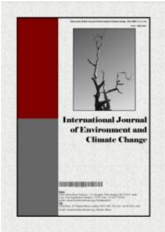

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Parental Diversity and Its Relationship with Performance of F1 Hybrid in Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out including 10 parents and their 45 half diallel crosses with the objective to study the relationship between heterosis and diverse genotype. The Mahalonobis D^2values resulted in grouping of 10 parents into 3 clusters. Cluster I was comprised of four genotypes, cluster II comprised of five genotypes while, cluster III was found monogenotypic. Cluster II and Cluster III had maximum mean values for 4 traits. Highest intercluster distance was also observed in these 2 cluster followed by cluster I and III . Maximum intra cluster distance was observed in cluster II followed by cluster I. The highest contribution in the manifestation of total genetic divergence was exhibited by grain iron content followed by grain zinc content. The relationship between parental diversity and heterosis indicated that majority of crosses belong to moderate divergence class. The cross $P_4 \times P_5$ exhibiting better parent heterosis for maximum traits also exhibited *at par* mean performance for 5 traits including grain yield per plant over the better parent. For grain zinc content, two crosses from high and low while, nine crosses from moderate

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divergence classes reported positive significant heterosis and SCA effects. For grain iron content, 1 cross with high, 2 crosses with moderate while four crosses with low divergence classes reported significantly positive heterosis and SCA effects.

Keywords: D2 analysis; genetic diversity; heterosis; rice; cluster analysis; grain Fe content.

1. INTRODUCTION

Rice is the staple food for billions of people throughout the developing world. But beyond easing hunger pains and providing carbohydrates for energy, it has little nutritional value. Over two billion people worldwide suffer from micronutrient deficiencies due to lack of essential vitamins and minerals in their diet. Iron (Fe) and zinc (Zn) deficiencies are the most widespread and are particularly prevalent in resource-poor countries where there is a heavy dietary reliance on staple crops [1]. Genetic variation for micronutrients in rice is reported to be narrow especially for iron and zinc [2,3]. To overcome micronutrient deficiencies in rice a genetic approach called bio-fortification [4] has been developed that aims at biological and genetic enrichment of food stuffs in edible portion of rice. Once rice is biofortified with vital nutrients, the farmer can grow these nutrient packed rice varieties indefinitely without any additional input in a sustainable way. Being a component of staple food, rice serves as an effective carrier to target common people for alleviating mineral deficiencies. This is also the only feasible way to reach and provide with essential nutrients to the malnourished population in rural India. Using a plant breeding approach to address micronutrient malnutrition would provide a new tool in combating the problem. The success of any plant breeding programmes largely depends on the existence of diversity among the genotypes [5] for trait of interest. Therefore, accurate assessment of the extent of genetic diversity acquires importance for diverse applications in crop breeding including introgression of desirable genes from donor source and widening of genetic base. Genetic diversity assessment helps in grouping the germplasm into different clusters based on trait similarity and differences that in turn helps in selection of parents for hybridization for the want of heterosis [6]. Multivariate analysis with D^2 technique measures the extent of genetic diversity in a given population with respect to several characters and assesses relative contribution of different traits to the total divergence [7]. Hence, estimation of genetic diversity among genotypes is important for planning the future crossing programme [8,9]. The extent of genetic diversity between parents has been proposed as a predictor of F_1 performance and magnitude of heterosis [10]. However, a strong correlation between heterosis and parental divergence has been rarely observed [9,11]. Hence, the proposed study was carried out with the objective to evaluate rice genotypes for assessment of relationship between the performance of F_1 hybrid and divergence of corresponding combining parents.

2. MATERIALS AND METHODS

Ten diverse genotypes of rice showing variability for iron and zinc (Table 1) were selected from Harvest Plus Trial conducted at Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. These genotypes were mated in half diallel fashion to obtain 45 crosses during *Kharif,* 2017. Observations for fourteen traits were recorded on 5 randomly selected plants in each entry (45 F_1's+ 10 parents) except for days to 50% flowering and days to maturity where observations were recorded on plot basis. The estimation of micronutrients by X-Ray Fluorescence Spectrometry [12] was carried out at Harvest Plus Division, ICRISAT, Hyderabad.

