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Genotype and environment interaction and stability analysis for yield and its contributing traits in rice

DA Shinde*and PB Patel

N. M. College of Agriculture, Navsari Agricultural University, Navsari-396 450, Gujarat, India
**Email: dheerajshinde4@gmail.com*

ABSTRACT

Forty cross combinations obtained through crossing of four female lines with ten testers in line x tester mating fashion were evaluated to study stability and genotype x environment interactions for yield and yield contributing characters in rice over three different locations in Gujarat state of India during wet season 2011. The coincidence of genotypic performance with environmental values was observed for all the ten characters studied, evident from significant G x E (linear) mean square when tested against pooled deviation. This suggested that the performance of genotypes over environments could be predicted reasonably for these traits. In the present study, it is concluded that IR-28, NVSR-176 and NAUR-1 were stable over three locations for yield and its component traits. Most high yielding potential stable hybrids were NVSR-178 x NAUR-1, NVSR-178 x IET-21682, NVSR-176 x IR81025-B-116-1, NVSR-176 x IR80501-B-96-1-B and NVSR-176 x IET-21682 as they fulfiled the all the criteria of stability.

Key words: *rice, stability analysis, genotype, environment interaction*

In a country like India rice is an integral part of daily diet and source of income for millions of people. It is estimated that nearly 38 per cent more rice has to be produced as compared to the present situation by 2030 for feeding five billion rice consumers of the world (Khush, 2007). Development of high yielding varieties and hybrids will be the probable solution to attain food security in future (Cheng *et al.,* 2007; Pugi Lestari *et al.,* 2010). But before releasing any variety or hybrid, its stability for a wider area must be worked out as genotype x environment interaction is a limitation in most of the plant breeding programmes. Additional, knowledge regarding the nature and relative magnitude of the various types of G x E interaction is important in making decisions concerning breeding methods, selection programmes and testing procedures in crop plants. The present investigation therefore, was undertaken to assess the stability and understand the differential G x E interaction of fourteen parents and their forty hybrids for yield and yield attributing characters.

MATERIALS AND METHODS

The experimental materials comprising of four females *viz.*, IET-19347, IR-28, NVSR-176 and NVSR-178 and ten males *viz.*, IR81025-B-116-1, IR79915-B83-4-4, IR79971-B-204-1-4, IR81024-B-254-4, IR80501-B-96-1-B, IET-21682, IET-21683, NAUR-1, RP-4075-129-07-3 and RP-4075-135-35-5 were procured from National Agricultural Research Project, Navsari Agricultural University, Navsari (Gujarat).

The crossing programme among the fourteen parents was carried out in line x tester mating design as given by Kempthorne, (1957) during dry season 2010-2011 to obtain forty cross combinations. Three complete sets of 54 entries comprising of parents and hybrids were planted in randomized block design (Panse and Sukhatme, 1978) during wet season 2011. The trials were replicated thrice at three research stations *viz.*, Navsari, Vyara and Waghai. The parents and F_1s were represented by a single row plot of 10 plants, placed at 20 x 15 cm. All the standard agronomical practices and plant protection measures were followed as per recommendations to raise good experimental crop. Five random competitive plants excluding border ones were selected from each row in each replication to record observations on ten characters *viz*., days to 50 per cent flowering, productive tillers plant^{-1}, plant height, panicle length, grain yield panicle^{-1}, 1000- grain weight grain yield plant^{-1}, kernel length: breadth ratio, amylose content (Stoskopf, 1985) and protein content (Juliano, 1971 and Anon., 2003) were recorded in field and laboratory and mean values were subjected for statistical analysis. All the field observations were recorded according to minimal descriptor developed by Mahajan *et al*. (2000). The mean values for all the characters across the environments were subjected to stability analysis as suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The pooled analysis of variance for stability revealed that genotypes as well as environments were significant for all the characters when tested against genotype x environment (Table 1). The G x E interaction was highly significant for all the traits when tested against pooled error suggesting that genotypes reacted differently in different environments for all the traits. The environment (linear) component was also significant for all the characters when tested against pooled deviation. Coincidence of genotypic performance with environmental values for all the characters was observed to be significant G x E interaction (linear) when tested against pooled error. It indicated that cultivars performance may differ markedly for these characters. Similarly, the coincidence of genotypic performance with environmental values was observed for all the traits as evident from significant G x E (linear) mean square when tested against pooled deviation. This suggested that the performance of genotypes over environments could be predicted reasonably for these traits. The prediction of performance based on regression analysis might not be reliable as observed from the significant pooled deviation for all the characters except days to 50 per cent flowering and amylose content when tested against pooled error indicating their fluctuating performance over environments. Various authors reported that both linear and non linear components of

Table. 1 Analysis of variance (mean square) for phenotypic stability for different characters in rice.

