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STUDY OF HETEROSIS FOR IMPROVEMENT IN AEROBIC RICE (*ORYZA SATIVA* L.)

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ABSTRACT

A field experiment was conducted to study the magnitude of heterosis among forty cross combinations developed trough line x tester mating design from four lines and ten aerobic rice testers. In general, it is observed that most of the characters exhibited high heterotic response and existence of substantial amount of genetic variability among parents and hybrids. Highest heterotic effect for grain yield per plant was exhibited by cross combination NVSR-178 x NAUR-1 (49.89 %) followed by hybrid NVSR-178 x IET-21682 (44.17 %) and IR-28 x NAUR-1 (39.51 %). It was also observed from present study that heterotic response for grain yield per plant was mainly due to high heterotic response observed for productive tillers per plant, panicle length, number grains per panicle and test weight. It is clear that yield attributing characters plays major role in yield maximization simultaneously, best performing genotypes such as NVSR-178 and NAUR-1 could be the potential source of breeding material for improvement in aerobic rice.

INTRODUCTION

Rice food grain productivity in majority part of the world is challenged by increasing food demand and threatened by declining water availability. Moreover, rising global environmental factors had forced the plant breeders to develop hybrids that high yielding ability. Similar work was carried out in rice by Parihar and Pathak, 2008; Srivastava and Seshu, 1982; Belhekar, 2012; Chandara, 2012; Prasad, 2012; Pratap (2013); Thakare (2013) and many other workers to study the heterosis in rice crop. But, there is need to develop the rice hybrids that will sustain food security in limited water supply, in this stipulation genetic study of aerobic cultivars of rice may play important role. Hence, present investigation entitled "Genetic analysis for yield and its component traits over locations in Rice (*Oryza sativa* L.)" was therefore, under taken with the objective to study of heterosis among forty hybrids developed line x tester mating design among four high yielding lines and ten aerobic males.

MATERIALS AND METHODS

The present investigation was undertaken during *rabi*-2010-2011 to *kharif*-2011 to study the nature and magnitude of heterosis for yield and its component traits. The experimental materials for the present investigation consisted of four females *viz*., IET-19347 (L_1), IR-28 (L_2), NVSR-176 (L_3) and NVSR-178 (L_4) and ten males *viz*., IR81025-B-116-1 (T_1), IR-79915-B83-4-4 (T_2), IR79971-B-204-1-4 (T_3), IR81024-B-254-4 (T_4), IR80501-B-96-1-B (T_5), IET-21682 (T_6), IET-21683 (T_7), NAUR-1 (T_8), RP-4075-129-07-3 (T_9) and RP-4075-135-35-5 (T_{10}) were obtained 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 (Kempthorne, 1957) by hand emasculation and pollination at National Agricultural Research Project Farm, Navsari during *rabi*-2010-2011 to obtain forty cross combinations. Further in next season, three complete sets of 54 entries comprising of 40 F_1s, 4 females and 10 males were planted in Randomized Block Design (RBD) during *kharif*-2011 (Panse and Sukhatme, 1978). The trials were conducted, replicated thrice at three research stations of the university *viz.,* Navsari (Loc-I), Vyara (Loc-II) and Waghai (loc-III). 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 by university 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 per plant, plant height (cm), panicle length (cm), grain yield per panicle, 1000- grain weight *i.e.,* test weight (gm), grain yield per plant (gm), kernel length: breadth ratio, amylose content (%) (Estimated as per suggested by Stoskopf, 1985) and protein content (%) (Estimated as per suggested by Juliano, 1971) 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 data for each character were analyzed independently for each location as well as pooled over locations by using standard statistical procedure (Panse and Sukhatme, 1978). Heterosis effects expressed as percentage increase or decrease over better parent (Hetrobelteois) were estimated as per procedure given by Fonseca and Patterson, 1968).

RESULTS AND DISCUSSION

The results revealed that the mean squares due to parents for all the characters were found significant. The mean squares due to hybrids were also found highly significant for all the characters. This indicated existence of substantial amount of genetic variability among parents and hybrids for all the traits under study. It can substantially be used in genetic improvement of rice crop. Similar results were recorded by Pandya and Tripathi (2006); Singh *et al.* (2007); Patil *et al.* (2011); Soni and Sharma (2011); Singh and Babu (2012); Belhekar (2012); Chandara (2012); Prasad (2012); Dhanwani (2013); Pratap (2013) and Thakare (2013).