The analysis of genetic divergence among the parents was done using Mahalanobis D^2 statistics [13] while the relationship between parental diversity and heterosis over better parent was carried out by the procedure as suggested by Arunachalam et al. [14].

Table 1. List of parental genotypes

Sl. No.	Genotypes	Sl. No.	Genotypes
1	IR68144-2B-2-2-3-1 (P_1)	6	KALA JIRA JAHA (P_6)
2	HATI BANDHA (P_2)	7	IR91175-27-1-3-1-3 (P_7)
3	TEVIRII (P_3)	8	R-RIZIH-7 (P_8)
4	NGOBANYO RED COVER (P_4)	9	MTU 1010 (P_9)
5	KHUSISOI-RI-SAREKU (P_5)	10	TEINEM RUISHENG MAA (P_{10})

3. RESULTS

Tocher's method of clustering utilizing D^2 values grouped ten parents into three clusters (Table 2). Cluster I was comprised of four parental genotypes (KHUSISOI-RI-SAREKU, TEINEM RUISHENG MAA, R-RIZIH-7 and NGOBANYO RED COVER), Cluster II comprised of five genotypes (TEVIRII, KALA JIRA JAHA, HATI BANDHA, IR68144-2B-2-2-3-1 and IR91175-27-1-3-1-3) while, the cluster III was monogenotypic in nature (MTU-1010). A comparison of the mean values of 14 traits for different clusters showed considerable differences (Table 3). Cluster II had maximum mean values for 4 traits including grain iron content and grain zinc content. Cluster III had minimum mean values for days to 50% flowering, days to physiological maturity, plant height and canopy temperature while, maximum mean value for 4 traits including grain yield per plant. The average intra cluster distance ranged from 0.00 to 200.40. Maximum intra cluster distance was observed in cluster II (200.40) followed by cluster I (145.72), while the lowest intra cluster distance was recorded for cluster III *i.e.* zero (0). The highest inter cluster distance was recorded between cluster II and III (536.72) followed by cluster I and III (370.74). The lowest inter cluster distance was observed between cluster I and II (355.34) (Table 4). The highest contribution in the manifestation of total genetic divergence was exhibited by grain iron content (44.00%) followed by grain zinc content (35.56%), plant height (8.89%), days to physiological maturity (6.67%), grain yield per plant (4.44%), days to 50% flowering (2.22%) and flag leaf area (2.22%). The contribution of remaining traits in manifestation of genetic divergence was even lower (Table 6).

The investigation of relationship between parental genetic diversity and heterosis (Table 7) indicated that majority of crosses belong to moderate divergence class. The cross P_4×P_5 exhibited significant better parent heterosis for maximum no. of traits including grain iron content, grain zinc content, days to 50% flowering, days to physiological maturity and chlorophyll content. Both parents P_4 and P_5 involved in the cross belong to the same cluster II. On the basis of intra-cluster D-value, the cross belongs to the low divergence class. Five crosses *viz*., P_1×P_4, P_1×P_6, P_3×P_6, P_4×P_7 and P_5×P_{10} exhibited better parent heterosis for 4 traits including grain zinc content. Based on intra and intercluster D-value P_1×P_4, P_3×P_6 and P_4×P_7 belongs to moderate divergence class while P_5×P_{10} belongs to low divergence class. The divergence classes of crosses exhibiting positive significant heterobeltiosis and SCA effects for grain yield per plant, grain iron content and grain zinc content is presented in Table 8 which indicate that out of forty five crosses, cross P_4×P_9 andP_5×P_8, the former from moderate divergence group and latter belongs to low divergence group-showed positive significant heterosis and SCA effects for grain yield per plant. For grain iron content, one cross (P_7×P_9) with high, two crosses (P_5×P_9 and P_8×P_9) with moderate and four crosses (P_4×P_5, P_4×P_{10}, P_5×P_{10}, P_8×P_{10}) with low divergence classes reported positive significant heterosis and SCA effects. For grain zinc content, among the 45 crosses, two crosses (P_2×P_9 & P_6×P_9) from high, nine crosses (P_1×P_4, P_1×P_{10}, P_2×P_3, P_2×P_7, P_2×P_{10}, P_3×P_6, P_4×P_7, P_6×P_7& P_9×P_{10}) from moderate and two crosses (P_4×P_5 & P_5×P_{10}) from low divergence classes reported positive significant heterosis and SCA effects.

