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Stability analysis of rice (*Oryza sativa*) hybrids and their parents

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ABSTRACT

An experiment was conducted to evaluate 115 rice (*Oryza sativa* L.) hybrids, their parents (5 cyto plasmic male sterile lines and 23 restorer parents) and four checks for their stability at three different locations, viz Hyderabad, Warangal and Jagtial representing three different agro-climatic zones of Andhra Pradesh. The study indicated that a substantial portion of G × E interaction was due to the linear component for days to 50% flowering, productive tillers/plant, panicle weight, filled grains/panicle, grain yield/plant and productivity/day. Hybrids were less predictable than the parents for days to 50% flowering, productive tillers/plant, panicle weight and grain yield/plant. Several high-yielding hybrids and parents were identified for general ('CRMS 32A' × 'RPHR 517' and 'APMS 6A' × 'RPHR 118'), favourable ('PUSA 5A' × 'RPHR 1096', 'IR 58025A' × 'KMR 3' and 'CRMS 32A' × 'GQ 120') and poor ('CRMS 32A' × 'GQ 70') environments. Thus the present study confirmed that stable hybrids were developed from stable parents but stable parents need not necessarily generate stable hybrids.

Key words: G × E, Rice hybrids, Yield stability

Rice (*Oryza sativa* L.) is the staple crop and important cereal crop of India, being a thermo- and photo-sensitive in nature, due to its buffering capacity it is being cultivated round the year in different agro-climatic zones of the country. However, the hybrids and breeding material are likely to interact differently with different environments. The presently cultivated varieties and hybrids though having high seed yield potential, they are erratic in their performance even under less varied conditions of cultivation. Lack of hybrids suitable to specific locations accounts for the decline in the area and productivity in rice, apart from the biotic and abiotic stresses. Therefore, assessment of its adaptability is of important concern. Productivity of a population is the function of its adaptation, whereas stability is the statistical measure of genotype × environment interaction. Relative ranking of genotype in different seasons for a given attribute is rarely the same. This results in difficulty in detecting superior genotypes. Therefore, it is necessary to select genotype(s) showing a high degree of stability of performance over a wide range of environments (Das *et al.* 2010). Precise knowledge on the nature and magnitude of genotype× environmental interaction is important in understanding the stability in yield of a particular variety or a hybrid before it is being recommended for given situation(s). However, little information is available on the stability of rice hybrids. Panwar *et al.* (2008) and Young and Virmani (1990) also observed varying magnitude of heterosis over environments and stressed the need to evaluate hybrids across environments to identify stable hybrids with high yield that shows least interaction with environment. Therefore, an attempt was made to study the stability parameters of the hybrids developed and evaluated at three different agro-climatic zones in Andhra Pradesh in the present investigation, using Eberhart and Russel (1966) model.

MATERIALS AND METHODS

One hundred and fifteen F_1 hybrids were generated by crossing 23 restorer parents with 5 male sterile lines in line × tester mating design during winter (*rabi*) season 2006–07. The resulting hybrids along with 28 parents including 5B lines and 23 restorers and four checks (two hybrid checks, viz 'KRH 2' and 'PA 6201' and 2 varietal checks, viz 'Jaya' and 'IR 64') were evaluated for their stability during rainy

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(kharif) season 2007 at three different locations, viz Directorate of Rice Research, Hyderabad, Regional Agricultural Research Station, Warangal and Regional Agricultural Research Station, Jagtial. All the entries at the age of 28 days were transplanted in randomized complete block design with two replications. Each entry was planted in two rows of 1.8 m length. Single seedling was transplanted/hill by adopting a spacing of 20 cm × 15 cm and all recommended package of practices were followed to raise a healthy crop. Observations were recorded for yield and its attributes such as productive tillers/plant, panicle weight, number of filled grains/panicle, spikelet fertility percentage, 1000-seed weight, grain yield/plant and productivity/day on five plants of each entry in each replication. Days to 50% flowering was recorded on plot basis. The data were subjected to stability analysis as per the model suggested by Eberhart and Russel (1966).