The parents *vs.* hybrids comparison was found significant for all the characters (Table No.1). Further, the study revealed that, out of 40 hybrids, 10 hybrids manifested significant positive heterosis over better parent for grain yield per plant with a range in variation from -48.66 % to 49.89 % (Table No.2). Hybrid NVSR-178 x NAUR-1 (49.89 %) showed highest heterotic effect for grain yield per plant followed by hybrid NVSR-178 x IET-21682 (44.17 %) and IR-28 x NAUR-1 (39.51 %). It signifies presence of substantial amount of heterosis in hybrids and heterosis for grain yield per plant.

Many hybrids exhibited significant heterosis over better parent in desirable direction for different component traits such as days to 50 per cent flowering (8), productive tillers per plant (7), plant height (6), panicle length (7), number grains per panicle (10), 1000-grain weight (4), grain yield per plant (10), L:B ratio (11), amylose content (%) (12) and protein content (%) (6). For all the traits except 1000-grain weight and protein content (%), quite a large number of crosses manifested significant heterosis over better parents in desirable direction. It indicates that quantitative traits are highly responsive in hybrids.

As observed in the present investigation, several workers have also reported similar presence of considerable amount of heterosis for grain yield in rice. High heterosis for grain yield was recorded by Lokaprakash *et al.* (1992); Pandya and Tripathi (2006); Singh *et al.* (2007); Patil *et al.* (2011); Soni and Sharma (2011) and Singh and Babu (2012); medium heterosis by Deosarkar and Nerkar (1994) and Parihar and Pathak (2008) and low heterosis by Srivastava and Seshu (1982); Belhekar (2012); Chandara (2012); Prasad (2012) and Pratap (2013).

Positive and high heterosis was observed in characters like productive tillers per plant, panicle length, number of grains per panicle, 1000 grain weight, L:B ratio, protein content and amylose content. For productive tillers per plant the highest positive heterosis being exhibited by cross IR-28 x NAUR-1 (37.56 %) followed by NVSR-178 x NAUR-1 (27.66 %) and significant heterosis for this character was ranged from 6.91 % to 37.56 %. Significant positive heterobeltiosis for Panicle length (cm) was observed to be ranged from-8.71 % (IR-28 x IET-21683) to 8.98 % (NVSR-178 x IET-21682). Further, maximum positive better parent heterosis was observed in NVSR-178 x IET-21682 (8.98 %) for Panicle length (cm). In case of grains per panicle ten hybrids showed significant positive heterobeltiosis and heterobeltiosis for grains per panicle was ranged from -13.64 % (NVSR-176 x IR79971-B-

Table 1: Analysis of variance (mean squares) of experimental design for different characters

Source of variance	d.f.	Days to 50 % flowering	Productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Grains per panicle
Replication within location	6@	11.245	0.475	21.826	0.161	102.965
Parents	13	535.886**	23.504**	2161.431**	75.852**	842.705**
Females	3	313.021**	5.468**	2315.616**	17.597**	885.964**
Males	9	537.458**	23.490**	2208.479**	101.502**	568.946**
Females vs. Males	1	1190.331**	77.728**	1275.528**	19.765**	3176.762**
Hybrids	39	245.682**	16.178**	2730.598**	37.124**	2992.839**
Parents vs. Hybrids	1	512.321**	142.592**	6304.113**	84.972**	9300.407**
Pooled error	954@	6.553	0.397	14.817	0.415	47.724

*, ** Significant at 5 and 1 per cent probability levels, respectively. @ for = individual location, d.f. = for error and replication were 318 and 2, respectively.
Note: Data presented in table is pooled data over the three locations *viz.*, Navsari, Vaghai, and Vyara of Gujarat State.

Table 1: continues......

