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Stability of Popular Rice Hybrids for Important Grain Yield Parameters

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Nine popular rice (*Oryza sativa* L.) hybrids were evaluated over three years during *kharif* season 2008- 2010 to assess stability for grain yield and its contributing traits. Analysis of variance of stability revealed highly significant variance due to environment for all seven traits. The variance for genotypic effect was significant for all traits indicating differential response of hybrids over the environments. Estimates of environmental index showed that performance of hybrids over three environments varied and environment E_2 exhibited highest favourable impact on grain yield. Only two hybrids, KRH-2 and PRH-10 revealed stability for grain yield. Hybrid 'KRH-2' showed stable performance for all seven characters whereas, PRH-10 exhibited stability for six traits *viz.*; days to 50% flowering, days to maturity, plant height, panicle length, number of filled grains per panicle and seed yield / m^2. Based on stability parameters these two hybrids can be considered as stable performers and may be exploited for yield enhancement of rice under varying environmental conditions while their parental lines could be used in breeding programme to develop new cultivars with combination of stable characters.

Key Words: G × E interaction, Regression coefficient, Rice hybrids, Stability analysis

Introduction

Rice (*Oryza sativa* L.) is the staple food crop and feeds more than half of the world's population. It plays a vital role in food security and accounts for 30-50 percent of the agricultural income in India (Yadav *et al.*, 2013). India is the second largest rice producing country after China with 105.24 million tons from 43 million hectares of land during 2012-13 (Anonymous, 2014). Despite achieving record rice production, India still needs steady growth to produce 125 million tons of rice by the year 2030 (DAC, 2010). Several varieties have been developed in India but the yield potentials remain stagnant since several years though there has been improvement in quality, disease and pest resistance. Hybrid rice provides an important avenue to achieve higher yields. In China, hybrids accounting for more than half of rice cultivated areas whereas, it is less than 10 percent in India (Spielman *et al.*, 2013). The increase in rice yields in China attributable to the spread of hybrid rice, in turn to, the improved food security for an estimated 60 million additional people per year (Li *et al.*, 2010). Moreover, hybrid rice could be a means of reinvigorating stagnant yield growth in rice in India, boosting rural incomes, and stimulating scientific interest in crop improvement. Widespread adoption of hybrids, therefore is highly depends on their stable high yield performances over the environments. Presently cultivated varieties and hybrids although having high yield potential, they are erratic in their performance even under less varied conditions of cultivation (Saidaiah *et al.*, 2011).

Environmental changes have serious implications on genotypic yield manifestations leads to inconsistency in performance due to genotype × environment interactions (Meena *et al.*, 2014). An understanding of environmental and genotypic causes leading to these interactions is highly important at all stages of plant breeding (Jackson *et al.*, 1996). Allard and Bradshaw (1964) defined stability as adaptation of genotypes to unpredictable and transient environmental conditions. This technique has been used to select stable genotypes unaffected by environmental changes (Das *et al.*, 2010). The method to measure stability was proposed by Finlay and Wilkinson (1963) and later improved by Eberhart and Russell (1966) was used in present study to understand the stability parameters of popular rice hybrids evaluated over three seasons for seed yield and its contributing traits.

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Materials and Methods

The experimental material consisted of nine popular rice hybrids, which were obtained from Indian Institute of Rice Research, Hyderabad. Of these, six hybrids (PRH-10, DRRH-2, KRH-2, CORH-3, Indira Sona and PSD-3) were developed by public sector and three (PA 6129, PA 6201 and PA 6444) were from Bayer Bio-Science (Table 1). Field experiments were carried out at Directorate of Seed Research, Mau located at 25°89' N latitude, 83°46' E longitude and an altitude of 209 feet above mean sea level under North Eastern Plains Zone (NEPZ) in the fertile plains of the Ganges–Ghaghara doab. The trials were conducted over three years from 2008 to 2010 during *Kharif* at same site in successive seasons representing three different environments E_1 (2008), E_2 (2009) and E_3 (2010), respectively. The average rainfall was 800 mm of which more than 80 per cent was received during the monsoon. Soil of experimental plots was silty loam having 55.9, 31.0 and 13.1 per cent proportions of sand, silt and clay, respectively, and slightly alkaline with pH ranging from 7.5 to 8.1. The organic carbon, available N, P and K were 0.32 per cent, 206 kg/ha, 19.7 kg/ha and 215 kg/ha, respectively. Experiments were laid out in randomized complete block design (RCBD) with 3

