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Studies on Parental Variability and Heterosis in Rice

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Abstract: Genetic variability was studied for eight quantitative traits in fourteen parental lines of hybrid rice. The characters were plant height, flag leaf initiation day, first panicle initiation day, days to 100% flowering, days to maturity, grain yield/10 hills, spikelet fertility/10 panicles and no. of effective tillers/hill. Two additional characters (flag leaf length and spikelet length) were included in heterosis study. In general high component of variation and coefficient of variability were observed for most of the characters. The highest component of variation, coefficient of variability and heritability were noticed in grain yield/10 hills. Characters those with high genetic variability and genetic advance were considered to be important for selecting the desirable lines. Heterosis was studied in ten F_1 lines for 10 characters. In general, the hybrids performed significantly better than the respective parents. Mid parent, standard variety and better parent heterosis were observed for all the characters under study. In comparison of F_1 hybrids with their respective mid parent, standard variety and better parent showed significant heterosis for most of the studied characters. Among the 10 hybrids three lines viz., IR62829 A x IR62036-222-3-3-1-2R, IR58025AxIR61614-38-19-3-2R and IR68888AxIR56381-139-2-2R exhibited the highest heterosis in grain yield/10 hills. In conclusion, there was an ample scope for developing suitable hybrid rice from the studied parental lines as the hybrids exhibited vigour and earliness.

Key words: Parental variability, genetic parameters, hybrid vigour, heterosis, rice

Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in developing world and is the staple food of over half of the world's population. It is normally a self-pollinated crop. However, strong heterosis is observed in it. Heterosis or hybrid vigour is manifested as an improved performance for F_1 hybrid generated by crossing two inbred parents. Heterosis can be quantitatively defined as an upward deviation of the mid parent, based on the average of the values of two parents (Johnson and Hutchinson, 1993). Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives. In general, positive heterosis is desired for yield and negative heterosis for earliness. Heterosis is expressed in three ways, depending on the reference, which is used to compare the performance of a hybrid. The three ways are: mid parent, standard variety and better parent heterosis. From the practical point of view, standard heterosis is the most important because it is desired to develop hybrids, which are better than the existing high yielding varieties grown commercially by farmers. Application of heterosis in agricultural production is a multi-billion dollar enterprise. It represents the single greatest applied achievement of the discipline of genetics. Ironically, however, the physiological and genetic basis of heterosis are not entirely understood (Griffing, 1990). Heterosis was the foundation of the great success of hybrid rice in China, from 1976, during which hybrid seeds were first released to rice farmers, to 1991 during which the planted acreage of hybrid rice accounted for 55% of total planted area of paddy rice in china, the cumulative increased grain yield from planting hybrid rice amounted to more than 200 million tons. It has been demonstrated empirically that hybrid rice varieties have 15-20% yield advantage over the best conventional inbred varieties using similar cultivation conditions. Currently, the high yielding hybrids in rice involve crosses between the two cultivated subspecies of rice *indica* and *japonica* (Xiao *et al*., 1995).

In order to achieve improvement of crops, there must exist variability in the materials, so that selection can be made effective. Yield is a character, which is governed by several factors and is thus very complex. This study was therefore under taken with the objective of studying the variability among parental lines of hybrids, identifying the characters for selecting better hybrids, heterosis, vigour and earliness in rice.

Materials and Methods

Rice germplasms needed for the development of hybrid rice have been collected from IRRI (International Rice Research Institute), Philippines. BRRI dhan 28 was used as a standard check. Fourteen parents and their ten hybrids were used. The experiment was conducted following randomized complete block design consisting of three replications during August to December 2000 and January to May 2001. Each plot was 1x3 m^2 having 12 rows. The row to row distance was 25 cm, plot to plot was 45 cm and replication to replication was 50 cm. There was a 50 cm wide footpath around the field.

Observations were recorded for different characters, such as plant height, flag leaf length, spikelets length, flag leaf initiation day, first panicle initiation day, days to 100% flowering, days to maturity, grain yield/10 hills, spikelet fertility/10 panicles and no. of effective tillers/hills. The genotypic (G), phenotypic (P) and environmental (E) coefficients of variations (CV) were calculated according to Burton and Devane (1953). Broad sense heritability estimates and genetic gain were calculated by Hanson *et al*. (1956) and Johnson *et al*. (1955), respectively. The heterosis was calculated in terms of difference of F_1 from mid parent (MP), standard variety (ST), better parents (BP) and was expressed as percentage increase or decrease over to MP, ST and BP. The level of heterosis was tested using students 't' test.