4. DISCUSSION

Based on clustering pattern Cluster I and II comprised of four and five genotypes respectively, while Cluster III was monogenotypic in nature. Similar studies based on D^2-statistic was also performed by Sudeepthi et al. [15], Singh et al. [16], Kumari et al. [17], Nirosha et al. [18], Sreedhar [19], Singh et al. [20] and Devi et al. [21]. The clustering pattern showed that genotypes of different geographical areas were clubbed in one group and also the genotypes of same geographical area were grouped into same cluster as well as in different cluster indicating that there was no formal relationship between geographical distribution and genetic diversity. Based on cluster mean values, genotypes belonging to cluster III are most promising and can be selected for development of varieties with earliness, dwarfness, better yield potential or combination of any of these parameters. Parents belonging to cluster II were found promising for high grain iron and zinc content; therefore, these can be utilized in breeding programs for the improvement of nutritional quality of grains. Selection of genotypes based on cluster mean for the better exploitation of genetic potential was also reported by Perween et al. [22], Rathod et al. [23], Radha et al. [24] and Shivani et al. [25]. The maximum intra cluster distance was observed in cluster II followed by cluster I indicating differences in genotypes within cluster. The genotypes in cluster II and cluster III, due to maximum inter cluster distance between them,

Table 2. Clustering pattern of ten parents on the basis of D^2 statistic

Cluster	No. of Genotypes within cluster	Genotypes in cluster
I	4	KHUSISOI-RI-SAREKU (P_5), TEINEM RUISHENG MAA (P_{10}), R-RIZIH-7 (P_8) and NGOBANYO RED COVER (P_4)
II	5	TEVIRII (P_3), KALA JIRA JAHA (P_6), HATI BANDHA (P_2), IR68144-2B-2-2-3-1 (P_1) and IR91175-27-1-3-1-3 (P_7)
III	1	MTU 1010 (P_9)

Table 3. Cluster mean for fourteen quantitative characters

Cluster	DFF	DPM	PH	FLA	CT	CC	PL	ETPP	GPP	TW	HI	GIC	GZC	GYPP
Cluster I	89.50	111.25	136.00	42.59	30.33	35.11	25.83	10.00	156.42	21.37	48.92	12.41	23.96	37.53
Cluster II	93.20	118.87	121.33	32.78	31.87	40.26	25.63	7.67	131.80	21.63	51.79	16.05	24.67	31.96
Cluster III	73.33	97.67	106.33	35.13	22.17	38.97	24.00	16.67	197.67	21.11	55.27	13.25	21.27	41.40

Table 4. Mean intra- and inter-cluster distance (D^2) among three clusters

Cluster	Cluster I	Cluster II	Cluster III
Cluster I	145.72		
Cluster II	355.34	200.40	
Cluster III	370.74	536.72	0.00

Table 5. Percentage contribution of fourteen characters towards total divergence

Sl. No.	Character	Times ranked 1st	Contribution (%)
1	Days to 50% flowering (d)	1	2.22
2	Days to Physiological maturity (d)	3	6.67
3	Plant Height (cm)	4	8.89
4	Flag leaf area (cm^2)	1	2.22
5	Canopy Temperature (^{0}C)	0	0.00
6	Chlorophyll Content (SPAD)	0	0.00
7	Panicle length (cm)	0	0.00
8	Effective Tillers per Plant (no.)	0	0.00
9	Grains per Panicle (no.)	0	0.00
10	Test Weight (g.)	0	0.00
11	Harvest index (%)	0	0.00
12	Grain Iron Content (ppm)	18	40.00
13	Grain Zinc Content (ppm)	16	35.56
14	Grain yield per plant (g)	2	4.44