Sources of variation	d.f.	Days to 50 per cent flowering	Productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Grains panicle^{-1}	Test weight (g)	Grain yield plant^{-1} (g)	L:B ratio	Amylose content (%)	Protein content(%)
Genotypes (G)	53	107.298**++	6.787**++	886.141**++	15.841**++	861.485**++	25.444**++	271.877**++	0.288**++	9.921**++	1.215**++
Environments (E)	2	2113.452**++	34.889**++	96.293**++	472.371**++	712.130**++	291.920**++	76.457**++	4.738**++	121.404**++	46.435**++
G x E	106	3.650**++	0.354**+	11.027**+	0.472**++	57.402**+	0.564**++	4.999**++	0.007**++	0.025*+	0.008**+
Environments (Linear)	1	4226.906**++	69.772**++	192.587**++	944.741**++	1424.261**++	583.840**++	152.913**++	9.476**++	242.809**++	92.860**++
G x E (Linear)	53	5.527**++	0.477**++	14.610**++	0.696**++	75.967**++	0.894**++	7.204**++	0.010**++	0.034**++	0.010**++
Pooled deviation	54	1.740	0.226**	7.306*	0.243**	38.117**	0.229**	2.741**	0.004*	0.02	0.005*
Pooled error	318	2.184	0.132	4.939	0.138	15.908	0.087	1.610	0.002	0.018	0.004

*, ** - indicates 5 % and 1 % probability levels of significance, respectively tested against pooled error.+, ++ - indicates 5 % and 1 % probability levels of significance, respectively tested against pooled deviation

G x E were significant for most of the traits studied Chaudhari *et al*. (2002), Panwar *et. al.*, (2008), Dushyanthakumar *et al.* (2010) and Subudhi *et al.* (2012).].

In the present study the mean performance coupled with regression coefficient (b_i) and variance of deviation from regression (S^2di) of each genotype denote its stability. Stability parameters worked out for 54 genotypes for ten characters revealed that none of the genotypes was stable for all the characters studied (Table 2-5). Any generalization regarding stability of genotypes for all the characters was not possible. Among 54 genotypes, two females (IR-28 and NVSR-176), one male (NAUR-1) and eighteen hybrids were found to be stable genotypes for grain yield plant^{-1} owing to high mean, regression coefficient (b_i) nearer to one and least deviation from regression (S^2di). Stability was observed in some of the genotypes studied in various studies by Mahapatra and Das (1999), Chaudhari *et al*. (2002), Deshpande *et al*. (2003), Dushyanthakumar *et al.* (2010), Belhekar (2012) and Subudhi *et al*. (2012).

Comparatively the best five stable hybrids *viz.*, NVSR-178 x NAUR-1, NVSR-178 x IET-21682, NVSR-176 x IR81025-B-116-1, NVSR-176 x IR80501-B-96-1-B and NVSR-176 x IET-21682 had and high stability for other yield attributing characters (Table 3) high grain yield plant^{-1} (Table 4). These

Table 2. Stability parameters of different genotypes for days to 50 per cent flowering, productive tillers per plant and plant height (cm)

Genotypes	Days to 50 % flowering			Productive tillers plant^{-1}			Plant height (cm)		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
IET-19347	97.00	0.84	-1.65	7.30	1.38	-0.06	119.60	5.56	-0.02
IR-28	83.85	1.34	-1.03	8.71	-0.01*	-0.13	86.66	0.36	-3.11
NVSR-176	86.70	1.27	-2.04	8.63	0.01*	-0.13	116.71	0.74	-4.35
NVSR-178	85.78	1.30	-1.78	9.09	0.99	-0.07	119.57	0.75	-4.94
IR81025-B-116-1	72.09	0.85	-2.00	5.17	0.91	-0.12	126.78	0.001*	-4.94
IR-79915-B83-4-4	76.10	-0.05	-0.40	6.95	1.30	0.10	124.89	1.31	3.86
IR79971-B-204-1-4	76.72	1.22	-2.13	5.28	1.74	-0.13	131.82	0.92	-4.88
IR81024-B-254-4	78.08	1.30*	-2.17	5.17	0.001*	-0.13	133.61	1.87	10.71
IR80501-B-96-1-B	77.99	1.14	-2.06	5.14	1.65	0.11	122.39	0.91	-3.77
IET-21682	79.37	0.91	0.50	9.01	0.004*	-0.13	115.67	-0.62	-4.74
IET-21683	78.52	0.92	9.42*	8.62	1.70	-0.06	123.67	-0.99	-4.46
NAUR-1	95.75	-0.05	-0.40	8.76	2.10	0.05	118.42	1.04	8.48
RP-4075-129-07-3	90.11	0.95	-0.59	7.10	1.25	-0.07	89.36	-2.52	3.15
RP-4075-135-35-5	90.58	1.05	7.98*	5.75	1.60	0.11	90.19	1.39	1.90
IET-19347 X IR81025-B-116-1	75.02	1.20	-1.73	7.98	1.01	0.26	122.65	1.45	-1.70
IET-19347 X IR-79915-B83-4-4	76.49	0.96	-1.29	8.16	0.70	-0.12	119.12	1.79	12.40
IET-19347 X IR79971-B-204-1-4	80.24	0.81	-2.14	6.82	0.79	0.20	124.94	0.19	-3.91
IET-19347 X IR81024-B-254-4	85.50	1.17	-1.96	6.99	1.08	0.08	118.89	1.41	-4.15
IET-19347 X IR80501-B-96-1-B	81.85	1.07	-1.94	7.06	-0.001*	-0.13	121.50	1.08	2.09
IET-19347 X IET-21682	79.45	1.17	0.23	9.25	1.33	-0.12	115.08	0.87	-4.88
IET-19347 X IET-21683	93.97	1.07	2.19	7.02	1.07	0.08	119.53	0.20	-0.15
IET-19347 X NAUR-1	92.33	0.93	-1.02	9.10	0.002*	-0.13	117.85	0.30	-2.78
IET-19347 X RP-4075-129-07-3	86.73	1.07	3.90	6.51	1.40	0.65*	87.65	0.77	0.92
IET-19347 X RP-4075-135-35-5	73.01	0.89*	-2.16	6.93	1.48	0.68*	90.80	-0.30*	-4.91
IR-28 X IR81025-B-116-1	76.74	0.99	-0.26	7.16	1.05	-0.13	101.77	2.33*	-4.93
IR-28 X IR-79915-B83-4-4	82.75	0.84	4.50	7.63	0.17	0.19	102.93	1.50	83.19**