Source of variance	d.f.	Test weight (g)	Grain yield per plant (g)	L:B ratio	Amylose content (%)	Protein content (%)
Replication within location	6@	0.003	4.835	0.001	0.017	0.003
Parents	13	55.109**	590.022**	0.79**	50.173**	4.192**
Females	3	128.485**	284.238**	2.387**	163.755**	6.114**
Males	9	32.166**	339.431**	0.345**	6.523**	3.866**
Females vs. Males	1	41.467**	3762.686**	0.001	102.287**	1.361**
Hybrids	39	72.732**	762.816**	0.835**	22.102**	3.501**
Parents vs. Hybrids	1	17.470**	5808.285**	2.880**	63.249**	2.096**
Pooled error	954@	0.241	4.830	0.007	0.053	0.011

*, ** Significant at 5 and 1 per cent probability levels, respectively. @ for = individual location, d.f. = for error and replication were 318 and 2, respectively. Note: Data presented in table is pooled data over the three locations *viz.*, Navsari, Vaghai, and Vyara of Gujarat State.

Table 2: Estimates of heterosis over better parent (BP) for yield and yield contributing characters

Sr. No. Hybrids	Day to 50 per cent Flowerings	Productive Tillers per plant	Plant height (cm)	Panicle length (cm)	Grains per panicles	Test weight (g)	Grain yield per plant (g)	L:B ratio	Amylose content (%)	Protein content (%)
$L_1 \times T_1$	4.06*	9.27*	2.55	0.03	2.99	-5.54**	5.86	-1.61	-0.05	-11.76**
$L_1 \times T_2$	0.51	11.70**	-0.40	4.44**	21.12**	1.33	34.50**	0.24	0.78	-5.65**
$L_1 \times T_3$	4.58*	-6.54	4.47**	-0.73	-7.68**	-3.23**	-5.98	8.35**	-3.53**	-3.43**
$L_1 \times T_4$	9.50**	-4.26	-0.59	-4.15**	-6.52**	-2.40**	-17.82**	3.02*	-7.32**	11.38**
$L_1 \times T_5$	4.96**	-3.27	1.59	-5.40**	-12.90**	-5.50**	-19.79**	5.24**	-1.54**	-12.50**
$L_1 \times T_6$	0.10	2.69	-0.51	0.03	2.67	12.23**	3.17	0.20	1.05*	-9.17**
$L_1 \times T_7$	19.68**	-18.58**	-0.06	-3.35**	-11.24**	-8.63**	-2.84	3.24*	-2.79**	-7.23**
$L_1 \times T_8$	-3.57*	3.90	-0.48	1.21	9.25**	6.90**	11.56**	5.66**	1.15**	-4.29**
$L_1 \times T_9$	-3.74*	-10.80**	-1.92	-5.44**	-13.37**	-1.68**	-18.84**	3.29*	-7.55**	5.11**
$L_1 \times T_{10}$	-19.40**	-5.08	0.68	-3.92**	-0.67	-2.38**	-7.83	5.60**	-3.22**	-5.94**
$L_2 \times T_1$	6.45**	-17.82**	17.44**	-2.28	-13.50**	-18.61**	-4.78	-9.33**	-5.80**	8.93**
$L_2 \times T_2$	8.74**	-12.44**	18.77**	-2.43	-10.12**	-2.79**	-26.12**	-2.05	-1.96**	-10.55**
$L_2 \times T_3$	-0.99	-13.00**	2.62	-5.58**	-13.64**	-15.02**	-48.66**	-5.37**	-7.20**	-5.09**
$L_2 \times T_4$	-0.61	2.21	-1.02	-0.12	0.74	-9.68**	2.56	-2.35*	1.63**	-8.49**
$L_2 \times T_5$	9.27**	0.93	9.86**	-4.54**	-2.68	-1.64	-5.76	-0.64	-1.37**	-12.94**
$L_2 \times T_6$	-7.52**	-7.76*	-4.97*	-5.43**	-11.82**	-7.75**	-28.49**	-7.86**	-6.36**	-0.82
$L_2 \times T_7$	1.45	-19.64**	-2.80	-8.71**	-7.69**	-14.17**	-29.59**	-10.32**	-2.31**	-12.43**
$L_2 \times T_8$	-0.86	37.56**	-7.35**	6.29**	22.16**	13.11**	39.51**	-0.29	8.52**	-16.07**
$L_2 \times T_9$	-1.81	23.36**	-11.14**	6.17**	20.40**	3.03**	36.84**	0.43	5.33**	-16.08**
$L_2 \times T_{10}$	-1.41	-15.81**	-10.68**	-7.32**	-4.64*	-3.03**	-3.25	-3.20**	-8.97**	-4.96**
$L_3 \times T_1$	6.30**	6.91*	3.94*	3.73**	16.38**	0.89	29.11**	1.44	2.73**	-4.27**
$L_3 \times T_2$	0.78	-14.62**	5.44**	-7.84**	-12.63**	-10.40**	-19.42**	4.97**	-1.96**	3.66**
$L_3 \times T_3$	1.95	0.99	5.01**	-0.09	-4.02	-7.42**	1.11	-4.52**	0.10	-4.94**

Table 2: Continues....