Table 1. Details of rice hybrids utilized for the study

Name	Year of release	Developed by	Area of adoption	Characteristics of hybrid
PRH-10 [S]	2001	Indian Agricultural Research Institute, New Delhi	Delhi, Haryana, Uttar Pradesh, Uttara Khand	Aromatic basmati hybrid, early maturity (115-120 days), high yielding (50-60q/ha), fine grain, high milling recovery, milled aroma, good cooking quality, enough volume expansion, non-glutinous and good taste.
DRRH-2[S]	2005	Directorate of Rice Research, Hyderabad	Haryana, Tamil Nadu, Uttara Khand, West Bengal	Suitable for irrigated conditions, semi dwarf (90 cm), early maturity 116 days, slender grains, resistant to lodging, LF, neck blast and RTV, moderately resistant to Sh.RBS & WBPH, and good yield (54 q/ha).
KRH-2 [S]	1996	VC Farm, (ARS of UAS, Bangalore), Mandya	Bihar, Haryana, Karnataka, Maharashtra, Odisha, Pondicherry, Rajasthan, Tamil Nadu, Tripura, Uttara Khand, West Bengal	Suitable for irrigated timely sown, maturity125-130 days, semi dwarf (102 cm), grains long slender and white, tolerant to LB, BS, & other diseases and high yielding (75-85 q/ha).
CORH-3[C]	2006	Tamil Nadu Agricultural University, Coimbatore	Tamil Nadu	Suitable for aerobic cultivation and mid-season drainage, early maturing (115days), high yielding (72 q/ha), grains medium slender and white, non-sticky, non-aromatic rice and good taste, tolerant to Rice Tungro Disease (RTD) and blast, resistant to Green Leaf Hopper (GLH) and tolerant to Brown Plant Hopper (BPH) and White Backed Plant Hopper (WBPH).
Indira Sona[S]	2006	Indira Gandhi Krishi Vshwa Vidyalay, Raipur	Chhattisgarh	Suitable for shallow lowlands, mid-early (125-130 days), high grain yield (60-65 q/ ha), grains long slender, mild aroma, resistant to gall midge and tolerant to blast.
PA 6129[S]	2007	Bayer Bio-Science, Hyderabad	Pondicherry, Punjab, Tamil Nadu	Early maturity (120 days), semi-dwarf, grains long slender, better N responsive, suitable to intermittent drought conditions, resistant to leaf blast, high yielding (60 – 80 q/ha).
PA 6201[S]	2000	Bayer Bio-Science, Hyderabad	Andhra Pradesh, Bihar, Karnataka, Odisha, Madhya Pradesh, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal	Suitable for irrigated conditions, mid-early (125-130 days), good yield (62 q/ha), grains long bold, resistant to blast, tolerant to SB, BPH & LF.
PA 6444 [S]	2001	Bayer Bio-Science, Hyderabad	Andhra Pradesh, Karnataka, Maharashtra, Odisha, Tripura, Uttar Pradesh, Uttara Khand	Suitable for irrigated conditions, matures in 135-140 days, semi tall (100-120 cm), compact and erect, medium slender grains and good yield (60-65 q/ha).
PSD-3[C]	2004	Govind Ballabh Pant University of Agriculture &Technology, Pantnagar	Uttara Khand	Suitable for irrigated plain areas, mid-early (125-130 days), fertilizer responsive and non lodging, tolerant to salinity & alkalinity, long slender grains with mild aroma, moderately resistant to BB, stem borer and BHP, yield 60-65 q/ha.

[S] State Release Hybrid; [C] Central Release Hybrid replications in plot size of 5 × 3m during each season. The 21 days old seedlings were transplanted keeping plant to plant and row to row spacing of 20 and 15 cm, respectively. All recommended cultivation practices prescribed for rice were followed precisely.

Observations were recorded from each plot for seven metric traits, *viz*. days to 50% flowering, days to maturity, plant height (cm), panicle length (cm), number of effective tillers per plant, number of filled grains per panicle and grain yield/m^2 (g). The data on grain yield was recorded on per m^2 basis, while, days to 50 % flowering was recorded on plot basis. Observations on remaining characters were recorded on ten randomly selected competitive plants from each plot of every replication. Standard procedures for analysis of variance were followed. Data were first subjected to the analysis followed for randomized block design as per Panse and Sukhatme (1967). Stability analysis was carried out following Eberhart and Russel (1966). Estimates of mean performance (x), regression coefficient (bi) and deviations from regression (S^2di) were used to draw inferences on stability of different rice hybrids.