Table 2....contd...

IR-28 X IR79971-B-204-1-4	75.97	0.70*	-2.15	7.58	0.97	1.18**	88.93	-0.43	-4.53
IR-28 X IR81024-B-254-4	77.61	0.83*	-2.16	8.90	1.09	0.01	85.77	0.02	-4.66
IR-28 X IR80501-B-96-1-B	85.22	1.18	-1.88	8.79	1.36	0.11	95.21	1.91	-4.07
IR-28 X IET-21682	73.40	1.18	-2.11	8.31	1.21	-0.08	82.35	0.16	-1.47
IR-28 X IET-21683	79.66	0.98	3.27	7.00	0.04	-0.11	84.23	1.11	-4.24
IR-28 X NAUR-1	83.13	1.03	-1.36	12.04	2.08	0.57*	80.29	0.89	-4.92
IR-28 X RP-4075-129-07-3	82.33	0.83	1.80	10.74	0.86	-0.13	77.00	0.98	-3.68
IR-28 X RP-4075-135-35-5	82.67	1.14	-2.01	7.33	1.03	0.30	77.41	0.21	-0.25
NVSR-176 X IR81025-B-116-1	76.63	1.19	-1.87	9.23	1.19	-0.06	121.31	1.51	-4.78
NVSR-176 X IR-79915-B83-4-4	76.69	1.03	-1.55	7.37	0.01*	-0.13	123.06	1.47	-3.52
NVSR-176 X IR79971-B-204-1-4	78.22	1.40*	-2.10	8.72	1.48	-0.10	122.56	-1.29	1.19
NVSR-176 X IR81024-B-254-4	73.22	1.03	-1.41	7.86	1.00	-0.04	116.13	-1.38	-4.17
NVSR-176 X IR80501-B-96-1-B	85.63	1.35	-1.37	9.06	0.54	0.63*	114.94	-0.78	6.67
NVSR-176 X IET-21682	72.95	0.82	-2.04	9.44	-0.01*	-0.13	113.93	1.95	1.08
NVSR-176 X IET-21683	82.53	0.94	-0.92	7.58	0.90	-0.12	122.52	1.28	-4.91
NVSR-176 X NAUR-1	86.00	1.13	-1.53	9.02	0.61	-0.03	125.83	-0.18	-1.38
NVSR-176 X RP-4075-129-07-3	86.32	1.08	1.58	6.91	1.39	0.34	89.06	0.87	-2.25
NVSR-176 X RP-4075-135-35-5	81.61	0.85	-2.03	8.81	1.25	-0.09	90.99	0.62	1.32
NVSR-178 X IR81025-B-116-1	83.73	0.84	1.10	8.01	1.31	-0.13	114.17	1.41	-3.86
NVSR-178 X IR-79915-B83-4-4	84.29	0.93	-0.12	9.04	1.86	-0.11	121.06	2.09	10.83
NVSR-178 X IR79971-B-204-1-4	78.67	1.27	-1.50	7.77	0.06*	-0.13	126.94	1.84	8.82
NVSR-178 X IR81024-B-254-4	82.46	0.90*	-2.16	9.09	0.94	0.09	119.95	-0.75*	-4.86
NVSR-178 X IR80501-B-96-1-B	89.84	0.88	0.75	8.20	1.39	0.18	131.74	12.81	94.15**
NVSR-178 X IET-21682	79.33	0.96	-1.88	11.38	0.84	1.06**	115.66	0.91	-2.30
NVSR-178 X IET-21683	78.98	1.18	2.34	8.08	1.35	-0.12	121.40	1.77	12.70
NVSR-178 X NAUR-1	73.74	1.08	0.05	11.60	2.25	1.11**	124.17	0.30	-4.88
NVSR-178 X RP-4075-129-07-3	84.74	1.08	-1.46	9.64	1.37	-0.07	76.72	0.94	-4.93
NVSR-178 X RP-4075-135-35-5	85.62	1.04	-0.52	8.98	0.94	0.30	91.84	1.47	-3.35
General mean	81.74	1.00		8.11	1.00		109.00	1.00	
S.E. ±	0.93	0.15		0.34	0.42		1.9	1.4	