Measurement of heterosis is quite simple. It is generally expressed as percent increase or decrease in the performance of a hybrid in comparison with the reference variety or a parent (Virmani *et al*., 1997).

$$\text{Mid parent heterosis (\%)} = \frac{F_1\text{-Mid parent}}{\text{Mid parent}} \times 100$$

$$\text{Better parent heterosis (\%)} = \frac{F_1\text{-Better parent}}{\text{Better parent}} \times 100$$

$$\text{Standard heterosis (\%)} = \frac{F_1\text{-Check variety}}{\text{Check variety}} \times 100$$

Statistical analysis were performed with the help of Microsoft Excel software.

Results and Discussion

Two major hypotheses have been proposed to explain the genetic basis of heterosis: dominance hypothesis (Davenport, 1908) and over dominance hypothesis (East, 1936). Dominance hypothesis

Table 1: Components of variation, coefficient of variability, broad sense heritability (Hb), genetic advance (GA) and expected genetic advance in percentage of mean for eight characters in rice

		Components of variation			Coefficient of variability			Genetic parameters		
Characters	Parental lines	P	G	E	PCV	GCV	ECV	Hb	GA	GA%
PH	A	31.27	29.27	2.03	41.64	38.98	2.66	93.59	10.87	14.35
	R	54.02	52.65	1.46	53.57	52.11	1.45	97.28	14.73	14.60
FLID	A	6.34	4.21	2.23	8.26	5.35	2.90	64.81	3.36	4.38
	R	27.73	19.59	8.13	32.72	23.12	9.60	70.65	7.66	9.04
FPID	A	3.13	2.64	0.49	3.54	2.98	0.56	84.21	3.07	3.47
	R	14.30	1.6	3.69	16.03	11.49	4.13	74.16	5.77	6.47
D100%F	A	9.06	5.63	3.43	9.17	5.70	3.46	62.20	3.85	3.90
	R	3.92	2.26	1.66	3.85	2.22	1.63	57.72	2.35	2.39
DM	A	18.00	17.04	0.95	15.53	14.70	0.82	94.67	8.27	7.14
	R	22.05	16.35	5.69	18.06	13.40	4.66	74.17	7.17	5.87
GY/10H	A	4107.85	4097.24	10.61	3958.31	3948.09	10.22	99.74	131.69	126.89
	R	9801.44	9722.86	78.58	2066.45	2049.89	16.56	99.19	202.30	42.65
SPF	A	230.52	60.99	169.23	174.21	46.09	28.12	26.45	8.27	6.25
	R	293.33	246.22	47.77	195.95	164.11	31.84	83.75	29.58	19.71
NET	A	18.74	17.03	1.74	179.87	163.14	16.73	90.69	8.08	77.61
	R	19.36	18.90	2.80	70.77	18.06	52.71	25.52	1.77	11.04

A = Cytoplasmic male sterile (CMS) line R = Restorer line
PH = Plant height (cm), FLID = Flag leaf initiation day, FPID = First panicle initiation day, D.100% F = Days to 100% flowering, DM = Days to maturity, GY/10H = Grain yield /10 hills (g), SPF = Spikelet fertility/10 panicles, NET = No. Of effective tillers/hills.
P = Phenotypic, G = Genotypic, E = Environmental, Hb = Heritability, GA = Genetic advance, GA% = Genetic advance as percentage,
PCV = Phenotypic coefficient of variability, GCV = Genotypic coefficient of variability, ECV = Environmental coefficient of variability.

Table 2: Mid parent heterosis (MPH), standard heterosis (STH) and better parent heterosis (BPH) is expressed in percent for ten characters in rice