RESULTS AND DISCUSSION

The analysis of variance of stability following Eberhart and Russell's model revealed that the genotypes and environments were significant for all the characters except for 1000-seed weight and spikelet fertility percentage for genotypes, indicating the diversity among the genotypes and environments studied. The GE interactions were significant for six characters, viz days to 50% flowering, productive tillers per plant, panicle weight, filled grains per panicle, grain yield/plant and productivity/day. Significant GE interactions implied differential behaviour of genotypes under three different locations. Similar reports were earlier made by Deshpande and Dalvi (2006) and Ramya and Senthil Kumar (2008). Significant variation due to environment (linear) revealed the linear contribution of environmental effects and additive environment variance on these characters. Similar results were reported earlier by Lavanya *et al.* (2005), Deshpande and Dalvi (2006) and Arumugam *et al.* (2007)**.** The linear component of GE interaction was significant for six characters suggesting that the genotypes differ for their linear response to environments as also revealed by Babu *et al.* (2005) and Ramya and Senthil Kumar (2008). The pooled deviation was significant for all the characters indicating the non-linear response and unpredictable nature of the genotypes by significantly differing for stability. Significant non-linear responses were also observed earlier by Babu *et al.* (2005), Bhaktha and Das (2008) and Johnson *et al.* (2010), while both significant and non-significant linear responses were reported by Lavanya *et al.* (2005) and Vidhu Francis (2005).

Environmental index reveals the favourability of an environment at a particular location. Breeze (1969) pointed out that the estimates of environmental index can provide the basis for identifying the favourable environments for the expression of maximum potential of the genotype. Based on environmental indices, Hyderabad was found to be the most favourable location for productive tillers/plant and grain yield/ plant, while Jagtial was the most favourable for days to 50% flowering and productivity/day. The Warangal location was most favourable for panicle weight and filled grains/ panicle. The results are in broad agreement with the findings reported by Babu *et al.* (2005) and Sedghi-Azar (2008).

Linear regression (bi) is a measure of response or sensitivity to environmental changes of a variety while deviation from regression measures the stability of genotypes with the lowest standard deviation near to zero being the most stable and *vice-versa*. According to Eberhart and Russel (1966), a stable genotype is one which shows high mean yield, regression coefficient (bi=1) equal to unity and mean square deviation from regression (S^2di) near to zero. In interpreting the results, S^2di was considered as the measure of stability as suggested by Breeze (1969). Then, the type of stability (measure of response or sensitivity to environmental changes) was decided on regression coefficient (bi) and mean values (Finlay and Wilkinson 1963). For the yield/plant, 48 hybrids, four lines, 10 testers and four checks recorded non-significant S^2di values, whose performance could be predicted. Among the stable hybrids, two hybrids 'CRMS 32A' × 'RPHR 517'

Table 1 ANOVA for yield and yield components for stability in rice

Source	df	Days to 50% flowering	Productive tillers/ plant	Panicle weight (g)	Filled grains/ panicle	Spikelet fertility (%)	1 000-seed weight (g)	Grain yield/plant (g)	Productivity/ day (kg/ha)
Genotypes	146	31.65**	6.32**	1.48**	3716.38**	60.23	12.78**	78.21**	349.03**
Environment + (genotype× environment)	294	54.64**	2.26**	0.49**	1216.05**	59.78	6.50	33.09**	155.36**
Environments	2	3598.62**	18.32**	5.08**	6506.24**	2168.37**	14.94**	142.53**	1421.45**
Genotype × environment	292	30.37**	2.15**	0.46**	1179.81**	45.34	6.44	32.34**	146.69**
Environments (linear)	1	6197.25**	74.47**	8.16**	12012.49**	4336.73**	29.88*	885.06**	4842.90**
Genotype × environment (linear)	146	42.04**	2.65**	0.59**	1549.53**	42.21	7.37*	36.26**	171.30**
Pooled deviation	147	25.36**	1.38**	0.34**	872.61**	48.13**	5.48**	24.14**	107.65**
Pooled error	438	1.90	0.48	0.076	68.72	3.12	0.19	1.81	8.12