*, ** - indicates 5 % and 1 % probability levels of significance

Table 3. Stability parameters of different genotypes for panicle length (cm), grains per panicles and test weight (g)

Genotypes	Panicle length (cm)			Grains per panicles			Test weight (g)		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
IET-19347	24.08	1.03	0.23	141.08	0.46	-15.54	19.03	1.05	0.04
IR-28	24.84	1.06	0.02	148.31	1.46	-14.85	21.81	0.70	0.05
NVSR-176	21.67	1.05	1.12**	124.63	-0.04	-15.15	30.21	0.94	0.09
NVSR-178	24.27	0.85	-0.04	139.01	-0.10	-13.64	29.31	1.34	0.18
IR81025-B-116-1	24.68	0.99	-0.14	115.98	-0.41	-8.18	29.59	0.33*	-0.06
IR-79915-B83-4-4	25.20	0.75	4.08**	117.58	3.78	2.98	26.54	1.25	-0.03
IR79971-B-204-1-4	24.03	0.96	-0.13	129.75	2.67	-6.60	27.72	1.10	0.02
IR81024-B-254-4	27.06	1.03	0.38	131.02	-0.07	-13.95	24.52	1.12	-0.04
IR80501-B-96-1-B	26.68	0.00*	-0.14	126.03	0.002*	-15.91	24.70	-0.04*	-0.08
IET-21682	26.30	0.95	-0.13	134.64	3.01	-11.39	23.54	0.76	0.08

Table 3....contd...