Characters	Heterosis	1	2	3	4	5	6	7	8	9	10
PH	MPH	2.81*	1.03	2.23	-8.32**	6.45**	-5.28**	-3.65*	-8.04**	5.00**	-2.45*
	STH	-18.74**	-15.52**	-17.74**	-4.95**	10.00**	-4.26**	17.00**	-2.82*	16.66**	2.74*
	BPH	-2.47*	-9.60**	-1.40	-8.91**	2.06	-6.53**	-6.01**	-12.33**	5.00**	-3.36*
FLL	MPH	14.10**	5.55**	-3.33*	-5.92**	16.92**	-13.03**	-0.33	-6.83**	32.14**	-0.66
	STH	9.76**	-1.90	0.66	-0.20	9.76**	-4.33**	3.00*	-6.13**	23.33**	5.90**
	BPH	11.02**	2.55*	3.8**	-3.33*	8.09**	-12.86**	-2.83*	-21.54**	19.25**	-4.63**
SPL	MPH	8.69**	0.76	12.38**	6.69**	13.04**	-1.85	1.54	-1.83	17.39**	1.31
	STH	8.22**	2.72*	6.06**	6.25**	12.55**	5.16**	9.19**	1.99	16.88**	-0.46
	BPH	6.38**	0.42	6.98**	3.65*	10.63**	-2.35	0.93	-4.37**	10.20**	-0.57
FLID	MPH	-3.63*	-9.46**	4.28**	0.45	-4.76**	3.59*	5.58**	-1.61	-5.63**	0.93
	STH	5.60**	-9.25**	3.79**	4.36**	-3.27*	2.36	5.09**	-1.38	-4.69**	1.89
	BPH	-4.16**	-8.41**	6.31**	1.85	-4.22**	6.40**	8.09**	-0.93	-4.28**	1.41
FPID	MPH	-3.80**	-2.01	-1.16	-1.47	-5.26**	-0.22	-1.55	1.76	-4.15**	-0.89
	STH	-3.58**	-6.00**	-8.58**	0.42	-11.15**	-5.57**	-0.44	3.58*	-6.00**	-5.15**
	BPH	-4.86**	-2.23	1.91	-1.26	-3.72*	1.38	-0.40	2.21	-3.52*	-0.45
D100%F	MPH	-6.54**	-5.24**	3.25*	-1.10	-8.33**	-3.32*	2.30	-3.42*	-8.25**	-2.24
	STH	-3.84**	-2.69*	-2.53*	-3.24*	-5.71**	-10.83**	2.31	-2.30	-4.49**	-5.77**
	BPH	-4.76**	-5.24**	3.84**	2.29	-6.60**	-1.98	2.70*	-3.05*	7.40**	0.38
DM	MPH	-11.52**	-2.83*	2.66*	3.04*	-11.27**	-9.11**	-1.57	3.70*	-10.66**	7.40**
	STH	-7.08**	-4.58**	2.58*	1.68	-10.26**	-6.26**	1.57	1.81	-6.83**	4.46**
	BPH	-13.93**	-3.66*	3.20*	2.42	-11.51**	-9.61**	-2.80*	3.39*	-14.39**	3.50*
Y10/C	MPH	96.66**	-42.36**	-1.70	-10.10**	69.04**	-36.50**	-1.00	0.59	93.54**	3.35*
	STH	18.00**	-80.32**	-21.33**	-11.00**	18.33**	-52.38**	-0.80	12.00**	20.00**	-20.00**
	BPH	68.57**	-39.17**	-86.41**	41.26**	59.91**	70.26**	-1.80	13.09**	71.42**	2.56*
SPF	MPH	31.35**	0.96	34.43**	24.68**	53.33**	17.56**	21.27**	8.20**	62.73**	16.38**
	STH	22.03**	-9.65**	35.59**	26.08**	65.46**	23.57**	50.35**	3.52*	69.01**	23.69**
	BPH	25.19**	-0.05	33.36**	24.24**	28.00**	14.36**	12.39**	3.13*	46.87**	13.30**
NET	MPH	50.31**	10.02**	2.31	7.91**	28.00**	19.95**	11.34**	8.55**	32.14**	1.53
	STH	30.78**	12.66**	-3.49*	7.20**	18.33**	7.64**	6.11**	1.09	23.33**	1.90
	BPH	27.17**	0.38	-6.35**	5.13**	16.39**	19.66**	10.20**	2.66*	25.42**	1.96

1= IR62829AxIR62036-222-3-3-1-2R, 2= IR62820AxIR68081-34-2-2R, 3= IR67684AxIR61614-38-19-3-2R,
4= IR68899AxIR63036-222-3-3-1-2R, 5= IR58025AxIR61614-38-19-3-2R, 6= IR68886AxIR58082-126-1-2R,
7= IR68897AxIR62036-222-3-3-1-2R, 8= IR69626AxIR62036-222-3-3-2R, 9= IR68888AxIR56381-139-2-2R,
10= IR62829AxIR60819-34-2-1R
*,** = Significant at 5% and 1% level of probability, respectively, FLL= Flag leaf length (cm), SPL= Spikelet length (cm)

states that heterosis is due to the accumulation of favourable dominant genes in a hybrid derived from the two parents. Over dominance states that heterozygotes are more vigorous and productive than either homozygote parents. This has been proved in traits controlled by single or few genes. Heterozygotes perform a given function, over a range of environments, more efficiently than either homozygotes (East, 1936). Studies on genetic basis of heterosis for polygenic traits in various crops have shown that heterosis is the result of partial to complete dominance, over dominance and epistasis and may be a combination of all these (Comstock and Robinson, 1952). Analysis of variance indicated that the studied parental lines differed significantly for the studied characters (the ANOVA tables are not presented here). The components of variation along with coefficient of variability and genetic parameters of the studied characters are presented (Table 1). The narrow difference between the phenotypic and genotypic components of variation for most of the characters revealed that the major portions of the phenotypic variance were genetic in nature. This finding is in agreement with Singh *et al.* (1985). Similar results were also reported by Rahman *et al.* (1988), Alam *et al.*

(1998) and Alam *et al.* (1989). Grain yield/10 hills showed the highest phenotypic, genotypic and environmental variability followed by no. of effective tillers/hill, spikelet fertility/10 panicles and plant height.

