1. IR 64	6.63	-1.432	-0.002	1.52	2.929	0.002	4.36	8.651	0.010
2. MTU 1010	6.31	-0.795	-0.002	1.42	16.147	0.008**	4.36	40.590	0.109**
3.Krishnahamsa	6.39	0.955	-0.002	1.65	-2.725	-0.001	3.83	-3.981	-0.005
4. Tellahamsa	6.32	-0.636	-0.002	1.60	4.626	0.001	3.98	5.704	-0.003
5. Erramallelu	6.37	0.636	-0.002	1.44	-5.705	0.007**	4.37	-18.649	0.013
6. Rajendra	6.16	0.795	-0.001	1.70	-1.111	0.000	3.59	-1.661	-0.002
7. JGL 1798	4.86	-2.545	-0.001	1.39	-2.728	0.003**	3.46	-3.887	0.016*
8. JGL 3844	4.93	6.045**	-0.002	1.49	11.990*	0.001	3.28	14.575**	-0.004
9. NLR 34449	5.06	-2.864	0.001	1.46	2.576	0.002	3.46	10.688	0.000
10. Rasi	5.30	1.432	-0.002	1.60	-15.272	0.007**	3.30	-16.831	0.022*
11. RNR C 28	6.26	1.432	-0.002	1.63	-14.589	0.032**	3.85	-38.364	0.091**
12. RNR 2465	4.60	1.591	-0.002	1.37	0.722	-0.001	3.3	3.479	-0.003
13. RNR 2354	5.80	1.273	-0.002	1.43	-1.717	0.000	4.03	-9.466*	-0.003
14. JGL 11118	5.41	0.636	-0.002	1.43	2.893	0.000	3.76	8.149**	-0.005
15. JGL 13595	4.85	3.182**	-0.001	1.42	3.382	0.001	3.40	4.513	0.004
16.WGL 32183	5.27	8.909**	0.000	1.61	3.146	0.000	3.24	2.884	-0.005
17. DRRH 2	7.02	-2.386*	-0.001	1.61	7.571	0.006**	4.44	16.142*	-0.001
18. KRH 2	6.29	1.909	-0.001	1.62	-2.187	-0.001	3.85	-4.482	-0.005
19. DRRH 44	5.47	4.136	0.000	1.53	2.809	-0.001	3.57	-1.504	-0.003
20. PA 6201	6.03	0.477	-0.002	1.68	3.314	0.000	3.57	1.849	0.007
21. PA 6444	6.46	-1.750*	-0.001	1.48	4.928	0.000	4.41	2.601	-0.005

has been found to be unpredictable because of their significant deviation from regression.

RNR 2465 registered an optimum height with regression co-efficient near to unity and minimum deviation from regression and was identified as superior. For better environment, Tellahamsa, KRH 2 and PA 6201 were suitable, as they exhibited desirable height with regression co-efficient greater than unity and predictable performance. The genotypes *viz*., Erramallelu, JGL 1798, JGL 11118 and JGL 13595 were found to be suitable for poor environments. The performance of IR 64, Krishnahamsa, NLR 34449, RNR 2354 and PA 6444 genotypes was entirely unpredictable as they recorded significant non linearity.

Normally, varieties with profuse tillering and high Leaf Area Index give higher yields in rabi by utilizing abundant sun light available throughout the season. Accordingly, the genotype MTU 1010 was identified as a stable variety for productive tillers per plant, as it had recorded high mean, unit regression co-efficient coupled with negligible deviation. Whereas, the genotypes Krishnahamsa, JGL 3844, Rasi and DRRH 44 were found to be suitable for favourable environments with predictable performance. At the same time, for poor environment, the genotype DRRH 2 was found to be the most suitable. The genotypes *viz*., IR 64, Tellahamsa, Rajendra, JGL 1798, RNR 2354 and PA 6444 with significant deviation from regression values were identified to have unpredictable performance.

The genotypes *viz.*, JGL 1798, RNR C 28, WGL 32183, DRRH 2 and DRRH 44 were considered to be stable with high mean for panicle length. Similarly, the genotypes MTU 1010 and KRH 2 were expected to perform well under favourable environment. For poor environment, IR 64, Tellahamsa, Erramallelu were suitable. Further, panicle density is an important trait to realize higher yields. Among the genotypes, Rajendra was found to be highly suitable for poor environments. The performance of other genotypes was unpredictable in nature, because of their significant s^2di values.