Table 6. Relationship between parental diversity and heterosis in F_1 crosses

Sl. No.	Crosses	Number of characters for which the F_l was heterotic	Cluster to which parents belong		Corresponding intra- or inter-cluster D-value	Divergence class
			Male	Female		
1.	P1 × P3	1	II	II	14.16	M
2.	P1 × P4	4	II	I	18.85	M
3.	P1 × P6	4	II	II	14.16	M
4.	P1 × P7	1	II	II	14.16	M
5.	P1 × P8	1	II	I	18.85	M
6.	P1 × P9	2	II	III	23.17	H
7.	P1 × P10	1	II	I	18.85	M
8.	P2 ×P3	3	II	II	14.16	M
9.	P2 × P6	1	II	II	14.16	M
10.	P2 × P7	1	II	II	14.16	M
11.	P2 × P9	2	II	III	23.17	H
12.	P2 × P10	1	II	I	18.85	M
13.	P3 × P4	3	II	I	18.85	M
14.	P3 × P5	2	II	I	18.85	M
15.	P3 × P6	4	II	II	14.16	M
16.	P3 × P7	2	II	II	14.16	M
17.	P3 × P9	1	II	III	23.17	H
18.	P3 × P10	2	II	I	18.85	M
19.	P4 × P5	5	I	I	12.07	L
20.	P4 × P6	3	I	II	18.85	M
21.	P4 × P7	4	I	II	18.85	M
22.	P4 × P9	1	I	III	19.25	M
23.	P4 × P10	2	I	I	12.07	L
24.	P5 × P6	1	I	II	18.85	M
25.	P5 × P7	1	I	II	18.85	M
26.	P5 × P8	1	I	I	12.07	L
27.	P5 × P9	2	I	III	19.25	M
28.	P5 × P10	4	I	I	12.07	L
29.	P6 × P7	1	II	II	14.16	M
30.	P6 × P9	1	II	III	23.17	H
31.	P6 × P10	2	II	I	18.85	M
32.	P7 × P8	1	II	I	18.85	M
33.	P7 × P9	2	II	III	23.17	H
34.	P8 × P9	1	I	III	19.25	M
35.	P8 × P10	2	I	I	12.07	L

H- High, M- Moderate, L- Low

Table 7. Divergence classes of crosses exhibiting positive significant heterobeltiosis and SCA effects for grain yield per plant, grain iron content and grain zinc content

Character	Crosses	Heterobeltiosis	SCA effect	Divergence class
Grain Yield per plant	P4 × P9	14.96*	3.741*	M
	P5 × P8	13.84*	4.964**	L
Grain Iron Content	P4 × P5	15.50**	1.157**	L
	P4 × P10	25.37**	2.586**	L
	P5 × P9	17.66**	1.320**	M
	P5 × P10	22.29**	2.362**	L
	P7 × P9	6.21*	2.524**	H
	P8 × P9	21.13**	2.502**	M
	P8 × P10	15.38**	0.861**	L
Grain Zinc Content	P1 × P4	5.92**	4.820**	M
	P1 × P10	2.83**	2.942**	M
	P2 × P3	9.81**	1.717**	M
	P2 × P7	5.46**	2.471**	M
	P2 ×P9	35.48**	6.596**	H
	P2 × P10	11.33**	1.585**	M
	P3 × P6	4.23**	1.176**	M
	P4 × P5	5.36**	3.497**	L
	P4 × P7	6.79**	3.829**	M
	P5 × P10	6.97**	2.902**	L
	P6 × P7	7.85**	3.380**	M
	P6 × P9	8.82**	2.205**	H
	P9 × P10	7.33**	0.925**	M