Table 2 Stable hybrids for various characters in rice

Character	Hybrids/parents
Days to 50% flowering (earliness)	*Hybrids:* 'IR 58025A'×'BR 827-35', 'CRMS 32 A'×' IBL 57', 'APMS 6A'×' GQ 37-1' (stable) *Parents:* 'PUSA 5A', 'CRMS 32 A', 'APMS 6A', 'KMR 3', 'BL 57', 'BR 827-35', 'SC5 9-3', 'SG 27-77', 'RPHR 124', 'RPHR 517', 'IR 43', 'IR 55', 'IR60' (stable); 'RPHR 1096' (favourable environments)
Productive tillers/plant	*Hybrids;* 'IR 79156A'×'KMR 3', 'IR 58025A'×'RPHR 619-2', 'IR 58025A'×'RPHR 612-1', 'IR 58025A'×'GQ 120', 'IR 79156A'×'RPHR 1096', 'IR 79156A'×'GQ 37-1', 'IR 79156A'×'GQ 70', 'IR 79156A'×'IBL 57', 'IR 79156A'×'BR 827-35', 'IR 79156A'×'SG 26-120', 'APMS 6A'×'GQ-25', 'APMS 6A'×'GQ 37-1', 'APMS 6A'×'GQ 70', 'APMS 6A'×'SC5 2-2-1', 'APMS 6A'×'SG 27-77', 'APMS 6A'×'SG 26-120' (stable); 'CRMS 32A'×'GQ 25' (favourable environments); 'CRMS 32 A'×'RPHR 1096', 'CRMS 32 A'×'KMR 3', 'CRMS 32A'x 'IBL 57' (poor environments) *Parents:* 'IR 58025A ', IR 79156A, PUSA 5A, 1005, 619-2, 611-1, GQ 25, GQ 70, GQ 120, KMR 3, BR 827-35, EPLT 109, SG 27-77, 118, 124, 517, IR 43, IR 55, IR60(stable)
Panicle weight	*Hybrids;* 'IR 79156A'×'SG 27-77', 'APMS 6A'×'RPHR 1005', 'APMS 6A'×'RPHR 619-2', 'APMS 6A'×'SG 27-77', 'APMS 6A'×'RPHR 124', 'PUSA 5A'×'RPHR 611-1', 'PUSA 5A'×'SC5 9-3', 'CRMS 32 A'×'IBL 57', 'CRMS 32 A'×'BR 827-35', 'CRMS 32 A'×'SC5 9-3', 'CRMS 32 A'×'RPHR 118' (stable);'APMS 6A'×'SC5 2-2-1' (favourable environments) *Parents:* 'IR 79156[a]', 'PUSA 5A', 'CRMS 32 A', 'RPHR 1096', 'RPHR 1005', 'RPHR 619-2', 'RPHR 611-1', 'RPHR GQ 37-1', 'IBL 57', 'EPLT 109', 'SC5 2-2-1, 'SG 27-77', 'RPHR 118', 'RPHR 124', 'IR 43', 'IR 55'(stable); 'RPHR 612-1' (favourable environments)
Filled grains/panicle	*Hybrids;* 'IR 79156A'×'SG 27-77', 'APMS 6A'×'RPHR 1096', 'APMS 6A'×'RPHR 619-2, 'APMS 6A'×'RPHR 124', 'PUSA 5A'×'RPHR 619-2', 'PUSA 5A'×'SG 26-120', 'CRMS 32 A'×'RPHR 1005', 'CRMS 32 A'×'RPHR 619-2', 'CRMS 32 A'×'IBL 57', 'CRMS 32 A'×'EPLT 109', 'CRMS 32 A'×'SC5 9-3' (stable); 'APMS 6A'×'SC5 2-2-1', 'CRMS 32 A'×'BR 827-35', 'CRMS 32 A'×'RPHR 118', 'CRMS 32 A'×'IR 60' (favourable environments) *Parents:* 'CRMS 32 A', 'RPHR 1096', 'RPHR 619-2', 'IBL 57', 'RPHR 118', 'RPHR 124', 'IR 43', 'IR 55'(stable)
Grain yield/plant	*Hybrids;* 'CRMS 32 A'×'RPHR 517', 'APMS 6A'×'RPHR 118', 'IR 79156A'×'RPHR 1096', 'IR 79156A'×'SG 26-120', 'APMS 6A'×'GQ 120', 'APMS 6A'×'SG 27-77', 'APMS 6A'×'RPHR 124', 'PUSA 5A'×'GQ 120', 'PUSA 5A'×'RPHR 124', 'PUSA 5A'×'RPHR 517', 'PUSA 5A'×'IR 55', 'CRMS 32 A'×'RPHR 1005' (stable), 'IR 58025A'×'KMR 3', 'PUSA 5A'×'RPHR 1096', 'CRMS 32 A'×'GQ 120' (favourable environments); 'CRMS 32 A'×'GQ 70' (poor environments) *Parents:* 'IR 58025A', 'APMS 6A', 'PUSA 5A', 'RPHR 1096', 'RPHR 612-1', 'GQ 37-1', 'GQ 70', 'GQ 120', 'SC5 9-3', 'SG 27-77', 'RPHR 517', 'IR 43' (stable); 'RPHR 619-2' (favourable environments); 'IR 79156A' (poor environments)
Productivity/day	*Hybrids;* 'APMS 6A'×'RPHR 118', 'PUSA 5A'×'RPHR 1096', 'APMS 6A'×'RPHR 124', 'PUSA 5A'×'RPHR 124', 'PUSA 5A'×'IR 55', 'CRMS 32 A'×'GQ 70' (stable); 'IR 58025A'×' SG 27-77', 'APMS 6A'×'RPHR 612-1', 'PUSA 5A'×'IR 43', 'CRMS 32 A'×'RPHR 517' (favourable environments) *Parents:* 'IR 58025A', 'IR 79156A', 'APMS 6A', 'CRMS 32 A', 'GQ 37-1', 'GQ 70', 'RPHR 517', 'IR 60' (stable); 'IBL 57', 'SG 27-77' (favourable environments) ; 'RPHR 1096', 'IR 43' (poor environments)