IET-21683	26.92	0.19*	-0.14	120.06	-1.65	-14.59	23.57	0.80	0.08
NAUR-1	27.56	0.79	0.15	140.17	-0.02	-3.13	24.94	1.17	-0.05
RP-4075-129-07-3	17.19	0.89	-0.13	123.02	-1.52	-10.21	26.00	0.73	0.81**
RP-4075-135-35-5	20.31	1.13	0.54**	133.21	2.55	-10.43	25.77	0.66	0.06
IET-19347 X IR81025-B-116-1	24.69	1.11	-0.13	145.30	3.71	33.81	27.95	0.94	-0.07
IET-19347 X IR-79915-B83-4-4	26.31	1.05	-0.03	170.87	-2.07	2.09	26.89	0.98	0.03
IET-19347 X IR79971-B-204-1-4	23.90	1.10	0.10	130.25	2.87	-15.06	26.83	1.04	0.03
IET-19347 X IR81024-B-254-4	25.94	1.04	-0.05	131.89	2.98	164.16*	23.93	1.01	-0.07
IET-19347 X IR80501-B-96-1-B	25.24	0.98	-0.10	122.89	-1.88	-0.76	23.34	1.02	-0.05
IET-19347 X IET-21682	26.31	1.14	-0.12	144.85	-0.48	42.02	26.42	1.10	-0.05
IET-19347 X IET-21683	26.02	1.00	-0.14	125.22	3.27	42.86	21.54	0.97	-0.04
IET-19347 X NAUR-1	27.89	1.04	-0.13	154.14	2.56	71.56*	26.66	1.11	-0.03
IET-19347 X RP-4075-129-07-3	22.77	1.06	-0.11	122.22	2.83	-7.39	25.57	1.17*	-0.08
IET-19347 X RP-4075-135-35-5	23.14	1.06	-0.10	140.14	1.20	76.99*	25.16	1.00	0.05
IR-28 X IR81025-B-116-1	24.27	1.13	-0.12	128.29	1.48	89.17*	24.08	1.28	-0.07
IR-28 X IR-79915-B83-4-4	24.58	1.07	-0.12	133.31	1.85	-15.37	25.80	0.99	-0.07
IR-28 X IR79971-B-204-1-4	23.45	1.07	-0.06	128.08	1.05	-13.58	23.56	1.10	-0.08
IR-28 X IR81024-B-254-4	27.03	1.08	-0.13	149.41	-0.16	0.63	22.14	1.12	-0.08
IR-28 X IR80501-B-96-1-B	25.47	1.02	-0.12	144.33	0.30	63.22*	24.29	1.03	-0.08
IR-28 X IET-21682	24.87	1.09*	-0.14	130.79	0.53	-12.38	21.72	1.10	0.21
IR-28 X IET-21683	24.57	1.21	-0.05	136.91	0.52	8.99	20.23	1.07	-0.03
IR-28 X NAUR-1	29.29	1.11	-0.13	181.19	1.88	9.88	28.21	1.02	0.06
IR-28 X RP-4075-129-07-3	26.37	1.11	-0.11	178.58	3.41	-12.48	26.79	1.13	-0.07
IR-28 X RP-4075-135-35-5	23.02	0.96	0.29	141.43	1.08	68.05*	24.99	1.09	2.48**
NVSR-176 X IR81025-B-116-1	25.60	1.13	-0.11	145.05	-3.60	56.12*	30.48	0.99	-0.06
NVSR-176 X IR-79915-B83-4-4	23.22	1.01	-0.12	108.89	-0.69	-11.49	27.07	1.03	-0.06
NVSR-176 X IR79971-B-204-1-4	24.01	1.09	0.25	124.53	1.68	15.54	27.97	1.11	-0.07
NVSR-176 X IR81024-B-254-4	26.80	0.99	1.22**	121.78	1.68	-12.21	24.60	1.11	-0.05
NVSR-176 X IR80501-B-96-1-B	27.12	1.01	-0.14	142.58	3.02	17.61	30.34	1.14	0.03
NVSR-176 X IET-21682	26.62	1.10	-0.12	149.09	0.20	-14.94	28.58	0.97	0.02
NVSR-176 X IET-21683	24.84	0.96	0.04	124.40	3.04	62.55*	24.99	1.01	-0.03
NVSR-176 X NAUR-1	27.88	1.12	-0.11	142.54	0.84	213.81*	29.88	1.03	-0.05
NVSR-176 X RP-4075-129-07-3	19.82	0.95	-0.08	115.63	2.87	-13.43	28.81	1.05	-0.03
NVSR-176 X RP-4075-135-35-5	21.48	1.03	-0.07	133.55	0.28	116.10*	30.23	1.27	-0.06
NVSR-178 X IR81025-B-116-1	24.24	1.17	0.08	126.89	1.43	31.79	26.94	0.97	-0.08
NVSR-178 X IR-79915-B83-4-4	25.32	1.09	0.01	139.35	0.40	81.83*	28.46	1.05	-0.01
NVSR-178 X IR79971-B-204-1-4	23.07	1.06	0.00	126.56	0.35	-13.66	24.55	1.17	-0.06
NVSR-178 X IR81024-B-254-4	26.65	0.95	1.07**	139.02	-0.09	28.05	28.68	0.72	0.03
NVSR-178 X IR80501-B-96-1-B	25.31	1.06	-0.09	126.67	0.42	8.20	22.48	1.08	-0.07
NVSR-178 X IET-21682	28.66	1.02	-0.12	177.04	1.10	67.79*	31.08	1.08	0.063
NVSR-178 X IET-21683	26.98	1.06	-0.09	139.57	-0.41*	-15.79	29.33	0.99	-0.08
NVSR-178 X NAUR-1	29.61	0.95	0.06	185.15	0.43	-9.35	30.62	1.01	0.05
NVSR-178 X RP-4075-129-07-3	25.29	1.04	-0.14	164.21	-0.65	-3.83	29.61	1.08	-0.06
NVSR-178 X RP-4075-135-35-5	24.16	1.10	-0.12	139.60	4.65	148.77*	28.59	0.98	-0.07
General mean	25.05	1.00		137.70	1.0		26.37	1.00	
S.E. ±	0.35	0.12		4.4	1.2		0.32	0.13	

*, ** - indicates 5 % and 1 % probability levels of significance

Table 4. Stability parameters of different genotypes for grain yield per plant (g), L:B ratio and amylose content (%)