H- High, M- Moderate, L- Low

Table 8. Mean performance of crosses over better parent

Crosses/Parents	DFF	DPM	PH	FLA	CT	CC	PL	ETPP	GPP	TW	HI	GIC	GZC	GYPP
$P_1 \times P_2$	93.00	111.67	100.7^{+}	35.14	32.26	40.1	24.17	8	134.67	21.18^{+}	55.49^{+}	11.9	22.2	32.80
$P_1 \times P_3$	84.67	109.00	107.3	29.04	33.24	28.1	25.17	6	123.67	22.26^{+}	59.62^{+}	14.6	27.6^{+}	30.39
$P_1 \times P_4$	82.67	105.33	114.0	25.66	31.37	47.9^{+}	27.00^{+}	9	146.47	21.45^{+}	53.29^{+}	16.5^{+}	29.8^{*}	38.03^{+}
$P_1 \times P_5$	87.67	108.33	100.7^{+}	43.61^{+}	31.81	41.5^{+}	23.33	8	141.60	22.41^{+}	56.11^{+}	12.4	25.8	35.54
$P_1 \times P_6$	72.00^{+}	105.67	104.7^{+}	41.63^{+}	33.19	44.5^{+}	28.83^{+}	6	125.78	21.46^{+}	54.55^{+}	15.6	20.8	30.60
$P_1 \times P_7$	70.33^{+}	96.67^{+}	100.3^{+}	20.21	30.36	41.8^{+}	22.17	11	162.42	22.94^{+}	53.22^{+}	13.0	21.3	42.09^{+}
$P_1 \times P_8$	73.33^{+}	108.33	104.7^{+}	40.72	30.83	31.9	24.83	10	154.51	23.22^{+}	52.95^{+}	13.0	24.7	39.72^{+}
$P_1 \times P_9$	73.00^{+}	103.67	166.0	29.28	30.50	38.6	28.83^{+}	11	161.82	24.63^{+}	54.51^{+}	15.5	28.7^{*}	39.87^{+}
$P_1 \times P_{10}$	99.67	118.00	107.3	34.54	31.93	43.6^{+}	26.17^{+}	8	140.80	23.94^{+}	54.22^{+}	13.4	28.9^{*}	35.15
$P_2 \times P_3$	104.67	128.00	97.7^{+}	28.12	33.18	50.9^{*}	29.67^{+}	6	126.62	23.05^{+}	55.07^{+}	13.5	25.8	31.47
$P_2 \times P_4$	107.00	133.00	122.7	30.89	31.97	42.0^{+}	23.67	8	140.18	22.74^{+}	56.59^{+}	16.8^{+}	22.8	34.42
$P_2 \times P_5$	108.33	129.33	132.7	44.24^{+}	31.05	38.1	25.50	9	149.47	22.06^{+}	50.80^{+}	13.2	20.1	38.28^{+}
$P_2 \times P_6$	103.33	123.33	128.7	32.45	32.37	36.0	24.00	8	129.53	22.93^{+}	49.17	12.0	23.6	32.42
$P_2 \times P_7$	82.33	103.67	134.0	35.71	29.64	33.7	26.33^{+}	11	168.03	21.75^{+}	47.51	16.1^{+}	26.4	43.12^{+}
$P_2 \times P_8$	101.00	127.67	127.3	43.00^{+}	30.87	44.0^{+}	26.33^{+}	10	154.35	18.52	37.93	15.4	24.3	39.18^{+}
$P_2 \times P_9$	81.33	102.00	119.7	42.53^{+}	31.57	40.6	28.67^{+}	9	144.68	22.88^{+}	42.95	15.5	30.8^{*}	37.07
$P_2 \times P_{10}$	88.33	107.67	170.3	40.68	32.15	33.9	28.00^{+}	8	136.67	21.56^{+}	54.90^{+}	15.4	26.0	33.07
$P_3 \times P_4$	90.67	113.00	154.7	41.58^{+}	31.37	46.2^{+}	22.67	9	145.68	22.43^{+}	52.80^{+}	15.4	20.9	37.37^{+}
$P_3 \times P_5$	85.00	110.3	130.7	40.93	32.73	37.7	27.33^{+}	7	126.67	22.36^{+}	48.42	13.4	25.5	31.70
$P_3 \times P_6$	75.67^{+}	104.67	156.7	37.76	34.48	35.6	23.33	4	109.33	22.40^{+}	46.62	11.4	25.0	26.75
$P_3 \times P_7$	82.00	105.00	134.0	32.97	30.55	35.6	23.67	10	160.12	21.18^{+}	43.34	14.4	23.2	39.79^{+}
$P_3 \times P_8$	88.00	107.00	138.3	44.51^{+}	32.60	30.8	25.17	7	127.75	20.41	38.01	15.6	20.4	32.34
$P_3 \times P_9$	74.67^{+}	105.33	165.7	27.22	31.23	45.6^{+}	27.33^{+}	9	146.57	22.71^{+}	57.17^{+}	14.6	23.5	38.23^{+}
$P_3 \times P_{10}$	91.67	111.67	112.3	43.96^{+}	32.31	36.1	24.83	8	129.75	25.05^{+}	46.04	12.4	24.4	32.76
$P_4 \times P_5$	74.00^{+}	101.00^{+}	166.7	29.55	30.97	51.5	25.63	9	151.33	22.90^{+}	52.87^{+}	15.3	27.3	38.51^{+}
$P_4 \times P_6$	93.33	116.00	107.7	46.79^{+}	32.63	39.7	23.67	7	127.12	19.85	49.11	11.2	20.5	31.93
$P_4 \times P_7$	80.33	105.67	136.3	32.56	27.98	43.7^{+}	26.50^{+}	12	178.27	23.99^{+}	48.21	11.3	26.8	46.21^{+}
$P_4 \times P_8$	92.67	113.33	107.0	42.85^{+}	30.13	38.3	22.67	11	167.38	21.49^{+}	46.01	12.7	20.9	43.01^{+}
$P_4 \times P_9$	95.00	118.00	142.3	40.23	27.17	43.4^{+}	27.33^{+}	12	184.67^{+}	23.74^{+}	58.66^{+}	12.2	19.2	47.60^{+}
$P_4 \times P_{10}$	92.67	114.33	87.7^{+}	37.74	30.87	34.5	26.17^{+}	10	154.32	22.46^{+}	50.08^{+}	16.3^{+}	23.4	39.17
$P_5 \times P_6$	92.00	113.33	92.3^{+}	38.45	32.01	34.9	27.83^{+}	8	137.33	23.90^{+}	55.13^{+}	14.1	26.1	33.24
$P_5 \times P_7$	81.67	101.67	159.3	34.32	29.37	44.2^{+}	23.33	11	172.65	22.60^{+}	52.70^{+}	16.1^{+}	23.3	43.54^{+}
$P_5 \times P_8$	82.33	107.00	166.7	44.37^{+}	28.31	35.0	24.17	11	175.23	23.29^{+}	56.39^{+}	13.1	21.9	46.03^{+}
$P_5 \times P_9$	94.67	120.33	167.7	38.99	30.20	44.0^{+}	26.50^{+}	11	164.99	22.74^{+}	56.21^{+}	15.6	22.1	42.69^{+}
$P_5 \times P_{10}$	107.67	129.33	125.0	35.16	31.57	44.5^{+}	25.00	9	145.32	23.90^{+}	54.03^{+}	16.2^{+}	27.7^{+}	37.19
$P_6 \times P_7$	97.33	119.00	100.7^{+}	30.60	30.96	45.9^{+}	23.50	9	153.47	22.57^{+}	47.88	8.9	27.0	38.53^{+}
$P_6 \times P_8$	98.67	124.67	100.0^{+}	39.78	32.00	46.3^{+}	27.33^{+}	8	138.40	21.74^{+}	51.46^{+}	9.9	25.2	33.92
$P_6 \times P_9$	94.00	117.00	106.7	33.05	30.73	45.3^{+}	24.83	10	158.71	20.97^{+}	53.53^{+}	10.7	26.1	39.74^{+}