Results and Discussion

Analysis of variance revealed significant differences amongst genotypes in each of the three environments. The significant variance due to environment and genotypes for the traits indicated distinct and differential effect of environments and differential response of genotypes (Table 2). Similarly, the variance due to environment + (genotype × environment) interactions was highly significant for all the traits interacted that genotypic and environment interaction was prominent. The findings are similar to those reported earlier by several researchers (Deshpande and Dalvi, 2006; Ramya and Senthil, 2008; Saidaiah *et al*., 2011). Highly significant variation due to environment (linear) was observed for days to 50% flowering, days to maturity, plant height, panicle length, number of effective tillers per plant, number of filled grains per panicle and seed yield / m^2 revealed linear contribution of environmental effects and additive environmental variance on these characters. Similar results were also reported by Lavanya *et al.* (2005), Deshpande and Dalvi (2006), Arumugam *et al.* (2007) and Saidaiah *et al*. (2011). Genotype × environment (linear) interaction was significant for days to maturity and plant height suggesting that genotypes differ for their linear response to environments. The pooled deviation was significant for five characters indicating that some portion of G × E interaction was unpredictable. Significant non-linear responses were earlier reported by Babu *et al.* (2005), Bhaktha and Das (2008) and Johnson *et al.* (2010), whereas both significant and non-significant linear responses were observed by Lavanya *et al.* (2005) and Vidhu Francis *et al*. (2005).

The estimates of environmental index can provide the basis for identifying favourable environments for expression of maximum potential of the genotype (Breeze, 1969). The comparison of environmental indices (Table 3) indicated that the performance of nine rice hybrids over three environments (cropping seasons) with respect to the grain yield / m^2 varied apparently and environment E_2 (*Kharif* 2009) exhibited highest favourable impact on grain yield followed by E_3 (*Kharif* 2010). Moreover, number of filled grains / panicle were higher under E_2 (*Kharif* 2009) while, favourable impact

Table 2. Analysis of variance for stability of important yield traits in rice hybrids

Source of variation	DF	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Number of effective tillers / plant	Number of filled grains / panicle	Grain yield / m^2 (g)
Genotype	8	93.07**	72.40**	212.41**	3.20*	1.53*	969.82**	7461.95*
Environment	2	102.52**	67.98**	299.27**	21.42**	4.83**	2582.81**	45876.13**
Genotype x Environment	16	1.73	1.69	21.65	0.645	0.51	79.38	3006.06
Environment + (Genotype x Env)	18	12.93**	9.05**	52.49**	2.95*	0.99*	357.54**	7769.36*
Environment (linear)	1	205.04**	135.97**	598.55**	42.83**	9.67**	5165.63**	91752.27**
Genotype x Environment (linear)	8	2.05	2.59*	33.51*	0.42	0.69	87.29	3828.12
Pooled deviation	9	1.25**	0.69*	8.71**	0.77	0.28	63.52**	1941.25**
Pooled error	48	0.25	0.313	2.94	0.41	0.17	17.27	34.72

*Significant at P=0.05; **Significant at P=0.01

Table 3. Effect of environment in the expression of grain yield and contributing traits

Character	Environmental indices		
	E_1	E_2	E_3
Days to 50% flowering	-3.765	1.012	2.753
Days to maturity	-3.173	1.531	1.642
Plant height (cm)	-4.182	6.578	-2.397
Panicle length (cm)	1.391	0.268	-1.659
Number of effective tillers / plant	-0.119	-0.667	0.785
Number of filled grains/ panicle	-19.556	10.185	9.370
Grain yield /m^2 (g)	-78.346	61.395	16.951

of effective tillers / plant was pronounced in environment E_3. Environment E_1 (*Kharif* 2008) was observed to be unfavourable in terms of grain yield; however, hybrids during this season exhibited early maturity and shorter plant height, while most of the traits were in lower side as indicated by negative values of environmental indices. The results are in agreement with the earlier findings of Babu *et al.* (2005), Sedghi-Azar *et al.* (2008) and Saidaiah *et al.* (2011).

According to Eberhart and Russel (1966), a stable genotype is one that shows higher mean yield, regression coefficient equal to unity (bi=1) and mean square deviation from regression near to zero (S^2di=0). Linear regression (bi) is a measure of response to environmental changes of a genotype whereas, deviation from regression measures the stability of genotypes with lowest standard deviation near to zero being the most stable and *vice-versa*. In interpreting the results, deviation from regression (S^2di) was considered as the measure of stability as suggested by Breeze (1969). Then, the measure of response to environmental changes (type of stability) was decided on regression coefficient (bi) and mean values (Finlay and Wilkinson 1963). With respect to plant height, days to 50% flowering and days to maturity the mean values lower than population mean were considered as desirable while, higher mean values were considered as desirable for remaining traits.