Genotypes	Grain yield (g)			L:B ratio			Amylose content (%)		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
IET-19347	27.33	0.51	-0.35	3.07	0.96	-0.002	25.26	0.89	0.03
IR-28	34.35	0.55	4.86	3.92	1.05	-0.002	23.87	0.96	0.01
NVSR-176	33.35	2.64	4.21	3.24	1.06	-0.001	15.73	0.98	0.00
NVSR-178	41.05	0.07	8.42*	2.69	0.84*	-0.002	20.17	1.10	0.04
IR81025-B-116-1	18.97	0.32	0.10	3.12	1.00	-0.001	23.24	0.80*	-0.02
IR-79915-B83-4-4	22.53	1.05	-1.53	3.21	1.14*	-0.002	24.15	0.87	-0.02
IR79971-B-204-1-4	17.26	2.08	0.60	2.89	1.09	0.000	24.57	0.88	-0.01
IR81024-B-254-4	14.72	1.28	0.40	3.32	1.13*	-0.002	23.44	0.97	0.03
IR80501-B-96-1-B	15.06	-0.03*	-1.61	3.41	0.03*	-0.002	23.10	1.06	0.01
IET-21682	30.59	-0.18	1.25	2.94	1.07	-0.001	21.30	0.95	-0.02
IET-21683	24.61	3.41	0.00	3.45	1.07	0.000	22.92	0.97	-0.01
NAUR-1	32.90	0.80	-1.13	3.28	1.09	-0.001	23.28	1.30	0.03
RP-4075-129-07-3	23.05	2.31	3.30	3.37	0.92	-0.002	23.19	1.01	0.00
RP-4075-135-35-5	19.56	-0.32	0.10	3.37	0.02*	-0.002	23.33	1.00	0.00
IET-19347 X IR81025-B-116-1	28.93	0.02*	-1.61	3.07	1.16	0.012*	25.25	1.09	0.03
IET-19347 X IR-79915-B83-4-4	36.76	3.33	-0.04	3.22	1.01	0.001	25.46	0.98	0.00
IET-19347 X IR79971-B-204-1-4	25.70	1.67*	-1.61	3.33	0.98	-0.002	24.37	1.02	0.01
IET-19347 X IR81024-B-254-4	22.46	0.15	-1.25	3.42	1.13	-0.002	23.41	0.96	0.02
IET-19347 X IR80501-B-96-1-B	21.92	-0.01*	-1.61	3.59	1.04	-0.002	24.87	0.98	-0.01
IET-19347 X IET-21682	31.56	-0.60	-1.02	3.08	1.18*	-0.002	25.53	0.89	-0.01
IET-19347 X IET-21683	26.55	0.06	-0.83	3.57	1.01	0.000	24.56	0.94	0.01
IET-19347 X NAUR-1	36.70	-0.75	0.11	3.46	1.12	0.013*	25.55	0.98	0.00
IET-19347 X RP-4075-129-07-3	22.18	-0.01*	-1.61	3.49	1.01	-0.002	23.35	1.07	-0.01
IET-19347 X RP-4075-135-35-5	25.19	0.06	-1.55	3.56	1.24	0.000	24.45	1.04	-0.01
IR-28 X IR81025-B-116-1	32.71	0.75	-1.61	3.55	1.09	-0.002	22.48	1.02	-0.01
IR-28 X IR-79915-B83-4-4	25.38	1.76	6.12	3.84	1.16	-0.002	23.68	1.04	0.00
IR-28 X IR79971-B-204-1-4	17.64	1.45	-1.28	3.71	0.96	-0.001	22.80	1.02	-0.02
IR-28 X IR81024-B-254-4	35.23	4.09*	-1.55	3.83	1.11	0.003	24.26	1.01	-0.02
IR-28 X IR80501-B-96-1-B	32.37	2.51*	-1.61	3.89	1.14	-0.002	23.54	1.03	-0.01
IR-28 X IET-21682	24.56	-0.58	1.92	3.61	0.87	0.001	22.35	1.05*	-0.02
IR-28 X IET-21683	24.19	2.25	-0.52	3.51	1.08*	-0.002	23.31	1.00	-0.02
IR-28 X NAUR-1	47.92	1.37	7.58*	3.91	0.88	-0.002	25.90	0.99	-0.02
IR-28 X RP-4075-129-07-3	47.00	0.65	18.52**	3.94	0.92*	-0.002	25.14	0.97	-0.02
IR-28 X RP-4075-135-35-5	33.23	2.81	1.91	3.79	1.15	-0.002	21.72	0.92	-0.01
NVSR-176 X IR81025-B-116-1	43.06	3.28	3.49	3.29	0.72	-0.002	23.87	0.95	-0.02
NVSR-176 X IR-79915-B83-4-4	26.88	1.12	-1.54	3.40	1.06	0.000	23.68	0.95	0.01
NVSR-176 X IR79971-B-204-1-4	33.72	2.88	-1.52	3.10	1.30	-0.001	24.59	0.96	-0.01
NVSR-176 X IR81024-B-254-4	33.55	-0.03*	-1.61	3.54	0.97	-0.002	19.07	1.12	-0.02
NVSR-176 X IR80501-B-96-1-B	36.03	1.13	-0.55	3.48	1.00	0.007	23.62	0.97	-0.01
NVSR-176 X IET-21682	36.62	1.42	0.99	3.17	1.24	-0.002	22.35	1.04	-0.02
NVSR-176 X IET-21683	27.55	3.79	-1.13	3.36	1.19	0.001	19.56	1.02	-0.02

Table 4....contd...