The performance of genotypes JGL 1798, RNR C 28 , RNR 2354, JGL 11118, JGL 13595 and DRRH 44 was unpredictable with respect to the trait, number of filled grains per panicle. Among all the genotypes,

Table 4. Classification of genotypes for different characters based on stability parameters

Character	Genotypes stable over all environments (b_i = 1, High Mean, s^2di= NS)	Genotypes suitable for favourable environments (b_i >1, High Mean, s^2di= NS)	Genotypes suitable for poor environments (b_i < 1, High Mean, s^2di= NS)
Days to 50 per cent flowering	IR 64	PA 6201	JGL 3844,RNR 2354, PA 6444
Plant height (cm)	RNR 2465	Tellahamsa, JGL 3844, Rasi, RNR C 28, KRH 2, PA 6201	Erramallelu, JGL 1798, JGL 11118, JGL 13595
Number of productive tillers per plant	MTU 1010	Krishna hamsa, JGL 3844, Rasi, DRRH 44	DRRH 2
Panicle length (cm)	JGL 1798, RNR C 28, WGL 32183, DRRH 2, DRRH 44	MTU 1010, KRH 2	IR 64, Tellahamsa, Erramallelu
Panicle density (%)	-	-	Rajendra
Number of filled grains per panicle	-	WGL 32183	PA 6444
Spikelet fertility (%)	NLR 34449, JGL 13595	PA 6444	Tellahamsa,, WGL 32183
1000 – grain weight	Rajendra, RNR C 28, DRRH 2, DRRH 44, PA 6201, PA 6444	IR 64, Erramallelu, JGL 11118	KRH 2
Grain yield per plant (g)	RNR 2465, WGL 32183	JGL 3844, RNR 2354, DRRH 44, PA 6444	IR 64, Krishna hamsa, JGL 11118, KRH 2
Hulling percentage	IR 64, Tellahamsa, Rajendra, RNR C 28, WGL 32183, PA 6201	DRRH 2	Erramallelu, JGL 11118, KRH 2, DRRH 44
Milling percentage	IR 64, Rasi, JGL 13595	MTU 1010, WGL 32183, PA 6201	Erramallelu, Rajendra, JGL 3844, RNR C 28, DRRH 44
Head Rice Recovery (%)	JGL 3844, Rasi, RNR 2354	MTU 1010, Krishnahamsa, PA 6201	RNR C 28
Kernel length (mm)	Krishnahamsa, Rajendra, RNR C 28, RNR 2354	WGL 32183	DRRH 2, PA 6444
Kernel breadth (mm)	--	JGL 3844	--
Kernel L/B ratio	--	JGL 11118, DRRH 2	RNR 2354

WGL 32183 with high mean can be recommended for favourable environments with better prediction. The hybrid PA 6444 was considered to be suitable for poor environment for this trait.

Interestingly, for spikelet fertility, the performance of all the genotypes was highly predictable in nature as they recorded non-significant deviation from regression and linear response. The genotypes, NLR 34449 and JGL 13595 were identified as stable based on statistical parameters for this character. The hybrid PA 6444 was found to be the most suitable for favourable environments, and the genotypes, Tellahamsa and WGL 32183 were considered to be suitable for poor environment, as they recorded high mean in addition to other criteria.

Six genotypes *viz*., Rajendra, RNR C 28, DRRH 2, DRRH 44, PA 6201 and PA 6444 were identified as stable for 1000-grain weight with higher mean values. The genotypes, IR 64, Erramallelu and JGL 11118 were found suitable for favourable environment with predictable performance. Whereas, for poor environment, the hybrid KRH 2 was considered to be highly suitable. It was interesting to note that the performance of all the genotypes except Tellahamsa was predictable for this trait.

Apportioning of mean sum of squares due to G x E interactions in case of grain yield/plant revealed that the linear component was more predominant over non-linear component. This indicated that the variation in performance of genotypes can be predicted with greater precission. Similar findings were reported by Hegde and Vidyachandra (1998); Ali *et al*., (2006); Arumugam *et al*., (2007); Bhakta and Das (2008). The genotypes RNR 2465, WGL 32183 were identified as superior genotypes recording stable yield performance across all the locations. Whereas, the genotypes IR 64, Krishnahamsa, JGL 11118 and KRH 2 were suitable for unfavourable environments. For better environment, four promising entries *viz*., JGL 3844, RNR 2354 (varieties), DRRH 44 and PA 6444 (hybrids) with high mean are recommended. The performance was highly unpredictable in case of Rajendra and JGL 1798.

Table 5. Analysis of variance for yield and yield components for stability in rice

Source	Df	Days to 50 per cent flowering	Plant height (cm)	Number of productive tillers per Plant	Panicle length (cm)	Panicle Density (per cent)	Filled grains per Panicle	Spike let Fertility (per cent)
Genotypes	20	28.96 **	84.03 **	7.07 **	5.63 **	5.56 **	3965.84 **	1.78
Environments	2	8.29	176.71 **	9.66 *	23.52 **	10.68 *	6723.72 **	4.00
Genotype X Environment	40	3.99**	16.12**	2.04**	0.78**	1.64**	398.15**	2.45
Environment + (Genotype X Environment)	42	4.20	23.77	2.40 *	1.86 **	2.07	699.37 **	2.53
Environments (linear)	1	16.58 *	353.42 **	19.31 **	47.04 **	21.36 **	13447.44 **	8.01
Genotype X Environment (linear)	20	5.05	15.81	2.85 *	0.99	1.33	552.77 *	1.45
Pooled Deviation	21	2.80 *	15.65 **	1.18 **	0.54 *	1.85 **	231.94 **	3.29
Pooled Error	120	1.48	2.60	0.34	0.33	0.09	44.81	19.52