(32.46 g) and 'APMS 6A' × 'RPHR 118' (31.86 g) possessed significantly higher grain yield than the best check 'KRH 2' (28.06 g) with unit bi values were considered as ideal and highly adaptable hybrids having average stability and predictable in performance over three locations. The stable performance in ten high yielding hybrids, viz 'PUSA 5A' × 'IR 55' (31.72 g), 'PUSA 5A' × 'RPHR 124' (31.29 g), 'APMS 6A' × 'GQ-120' (31.23 g), 'APMS 6A' × 'SG 27-77' (30.69 g), 'APMS 6A' × 'RPHR 124' (29.54 g), 'PUSA 5A' × 'RPHR 517' (29.29 g), 'CRMS 32A' × 'RPHR 1005' (28.94 g), 'IR 79156A' × 'RPHR 1096' (28.77 g), 'IR 79156A' × 'SG 26-120' (28.67 g) and 'PUSA 5A' × 'GQ 120' (28.38 g) was found to be predictable under all the environments.

Other superior performing hybrids 'PUSA 5A' × 'RPHR 1096' (32.80 g), 'IR 58025A' × 'KMR 3' (29.88 g) and 'CRMS 32A' × 'GQ-120' (28.49 g) which showed above average response were stable under favourable environments. The hybrid 'CRMS 32A' × 'GQ-70' (30.33 g) recorded

Table 3 Overall performance of top 15 heterotic hybrids for grain yield/plant in rice

Hybrid	Standard heterosis (%)	Average heterosis (%)	Heterobe ltiosis (%)	Mean per-formance	Sca effect	Stable/ unstable
'APMS 6A'×'GQ-25'	36.54**	87.13**	77.48**	38.31	10.49**	Unstable
'PUSA 5A'×'KMR 3'	35.77**	90.27**	62.65**	38.09	7.10**	Unstable
'APMS 6A'×'RPHR 1005'	29.90**	13.31**	88.28**	36.44	7.56**	Unstable
'APMS 6A'×' SC5 9-3'	28.93**	70.17**	56.21**	36.17	7.63**	Unstable
'IR 79156A'×'SG27-77'	23.86**	74.53**	98.68**	34.75	5.96**	Unstable
'APMS 6A'×'RPHR 612-1'	23.34**	58.59**	68.08**	34.60	6.99**	Unstable
'PUSA 5A×IR 43'	23.28**	121.69**	108.10**	34.59	10.08**	Unstable
'IR 79156A'×'IBL 57'	18.08**	102.33**	87.46**	33.12	7.55**	Unstable
'PUSA 5A'×'RPHR 1096'	16.91**	59.32**	33.57**	32.80	4.45**	Unstable
'PUSA 5A'×'SG 27-77'	16.78**	79.37**	64.55**	32.76	0.65	Unstable
'CRMS 32A'×'IBL 57'	16.68**	55.29**	33.64**	32.74	3.02**	Unstable
'IR 79156 A'×'KMR 3'	16.44**	69.75**	39.48**	32.67	5.01**	Unstable
'CRMS 32A'×'RPHR 517'	15.71**	55.12**	32.54**	32.46	3.85**	Stable
'APMS 6A'×'RPHR 118'	13.57**	55.67**	47.65**	31.86	3.57**	Stable
'PUSA 5A'×'IR 55'	13.07**	77.21**	365.38**	31.72	7.89**	Stable
				CD (*P*=0.05) =3.76	SE ij = 0.81	