Sr. No. Hybrids	Day to 50 per cent Flowerings	Productive Tillers per plant	Plant height (cm)	Panicle length (cm)	Grains per panicles	Test weight (g)	Grain yield per plant (g)	L:B ratio	Amylose content (%)	Protein content (%)
$L_3 \times T_4$	-6.23**	-8.99**	-0.50	-0.96	-7.05**	-18.59**	0.59	6.84**	-18.63**	2.31**
$L_3 \times T_5$	9.80**	4.97	-1.51	1.63	13.13**	0.41	8.03*	2.02	2.25**	-5.93**
$L_3 \times T_6$	-8.08**	4.81	-1.50	1.21	10.73**	-5.39**	9.79**	-2.09	4.94**	0.68
$L_3 \times T_7$	5.11**	-12.21**	4.98**	-7.73**	-0.19	-17.28**	-17.40**	-2.74*	-14.64**	7.25**
$L_3 \times T_8$	-0.81	2.99	7.82**	1.19	1.69	-1.09	9.21**	0.88	2.23**	-1.56
$L_3 \times T_9$	-0.44	-20.00**	-0.35	-8.54**	-7.22**	-4.65**	-24.70**	2.14	-4.64**	-7.68**
$L_3 \times T_{10}$	-5.87**	2.01	0.89	-0.91	0.26	0.04	1.38	1.19	0.08	1.08
$L_4 \times T_1$	16.14**	-11.86**	-4.52**	-1.79	-8.72**	-8.96**	-11.25**	5.73*	-7.76**	-2.90**
$L_4 \times T_2$	10.76**	-0.55	1.24	0.48	0.24	-2.88**	-16.55**	-9.87**	-0.37	0.10
$L_4 \times T_3$	2.53	-14.48**	6.17**	-4.93**	-8.96**	-16.23**	-26.89**	-12.68**	-15.79**	-7.72**
$L_4 \times T_4$	5.61**	0.02	0.32	-1.54	0.01	-2.14**	-14.47**	0.62	-0.10	-2.38**
$L_4 \times T_5$	15.20**	-9.76**	10.17**	-5.15**	-8.88**	-23.29**	-18.52**	6.70**	-1.47**	-3.45**
$L_4 \times T_6$	-0.05	25.29**	0.00	8.98**	27.35**	6.03*	44.17**	1.65	7.99**	-6.13**
$L_4 \times T_7$	0.59	-11.06**	1.53	0.23	0.40	0.07	-20.01**	-3.38*	0.14	0.60
$L_4 \times T_8$	-14.04**	27.66**	4.85**	7.46**	32.09**	4.49*	49.89**	1.22	11.78**	1.10
$L_4 \times T_9$	-1.22	6.14	-14.15**	4.23**	18.12**	1.03	3.94	-15.67**	5.75**	-10.18**
$L_4 \times T_{10}$	-0.19	-1.21	1.83	-0.45	0.42	-2.46**	-16.34**	-0.36	0.10	1.52
S.E.±	1.181	0.252	1.614	0.283	2.804	0.205	0.967	0.040	0.096	0.046
C.D. at 5%	2.326	0.496	3.179	0.557	5.525	0.405	1.905	0.079	0.188	0.091
C.D. at 1%	3.540	0.653	4.190	0.735	7.283	0.533	2.511	0.105	0.248	0.120
No. of Significant crosses										
Total	23	23	18	22	27	32	27	23	32	32
+Ve	15	7	12	7	10	6	10	11	12	6
-Ve	8	16	6	15	17	26	17	12	20	26

*, ** Significant at 5 and 1 per cent probability levels, respectivelyNote: Data presented in table is pooled data over the three locations *viz*., Navsari, Vaghai, and Vyara of Gujarat State.