NVSR-176 X NAUR-1	36.43	1.81	3.34	3.30	1.00	0.003	23.80	0.98	-0.01
NVSR-176 X RP-4075-129-07-3	25.12	0.45	0.74	3.45	1.05	-0.001	22.11	1.00	-0.02
NVSR-176 X RP-4075-135-35-5	33.81	1.72	2.26	3.41	1.22	0.003	23.35	0.96	-0.01
NVSR-178 X IR81025-B-116-1	36.43	2.16	5.56*	3.30	0.77	0.002	21.44	1.08	-0.02
NVSR-178 X IR-79915-B83-4-4	34.26	-1.46	0.37	2.89	1.40	-0.001	24.06	0.96	-0.02
NVSR-178 X IR79971-B-204-1-4	30.01	2.78*	-1.59	2.53	1.05	0.004	20.69	1.05	-0.01
NVSR-178 X IR81024-B-254-4	35.11	0.24	-1.04	3.34	0.96	-0.002	23.42	1.02	0.04
NVSR-178 X IR80501-B-96-1-B	33.45	-1.90	2.82	3.64	1.16*	-0.002	22.76	1.00	0.00
NVSR-178 X IET-21682	59.18	0.80	-1.31	2.99	0.84	0.043**	23.00	0.98	-0.02
NVSR-178 X IET-21683	32.84	-0.29	-1.16	3.34	1.03	0.002	22.95	0.98	-0.02
NVSR-178 X NAUR-1	61.53	1.25	1.25	3.32	0.84	0.030**	26.02	1.31	0.05
NVSR-178 X RP-4075-129-07-3	42.67	-4.10	11.46**	2.85	0.57	-0.002	24.52	0.85	-0.01
NVSR-178 X RP-4075-135-35-5	34.34	-1.02	1.65	3.36	0.91	0.006	23.35	1.07	0.00
General mean	31.22	1.00		3.37	1.00		23.29	1.00	
S.E. ±	1..17	0.98		0.04	0.144		0.085	0.06	

*, ** - indicates 5 % and 1 % probability levels of significance

Table 5. Stability parameters of different genotypes for protein content (%)

Genotypes	Protein content (%)		
	Mean	b_i	S^2di
IET-19347	5.83	0.99	-0.003
IR-28	7.82	1.08	-0.001
NVSR-176	6.68	0.99	-0.003
NVSR-178	6.49	0.98	-0.003
IR81025-B-116-1	6.78	0.99	0.003
IR-79915-B83-4-4	5.29	1.05	-0.003
IR79971-B-204-1-4	5.82	1.03	0.006
IR81024-B-254-4	6.96	0.96	0.008
IR80501-B-96-1-B	6.90	1.00	0.001
IET-21682	7.54	1.01	0.002
IET-21683	6.27	1.08*	-0.004
NAUR-1	6.37	1.04	-0.002
RP-4075-129-07-3	6.00	1.11*	-0.004
RP-4075-135-35-5	6.81	1.00	-0.002
IET-19347 X IR81025-B-116-1	5.99	0.94	0.004
IET-19347 X IR-79915-B83-4-4	5.50	1.03	-0.003
IET-19347 X IR79971-B-204-1-4	5.63	1.16	0.000
IET-19347 X IR81024-B-254-4	7.76	0.99	-0.003
IET-19347 X IR80501-B-96-1-B	6.04	1.08	0.000
IET-19347 X IET-21682	6.85	1.06	-0.003
IET-19347 X IET-21683	5.82	0.95	-0.002
IET-19347 X NAUR-1	6.10	0.95	-0.003
IET-19347 X RP-4075-129-07-3	6.30	1.08	0.008
IET-19347 X RP-4075-135-35-5	6.41	1.07	0.008
IR-28 X IR81025-B-116-1	8.51	1.01	0.000
IR-28 X IR-79915-B83-4-4	6.99	1.02	-0.003
IR-28 X IR79971-B-204-1-4	7.42	0.99	0.011*
IR-28 X IR81024-B-254-4	7.15	0.97	-0.004
IR-28 X IR80501-B-96-1-B	6.80	1.05	0.000
IR-28 X IET-21682	7.75	1.06	-0.003
IR-28 X IET-21683	6.84	1.00	0.015*
IR-28 X NAUR-1	6.56	0.89	-0.001
IR-28 X RP-4075-129-07-3	6.56	0.94	0.001
IR-28 X RP-4075-135-35-5	7.43	1.05	0.003
NVSR-176 X IR81025-B-116-1	6.49	1.06	0.013*
NVSR-176 X IR-79915-B83-4-4	6.93	1.00	-0.002
NVSR-176 X IR79971-B-204-1-4	6.35	0.61	0.023**
NVSR-176 X IR81024-B-254-4	7.12	1.07	0.007
NVSR-176 X IR80501-B-96-1-B	6.49	0.93	-0.003
NVSR-176 X IET-21682	7.59	0.97	-0.002
NVSR-176 X IET-21683	7.17	0.96	0.008
NVSR-176 X NAUR-1	6.58	1.05	-0.002
NVSR-176 X RP-4075-129-07-3	6.17	0.90	0.000
NVSR-176 X RP-4075-135-35-5	6.89	1.08	0.005
NVSR-178 X IR81025-B-116-1	6.59	1.00	0.000
NVSR-178 X IR-79915-B83-4-4	6.50	0.90	-0.003
NVSR-178 X IR79971-B-204-1-4	5.99	1.06	0.020*
NVSR-178 X IR81024-B-254-4	6.80	0.99	0.006
NVSR-178 X IR80501-B-96-1-B	6.66	0.91	-0.001
NVSR-178 X IET-21682	7.08	1.00	0.004
NVSR-178 X IET-21683	6.53	0.99	0.001
NVSR-178 X NAUR-1	6.56	0.95	0.003
NVSR-178 X RP-4075-129-07-3	5.83	0.96	-0.003
NVSR-178 X RP-4075-135-35-5	6.92	1.01	-0.003
General mean	6.65	1.00	
S.E. ±	0.051	0.05	