The estimates of stability parameters for seven characters presented (Table 4) revealed that hybrids, PRH-10, KRH-2 and PA 6201 possessed minimum deviation from regression (S^2di) indicating their high predictability in terms of grain yield /m^2. The hybrid KRH-2 possessed higher grain yield, non-significant regression coefficient (bi) less than one and with predictable performance over three seasons was considered to be stable and ideal for unfavourable environments. The stability parameters for hybrid, PRH-10 revealed non-significant S^2di values and regression coefficient (bi) with mean yield of 579.1g which was slightly lower than population mean (611.01g), and higher regression coefficient indicated that its suitability for favourable environments. Lavanya *et al.* (2005), Panwar *et al.* (2008) and Saidaiah *et al.* (2011) recorded variable response and specific adaptability of rice hybrids. Similarly, Bhakta and Das (2008) also reported average stability of rice genotypes with low yield potential, unit regression and non-significant S^2di values. Thus, the results shows that genotypes with moderate productivity can exhibit wide adaptability over range of environments and high yielding genotypes that are brought about by genetic manipulation may lead to variable performances. It is therefore, necessary to combine these two important genetic traits *viz.*; high yield potential and greater stability in the development of superior hybrids / genotype (s) in rice. Madariya *et al.* (2001) emphasized that grain yield is a complex trait and the analysis of individual yield parameter may lead to simplification in explaining stability for grain yield. Hence, it was observed (Table 4) that KRH-2 was the only hybrid showed stable performance for all seven characters with non-significant regression coefficient and S^2di values although, it was slightly late in maturity (128.2) and taller in height (131.4cm) compared to population means of 125.6 and 116.1, respectively. Hybrid PRH-10 exhibited stability for six traits, including days to 50% flowering, days to maturity, plant height, panicle length, number of filled grains per panicle and seed yield / m^2. Thus, the stability for grain yield in these hybrids (KRH-2 and PRH-10) was compensated by stability of different yield contributing parameters, resulted into wider adaptability of the hybrids.

All hybrids except DRRH-2 and PSD-3 showed linear predictability with non-significant deviation from regression (S^2di) for days to 50% flowering. Two hybrids, CORH-3 and PA 6129 possessed desirably lower mean values and non-significant regression coefficient (bi) greater than unity, hence were stable and suitable for favourable environments whereas, hybrid PRH-10 having regression coefficient less than unity with desirable mean was stable and suitable for unfavourable conditions. For days to maturity, six hybrids exhibited non-significant deviation from regression (S^2di) signifies their linear predictability. Among the hybrids, CORH-3 revealed stability and suitability for favourable environments while, two hybrids PRH-10 and PA 6129 observed to be stable and ideal for unfavourable conditions. Similarly, with respect to plant height, seven hybrids showed linear predictability and out of them four hybrids namely, PRH-10, Indira Sona, PA 6129 and PSD-3 had desirable mean values, non-significant regression coefficient (bi) greater than one showed stability and were suitable for favourable environments.

The stability parameters for number of effective tillers / plant, in eight hybrids indicated predictable S^2di values of them four hybrids *viz*; DRRH-2, KRH-2, CORH-3 and Indira Sona possessed higher mean values. KRH-2 and Indira Sona had regression coefficient greater than one while, DRRH-2 and CORH-3 had less than one meaning thereby that these hybrids were stable and ideal for favourable and unfavourable environments, respectively. Similarly, with respect to number of filled grains / panicle, six hybrids showed linear predictability with non-significant deviation from regression (S^2di) as per stability criteria's, hybrid KRH-2 revealed stability under favourable environments and hybrids PRH-10 and PA 6129 under poor environments.

Genotype × environment (GE) interaction for grain yield in rice has been reported in numerous studies under several designations like different response patterns, adaptation, or stability of a genotype, *etc*. The adaptability of a genotype to a range of environments can be best explained by its phenotypic stability (Elfadl *et al.*, 2012). This concept of stability implies that a stable variety may not necessarily respond to better growing conditions with increased yield (Becker, 1981). Identification of yield-contributing traits and estimation of genotype × environment (GE) interaction, and yield stability are the important parameters for breeding new cultivars adapted to specific environmental conditions (Rao *et al.*, 2002). Selection of genotypes for adaptability could be severely limited in terms of GEI. Therefore, it is necessary to assess the environmental sensitivity of genotypes in terms of higher yield and stability (Thillainathan and Fernandez, 2001). The hybrids with specific adaptability (favourable/poor environments) rather than general might overcome the problem of genetic vulnerability (Saidaiah *et al.*, 2011).