204-1-4) to 32.09 % (NVSR-178 x NAUR-1). Only six hybrids manifested significant positive heterotic effect for test weight over better parent and rest of the twenty-six hybrids exhibited negative heterosis. Heterobeltiosis ranged from -23.29 (NVSR-178 x IR80501-B-96-1-B) to 13.11 per cent (IR-28 x NAUR-1) for test weight.

Negative heterosis was desirable for characters *viz*., days to 50 per cent flowering and plant height (cm). In case of days to 50 per cent flowering, out of 23 heterotic hybrids, 8 hybrids manifested significant negative heterosis over better parent with range from -3.57 % (IET-19347 x NAUR-1) to -19.40 % (IET-19347 x RP-4075-135-35-5). Heterobeltiosis for plant height was ranged from 4.52 per cent (NVSR-178 x IR81025-B-116-1) to -14.15 per cent (NVSR-178 x RP-4075-129-07-3). Moreover hybrid NVSR-178 x RP-4075-129-07-3 (-14.15 %) was showed highest heterosis in desired direction followed by hybrid IR-28 x RP-4075-129-07-3 (-11.15 %) and IR-28 x RP-4075-135-35-5 (-10.68 %) for plant height.

Similar findings for productive tillers per plant, Panicle length (cm), grains per panicle, test weight, days to 50 per cent flowering and plant height (cm) were also reported by Singh and Singh (1979); Amirthadevarathinam (1983); Ram (1992); Vishwakarma *et al.* (1999); Yadav *et al.* (2004); Patil *et al.* (2011); Belhekar (2012); Chandara (2012); Prasad (2012); Reddy *et al.* (2012) and Pratap (2013).

As per as to quality traits are concern, amylose content (%) was found to be most heterotic attribute followed by L:B ratio exhibiting significant positive heterosis in 12 and 11 crosses, respectively.

The heterobeltiosis for L: B ratio was ranged from -15.67 per cent (NVSR-178 x RP-4075-129-07-3) to 8.35 per cent (IET-19347 x IR79971-B-204-1-4). Significant positive heterosis for L: B ratio by Singh and Singh (1985); Geetha *et al.* (1994); Venkatesan *et al.* (2008) and Patil *et al.* (2011).

For amylose content, out of forty crosses, thirty two crosses exhibited significant heterotic effects in which only twelve crosses had positive heterotic effect over their respective better parent. Cross combination NVSR-178 x NAUR-1 exhibited maximum heterotic effect (11.78 %). for amylose content, Sarthe *et al.* (1986) and Patil *et al.* (2011) reported the similar instances.

As per as protein content is concerned, cross combination IET-19347 x IR81024-B-254-4 recorded maximum heterotic effect (11.38 %). Range of heterotic effect for protein content was varied from -16.08 % (IR-28 x RP-4075-129-07-3) to 11.38 % (IET-19347 x IR81024-B-254-4). Comparable harmony for this character was recorded by Quah and Rao (1975) and Patil *et al.* (2011).

Present experimental results showed that the estimates of heterosis values for quality traits were low as compared to yield and yield contributing components. It is in confirmation with experimental findings of Veni *et al.* (2005) and Roy *et al.* (2009). Many of the crosses in present study showed low expression of heterosis for yield and its component characters which are attributed to disharmony between the gene combinations of the parents involved (Paramasivan and Sreerangaswamy, 1988).

In general, it was also observed that hybrid showing high heterosis for grain yield per plant, also manifested heterotic effects for productive tillers per plant, panicle length, number grains per panicle and 1000-grain weight. This study thus substantiates the findings of Paramasivan and Rangaswamy (1988); Vishvakarma *et. al.* (1999); Pandya and Tripathi (2006); Roy *et al.* (2009); Patil *et al.* (2011); Belhekar (2012); Chandara (2012); Prasad (2012); Singh (2012); Reddy *et al.* (2012) Singh and Babu (2012) and Pratap (2013).

From these results it is clear that, all the promising hybrids developed from ten aerobic testers, showed significant positive heterosis over their respective better parent showing presence of high heterobeltiosis for yield and yield contributing characters in rice. So, it is clear that rice crop holds great potential to develop high yielding aerobic rice hybrids. Further, in present exploration it is observed that yield attributing characters plays major role in yield maximization and most of the best hybrids exhibiting higher heterosis involve parents such NVSR-178 and NAUR-1. Such genetic material could be utilized for developing high yielding aerobic rice hybrids that will sustain limiting environmental sources.

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