Crosses/Parents	DFF	DPM	PH	FLA	CT	CC	PL	ETPP	GPP	TW	HI	GIC	GZC	GYPP
$P_6 \times P_{10}$	74.67^{+}	107.33	148.7	30.51	31.98	45.7^{+}	28.67^{+}	8	138.78	22.60^{+}	53.84^{+}	12.5	21.7	34.11
$P_7 \times P_8$	90.00	110.00	117.3	47.26^{+}	27.28	34.5	27.83^{+}	12	183.58^{+}	21.90^{+}	53.30^{+}	14.9	21.6	46.62^{+}
$P_7 \times P_9$	76.00^{+}	104.33	171.3	43.66^{+}	23.37^{+}	39.6	28.50^{+}	17^{+}	197.17^{+}	22.45^{+}	51.55^{+}	16.9*	21.7	50.81*
$P_7 \times P_{10}$	82.00	106.33	106.3	38.88	28.56	33.8	25.17	11	174.7	23.74^{+}	55.07^{+}	14.0	20.1	44.55^{+}
$P_8 \times P_9$	99.00	119.33	151.0	31.33	28.51	39.0	26.67^{+}	11	174.80	22.83^{+}	51.21^{+}	16.1^{+}	24.5	45.73^{+}
$P_8 \times P_{10}$	81.67	102.67	107.3	27.09	30.39	41.5^{+}	26.00	11	162.13	23.07^{+}	45.46	14.0	23.2	40.94^{+}
$P_9 \times P_{10}$	109.00	128.00	167.0	36.54	30.23	33.1	26.50^{+}	11	164.02	21.41^{+}	53.55^{+}	11.4	25.1	42.31^{+}
IR68144-2B-2-2-3-1	91.6	116.33	95.7	36.85	32.77	41.9	22.33	7	126.67	20.73	55.74	16.1	28.1	31.61
HATI BANDHA	82.00	112.00	138.7	25.68	33.27	39.9	29.00	6	113.67	22.06	53.52	16.4	22.7	29.90
TEVIRII	96.00	124.00	144.7	28.63	33.71	32.0	26.50	5	113.57	21.79	51.55	15.7	23.5	28.25
NGOBANYO RED COVER	103.33	127.67	99.0	42.53	30.70	41.1	26.33	10	159.52	17.51	40.26	13.0	21.8	39.75
KHUSISOI-RI-SAREKU	85.00	105.67	185.7	45.41	31.71	30.3	25.00	9	141.88	22.05	52.75	13.3	25.9	37.03
KALA JIRA JAHA	108.00	132.33	124.0	29.75	34.18	45.2	23.67	5	111.67	22.69	51.29	16.1	24.0	27.17
IR91175-27-1-3-1-3	88.33	109.67	103.7	42.98	25.43	42.3	26.67	16	193.35	20.88	46.84	15.9	25.1	42.89
R-RIZIH-7	84.67	106.67	101.0	40.79	26.74	36.7	27.33	13	189.18	23.48	51.25	11.3	24.8	40.43
MTU 1010	73.33	97.67	106.3	35.14	22.17	39.0	24.00	17	197.48	21.11	55.25	13.3	21.3	41.40
TEINEM RUISHENG MAA	85.00	105.00	158.3	41.61	32.17	32.3	24.67	8	135.00	22.41	51.41	12.1	23.4	32.90
Mean of Best Parent	73.33	97.67	95.7	45.41	22.17	45.2	29.00	17	197.48	23.48	55.74	16.4	28.1	42.89
C.D. 5%	4.22	3.83	9.93	3.88	3.01	4.30	2.95	2.53	15.41	2.96	5.56	0.49	0.58	5.53