Source	Df	1000 Grain weight (g)	Grain yield per Plant (g)	Hulling per cent	Milling per cent	Head Rice Recovery per cent	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
Genotypes	20	40.59 **	30.72 **	5.29 **	9.59	24.44 **	1.467 **	0.0316 **	0.5144 **
Environments	2	10.24 **	87.38 **	33.32 **	73.30 **	226.59 **	0.0022	0.0005	0.0009
Genotype X Environment	40	0.37*	5.86 **	1.65 **	5.53 **	9.60**	0.0011	0.0035**	0.018**
Environment + (Genotype X Environment)	42	0.84 **	9.74 **	3.16 **	8.76 **	19.94 **	0.0012 *	0.0033	0.017
Environments (linear)	1	20.48 **	174.76 **	66.63 **	146.59 **	453.18 **	0.0045	0.0011	0.0018
Genotype X Environment (linear)	20	0.43	9.32 **	2.69 **	8.85 **	12.43	0.0017	0.0028	0.019
Pooled Deviation	21	0.30	2.27 **	0.58	2.10 **	6.45 **	0.0005	0.0036 **	0.015 **
Pooled Error	120	0.23	1.02	0.43	0.53	0.91	0.0015	0.0008	0.005

* Significant at 5per cent level ** Significant at 1 per cent level

Grain yield is the ultimate result which is dependent on its components. Grafius (1959) suggested that there would be no separate gene system for yield per se and yield is an end product of multiplicative interaction between the yield components. Interestingly, in the present study also, the varieties *viz*., RNR 2465 and IR 64 which exhibited stability for yield performance in three environments, and also showed stability in component characters, especially for number of productive tillers per plant, 1000-grain weight and maturity period. The genotypes identified for better environment possessed more grains per panicle and more productive tillers with perfect linearity with changing environments.

Among the milling traits, higher hulling percentage is more desirable in rice to realize higher proportion of economic product with less wastage. The genotypes viz., IR 64, Tellahamsa, Rajendra, RNR C 28, WGL 32183 and PA 6201 were identified for stability. DRRH 2 for better environment and Erramallelu, JGL 11118, KRH 2 , DRRH 44 and PA 6444 for unfavourable environment were identified as per the criteria followed in the present model. The performance of NLR 34449 and RNR 2465 was unpredictable due to the significant nonlinear values. IR 64, Rasi and JGL 13595 are the stable genotypes for milling per cent with high mean. The genotypes MTU 1010, WGL 32183 and PA 6201 were suitable for favourable environments and for the poor environments, the genotypes viz., Erramallelu, Rajendra, JGL 3844, RNR C 28 and DRRH 44 were better.

Head rice recovery is one of the most important quality parameters based on which the final market price is fixed. It is highly influenced by seasonal conditions, management practices in addition to genetic factors. Generally, kernels which are transluscent, medium in size with no sun cracks and chalkiness are not broken easily in the mills resulting in high head rice recovery. The stable genotypes having high mean for this character are JGL 3844, Rasi and RNR 2354. Whereas, MTU 1010, Krishnahamsa and PA 6201 having high mean are suitable for favourable environment. The performance with respect to this trait, in case of Tellahamsa, Erramallelu, JGL 1798, NLR 34449, RNR 2465, JGL11118, JGL 13595, WGL 32183, DRRH 2 and DRRH44 was highly unpredictable on account of significant deviations from regression.

Interestingly, for kernel length, all the genotypes showed non-significant deviation from regression giving the scope to predict their performance. The genotypes Krishnahamsa, Rajendra, RNR C 28 and RNR 2354 are considered as stable with high mean. The genotype, WGL 32183 for favourable environment and the hybrids DRRH 2 and PA 6444 for poor environment were treated as, otherwise desirable. The genotypes RNR 2354, RNR 2465, JGL 11118, JGL13595 were considered stable and superior ones due to low mean for kernel breadth. The performance of genotypes MTU 1010, Erramallelu, JGL 1798, Rasi, RNR C 28 and DRRH 2 was unpredictable for this character.

The quality and shape of kernel is classified based on L/B ratio. Generally, kernels with L/B ratio of 3.0 and above is classified as fine and slender. None of the genotypes included in the present study showed stable performance. However, the genotypes JGL 11118 and DRRH 2 having higher mean values and high regression co-efficients, and the genotype RNR 2354 with high mean but low regression coefficients were identified for better and poor environments, respectively. The performance was unpredictable in case of MTU 1010, JGL 1798, Rasi and RNR C 28. Based on stability performance, the genotypes were classified for different environments (Table.4).

On the basis of overall performance for yield and quality parameters, the genotypes RNR 2465 and WGL 32183 were found to be stable for yield performance. The hybrids KRH 2, DRRH 44, PA 6444 excelled in yielding ability, but they were more adapted to favourable environment, indicating the scope of their cultivation in high input management to raise the productivity levels in rabi season. Based on the stability parameters, the varieties RNR 2465 and WGL 32183; and the hybrids KRH 2, DRRH 44 and PA 6444 were identified as stable genotypes suitable for favourable environments, respectively.

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