regression coefficient value (bi) of less than one and considered to perform stably in poor environments.

Among the stable parents (Table 2), none could record significantly higher grain yield/pant than the best check 'KRH 2'. However, the lines 'IR 58025A', 'APMS 6A', and 'PUSA 5A' and the testers 'SC5 2-2-1', 'GQ 37-1', 'RPHR 1096', 'RPHR 612-1', 'GQ 120', 'SG 27-77', 'GQ 70', 'RPHR 517' and 'IR 43' exhibited average stability, while, the line 'IR 79156A' exhibited more than the average stability. The tester 'RPHR 619-2' recorded more than one of bi values and behaved stably under better environments. All the four standard checks, viz 'KRH 2', 'PA 6201', 'Jaya' and 'IR 64' were ranked as highly stable in performance for grain yield that can be predictable.

Hybrids were less predictable than parents for days to 50% flowering, productive tillers/plant, panicle weight and grain yield/plant. While both hybrids and parents were less predictable for filled grains/panicle and/day productivity (Table 4). This is in conformity to Babu *et al.* (2005) and Deshpande and Dalvi (2006), who reported that hybrids were less stable and less predictable than parents for grain yield and days to 50% flowering.

Fifteen superior yielding hybrids (also showing significant *sca* effects) with significant standard heterosis (> 13% over 'KRH 2', leading public hybrid) were compared for their stability parameters of grain yield and yield component traits (Table 3). The first 12 high-yielding hybrids were unpredictable in their performance and a hybrid, 'CRMS 32A' × 'RPHR 517' which was ranked 13th in grain yield was stable over the environments with predictable performance for grain yield/plant. This stable hybrid was of medium duration (129 days). Other stable hybrids with predictable performance for yield and other yield traits were 'APMS 6A' × 'RPHR 118' and 'PUSA 5A' × 'IR 55' for grain yield/ plant and productivity/day. One hybrid 'PUSA 5A' × 'RPHR 1096' with above average response was desirable for specific (favourable) environments. These three hybrids were also medium in duration. The hybrids with specific adaptability (favourable/poor environments) rather than general might overcome the problem of genetic vulnerability. Lavanya *et al.* (2005) and Panwar *et al.* (2008) also recorded similar results.

The stable hybrid 'CRMS 32A' × 'RPHR 517' was derived from one stable parent 'CRMS 32A' and an unstable parent 'RPHR 517'. Among the two other stable hybrids, 'APMS 6A' × 'RPHR 118' was with stable 'APMS 6A' and an unstable 'RPHR 118'; 'PUSA 5A' × 'IR 55' was with an unstable 'PUSA 5A' and stable 'IR 55'. Thus the present

Table 4 Per cent of stability of parents, hybrids and checks in rice

Character	No. of parents	Parents (%)	Crosses	Crosses (%)	Checks (no.)	Checks (%)
Days to 50% flowering	14	50.00	33	28.70	3	75
Productive tillers/plant	22	78.57	80	69.57	4	100
Panicle weight	17	60.71	67	58.26	3	75
Filled grains/panicle	8	28.57	47	40.87	2	50
Grain yield/plant	14	50.00	48	41.74	4	100
Productivity/day	12	42.86	45	39.13	3	75

study also confirmed the earlier reports of Lavanya *et al.* (2005) and Deshpande and Dalvi (2006) that stable hybrids involved stable parents but stable parents need not necessarily generate stable hybrids. For example, 'IR 79156A' and 'SG 27-77' were stable parents for grain yield but their hybrid 'IR 79156A' × 'SG 27-77' was unstable for grain yield.

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