*, ** - indicates 5 % and 1 % probability levels of significance

hybrids were found to be stable for some of the common traits *viz.*, panicle length, productive tillers plant^{-1}, panicle length, number of grains panicle^{-1}, test weight and grain yield plant^{-1}. It is clear that stability of these hybrids might have resulted due to stability for various component traits. Similar trend was found in most of the reaming hybrids when they were evaluated for stability in respect of grain yield and its related characters. This indicated that the stability of various component traits might be responsible for the observed stability of different hybrids for grain yield. The chances for selection of stable hybrids could be strengthen by selection in favour of stability in individual yield component. Similar results were also reported by Sreedhar *et al.* (2011) and Belhekar (2012). Further, it was also observed that four hybrids had higher than average yield but due to significant deviation mean squares (S^2di), categorized as an unstable or unpredictable over environments for grain yield plant^{-1}.

Study of stability parameters for component traits revealed that 21 genotypes were found stable for days to 50 per cent flowering. Similarly, 16 genotypes for productive tillers plant^{-1}, 9 genotypes for plant height and 24 genotypes for panicle length were found to be stable. Seven genotypes had non-significant regression coefficient and deviation mean square with high mean for number of grains panicle^{-1} indicating their stability across the environments. Similarly, 20 genotypes for test weight, 21 genotypes for grain yield plant^{-1} and 21 genotypes for L:B ratio was found to be stable. On the other hand, 33 and 24 genotypes had high mean, non-significant regression coefficient and deviations from regression for protein content and amylose content, respectively.

The stability of genotypes also revealed that none of the parents and hybrids was found to be ideal for better as well as poor environmental condition for all the characters. Two genotypes (IR81024-B-254- 4-1 and NVSR-176 x IR79971-B-204-1-4) and three genotypes (IET-19347 x RP-4075-135-35-5, IR-28 x IR79971-B-204-1-4 and IR-28 x IR81024-B-254-4) adapted each in favorable (better condition) and unfavorable (poor condition) environments for days to 50 per cent flowering. For number of productive tillers plant^{-1}, five genotypes (IR-28, NVSR-176, IET-21682, NVSR-176 x IET-21682 and IET-19347 x NAUR-1) were specifically adapted to poor environmental conditions, whereas for plant height one genotype (IR-28 x IR81025-B-116-1) for favorable and three genotypes (IR-28, RP-4075-129-07-3 and IET-19347 x RP-4075-135-35-5) for unfavorable environment were found to be adaptable. Two genotypes (IET-21683 and IR80501-B-96-1-B) were found to be adaptable for unfavorable environments for panicle length. While, for both number of grains panicle^{-1} and test weight one genotype (NVSR-178 x IET-21683 and IR81025-B-116-1, respectively) was found to be adaptable for unfavorable (poor condition) environments. For grain yield plant^{-1}, two genotypes (IR-28 X IR81024-B-254-4 and IR-28 X IR80501-B-96-1-B) were found to be specifically adapted to good environment while one genotype (NVSR-176 x IR81024-B-254-4) for poor environmental condition. With regards to L:B ratio, it was observed that two genotypes (NVSR-178 x IR80501-B-96-1-B and IR-28 x IET-21683) and three genotypes (RP-4075-135-35-5, IR80501-B-96-1-B and IR-28 X RP-4075-129-07-3) genotypes were found to be highly responsive under both favorable and unfavorable environments, respectively (Table 4).

The present study indicates that the mean yield of each genotype depends on the particular set of environmental conditions. It is, therefore, suggested that in order to identify stable genotypes, actual testing over a wide range of environments including poor and good ones would be advantageous. In selection programme of individual genotypes attention should be paid to the phenotypic stability of characters directly related to grain yield, particularly productive tillers plant^{-1}, panicle length, number of grains panicle^{-1}, and test weight so as to achieve maximum stability for the final character *i.e.*, grain yield in rice. Furthermore, superior performing parents such as IR-28, NVSR-176 and NAUR-1 stable over three locations for yield and its component traits can be used for developing stable hybrids. Even though many hybrids were identified as stable among hybrids, most high yielding potential stable hybrids were NVSR-178 x NAUR-1, NVSR-178 x IET-21682, NVSR-176 x IR81025-B-116-1, NVSR-176 x IR80501-B-96-1-B and NVSR-176 x IET-21682 as they fulfil all the criterion of stability. Those genotypes, which showed specific adaptability to favourable and unfourable environments, can also be utilized as good source of genetic material in crop improvement programmes related to specific area.

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