**Significant, + at par @5% level of significance* exhibited high degree of genetic diversity and thus may be utilized under inter-varietal hybridization programmes (transgressive breeding) for getting high yielding recombinants. Similar inter-varietal crosses may also be attempted between genotypes in cluster I and III. Similar studies based on D^2 statistic was also performed by Patil et al*.* [26] and Ali et al. [27]. The selection and choice of parents mainly depends upon contribution of characters towards divergence. The maximum contribution in the manifestation of genetic divergence was exhibited by grain iron content followed by grain zinc content, plant height, days to physiological maturity and grain yield per plant. Therefore, selection for these characters in particular may be rewarding. The maximum contribution towards total divergence was reported by Nirosha et al. [18] for grain zinc content, Garg et al*.* [28] for days to maturity and Apsath Beevi & Venkatesan [29] for grain yield per plant. The study of relationship between parental diversity and heterosis in F_1 crosses indicated that majority of crosses belongs to moderate divergence class. The cross $P_4 \times P_5$ exhibiting better parent heterosis for maximum traits also exhibited *at par* mean performance for 5 traits including grain yield per plant over the better parent (Table 9). This suggests the accumulation of favourable alleles in parents and when they converge in hybrid combination gives superior performance even if they belong to low divergence class. Earlier workers have also reported similar results in different crops like Suman et al*.* [30] in maize, Krishnamurthy et al*.* [31] in chilli, Usatov et al*.* [32] in sunflower, Pandey et al*.* [33] in Indian pigeonpea and Tripathy et al*.* [34] in sesame.

5. CONCLUSION

Experience of hybrid rice breeding generally showed that the chance of developing heterotic hybrids is much higher when parents have high genetic distance or when they are selected from inter-clusters than from intra-cluster, wherein the clusters could mean geographic regions, ecotypes and sub-species. However, it does not necessarily mean that all hybrids originating from parents selected from distant clusters give a high yield or heterosis. In our study the frequency of heterotic crosses and magnitude of heterosis for yield and its component traits were found to be higher in crosses involving the parents with intermediate genetic distance than the extreme ones.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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