High broad sense heritability (Hb) along with high genetic advance (GA) is usually more helpful in predicting the resultant effect for selection of the best individuals than heritability alone (Johnson *et al.*, 1955). In present study, high heritability for plant height, flag leaf initiation day, first panicle initiation day, days to 100% flowering, days to maturity, grain yield/10 hills and spikelet fertility was associated with high GA, indicating the presence of additive gene effects in controlling these characters. Therefore, considerable scope of improvement of rice exists by selecting for these characters. Similar findings were also reported by Singh *et al.* (1985), Rahman *et al.* (1988), Alam *et al.* (1998) and Alam *et al.* (1989). Low heritability estimates were obtained in trait no. of effective tillers/hill and days to 100% flowering for restorer (R) line.

Heterosis of F_1 hybrids over their respective mid parent, standard variety and better parents are presented in Table 2. For each character, the percentage values of the ten hybrids have been compared with mid parent, standard variety and high parent, the relative superiorities being termed as mid parent heterosis, standard heterosis and better parent heterosis.

The crosses IR62829AxIR62036-222-3-3-1-2R, IR68888AxIR56381-139-2-2R and IR58025AxIR61614-38-19-3-2R, have shown highly significant positive heterosis in all levels for flag leaf length, where as, the cross IR68888AxIR56381-139-2-2R has shown highly positive better parent heterosis for the same character. This indicated that these crosses could be the good materials for developing high yielding hybrids. In rice, flag leaf length had great contribution for high grain yield production. The crosses IR62829AxIR62036-222-3-3-1-2R, IR67684AxIR61614-38 19-3-2R, IR68899AxIR63036-222-3-3-1-2R, IR58025AxIR61614-38-19-3-2R and IR68888AxIR56381-139-2-2R showed similar performance like flag leaf length in case of spikelet length. Julfiquar and Tepora (1994) reported positive heterosis for flag leaf length and panicle length in rice. Regarding flag leaf initiation day, first panicle initiation day, days to 100% flowering and days to maturity characters negative heterosis were observed in most of the crosses. Among the ten crosses, highly negative heterosis was observed in three crosses (IR62829AxIR62036-222-3-3-1-2R, IR58025AxIR61614-38-19-3-2R,IR68888AxIR56381-139-2-2R)for both days to 100% flowering and days to maturity, which indicated the possibility of developing early maturing hybrid lines. Negative heterosis for earliness was also reported by Khaleque *et al.* (1977) in rice, and Hanna and Hernandez (1979) and Popova *et al.* (1980) in tomato. Heterosis rice hybrids were observed to possess varying growth duration ranging from 105 to 136 days (Virmani, 1987). In case of grain yield/10 hills most of the crosses showed highly significant positive values for three levels of heterosis. For mid parent, standard variety and better parent the heterosis ranged from -42.36 to 96.66%, -80.32 to 20% and -86.41 to 71.42%, respectively. Three crosses IR62829AxIR62036-222-3-3-1-2R, IR58025AxIR61614-38-19-3-2R and IR68888AxIR56381-139-2-2R were identified as the most expected combination for developing high yield hybrid rice varieties among the ten crosses. However, the highest heterosis for grain yield/10 hills value was obtained from the cross IR62829AxIR62036-222-3-3-1-2R (96.66%) for mid parent heterosis. High percentage (91.8 to 150.4) of heterosis for yield per plant was also reported by Zhang *et al.* (1994) and Alzona and Arraudeau (1995). Those cross combinations have shown positive and significant values for all the three levels of heterosis (mid parent heterosis, standard heterosis and better parent heterosis), whose are expected to be the high yielding hybrid varieties. In radish, similar results were also reported by Hawlader (1995), Ling *et al.* (1986), Singh *et al.* (1986) and Singh and Singh (1984). Positive and significant heterosis were obtained for these crosses in case of spikelet fertility and no. of effective tillers/hill, which are expected for high grain yield. Exploitation of heterosis for increasing grain yield in rice is reported by Virmani *et al.* (1991).

In conclusion for selecting the desirable parents and hybrids emphasis should be given on the characters such as plant height, flag leaf initiation day, first panicle initiation day, days to 100% flowering, days to maturity, grain yield/10 hills and spikelet fertility. Because, these characters have shown high heritability with high genetic advance. For selecting the F_1 hybrids, the crosses IR62829AxIR62036-222-3-3-1-2R, IR58025AxIR61614-38-19-3-2R and IR68888AxIR56381-139-2-2R were found promising for developing good hybrid rice varieties, as they have shown vigour for yield contributing characters including the earliness for grain maturity. The F_1 hybrids in rice are already being exploited in many countries of the world.

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