Based on stability criteria's *i.e.* regression coefficient (bi values), deviation from linearity (S^2di values) and mean performance, some of the hybrids were identified with stable performance under favourable and some under poor environments in terms of grain yield and contributing attributes (Table 5). The stability of various contributing traits varied in compensating manner in different hybrids imparted grain yield stability. The hybrids exhibited stable yield performance could be exploited for general cultivation. The parental lines of such hybrids may be used to develop new diverse strains with combination of stable characters. In nut shell, two hybrids KRH-2 and PRH-10 have shown higher mean values, desirable regression coefficient and deviation from the regression coefficient for yield and contributing traits, and were good in yield can be exploited for yield enhancement of rice under varying environments.

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Table 4. Mean performance and stability parameters for yield parameters of rice hybrids over environments

	Days to 50% flowering			Days to maturity			Plant height (cm)			Panicle length (cm)			Number of effective tillers / plant			Number of filled grains / panicle			Grain yield / m^2 (g)		
	μ	βi	σ^2di	μ	βi	σ^2di	μ	βi	σ^2di	μ	βi	σ^2di	μ	βi	σ^2di	μ	βi	σ^2di	μ	βi	σ^2di
PRH 10	83.44	0.89	-0.06	119.67	0.74	0.94	106.38	1.07	1.99	28.19	1.66	1.23	8.76	1.82	0.65*	155.22	0.85	-9.15	579.11	1.40	88.80
DRRH 2	86.11	0.88	4.20**	122.11	0.77*	-0.31	111.48	0.21*	-2.94	28.84	1.20	-0.36	10.76	0.38	0.18	115.55	1.12	-10.52	546.44	1.26	4733.62**
KRH 2	92.22	0.95	-0.16	128.22	1.12	-0.31	131.48	1.47	-3.00	29.23	0.96	1.17	9.74	1.09	0.01	161.88	1.15	-13.66	655.22	0.66	2.81
CORH 3	84.00	1.46	0.19	121.88	1.43	1.35*	114.78	0.71	34.23**	28.69	1.00	0.93	10.09	-0.61	0.03	145.00	1.34	-11.96	628.66	0.13	764.29**
Indira Sona	91.78	0.49	-0.10	128.11	1.19	-0.31	115.10	1.81	-0.35	29.65	0.80	0.37	9.43	1.16	-0.04	139.67	1.50	207.23**	528.11	0.70	9408.44**
PA 6129	82.67	1.39	-0.12	120.22	0.39	1.00*	106.09	1.22	-1.55	26.17	0.97	-0.37	9.01	0.69	-0.04	169.22	0.48	0.63	657.55	1.40	590.56**
PA 6201	92.11	1.08	-0.19	128.44	1.50	1.36*	121.35	0.54	3.19	27.91	0.63	-0.32	8.98	1.53	0.16	162.33	0.36	218.20**	641.88	0.77*	31.14
PA 6444	99.44	0.77	0.28	134.22	0.49*	-0.31	124.98	-0.05	19.83**	28.89	0.97	-0.27	8.51	2.06	-0.01	168.33	0.88	51.75*	659.78	0.52	286.09**
PSD 3	91.77	1.04	5.19**	128.33	1.36	0.04	113.90	2.04	-0.11	29.22	0.80	0.68	9.04	0.88	-0.01	134.44	1.31	-2.91	602.33	2.16	1345.17**
Pop.mean	**89.28**			125.69			116.17			28.53			9.37			150.18			611.01		
SE (mean)	0.79			0.60			2.10														
SE (bi)	0.23			0.20			0.40														

*Significant at P=0.05; **Significant at P=0.01

Table 5. Stability of rice hybrids over different environments for grain yield and yield attributes

Character	Hybrids		
	Average stability	Below average stability (suitable for favourable environment)	Above average stability (suitable for unfavourable environment)
Days to 50% flowering	-	CORH-3, PA 6129	PRH-10
Days to maturity	-	CORH-3	PRH-10, PA 6129
Plant height (cm)	-	PRH-10, Indira Sona, PA 6129, PSD-3	-
Panicle length (cm)	CORH-3	DRRH-2	KRH-2, Indira Sona, PA 6444, PSD-3
Number of effective tillers/ plant	-	KRH-2, Indira Sona	DRRH-2, CORH-3
Number of filled grains/ panicle	-	KRH-2	PRH-10, PA 6129
Grain yield /m^2 (g)	-	PRH-10	KRH-2

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