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HETEROTIC EXPRESSION OF RICE (*Oryza sativa* L.) HYBRIDS FOR YIELD AND SOME YIELD COMPONENTS

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ABSTRACT: Present study was conducted involving 13 parents and their 30 F_1s to study heterotic expression in rice for yield and some yield components i.e., days to 50% flowering, panicle length, number of effective tillers per plant, number of grains per panicle, seed index and yield per plant. Heterobeltiosis, standard heterosis with standard check (Pusa basmati 1) were estimated. Among the heterotic crosses Jaya x Pant 12 (for days to 50% flowering), NDR 359 x Pant 12 (for number of effective tillers per panicle), Sarjoo 52 x Pant 12 (for panicle length), NDR 359 x NDR 97 (for number of grains per panicle), NDR 359 x NDR 97 (for seed index), NDR 359 x HUR 3022 (for grain yield per plant) over better parent and NDR 359 x Pant 12 (for days to 50% flowering), Jaya x NDR 97 (for number of effective tillers per panicle), NDR 359 x Sahabhagi dhan (for panicle length), Sarjoo 52 x Krishna hamsha (for number of grains per panicle), Sarjoo 52 x Krishna hamsha (for seed index) and NDR 359 X Pusa Basmati 1(for grain yield per plant) over standard check were found to be superior cross, expressing heterobeltiosis and standard heterosis in desirable direction. On the basis of heterobeltiosis and standard heterosis among top five crosses most of the crosses exhibiting desirable of heterobeltiosis/standard heterosis included poor x poor or poor x good general combiners. SCA effect of cross combinations, on the basis of heterobeltiosis and standard heterosis, was of both type *i.e.,* significant in desirable direction and non-significant.

Key words: Heterobeltiosis, Standard heterosis, General Combiner, SCA effect

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INTRODUCTION

Rice consumption provides instant energy as its most important component is carbohydrate (starch). It is an important cereal crop and stable food of India. Though during green revolution and later high yielding rice varieties have been released in India, but now rice productivity has reached a plateau in the recent years (Gupta, 2000).To increase rice productivity in a sustainable manner with limited resources, heterosis breeding with hybrid vigour provides an opportunity to boost the yield of rice. The commercial exploitation of hybrid vigour in rice was demonstrated in china by Professor Yuan Long Ping and his team in 1976 and, in result, rice productivity increased in China. Development in China encouraged the international Rice Research Institute (IRRI) and other countries to initiate research on exploring potential of hybrid rice technology. Even though tremendous gains in heterosis breeding have been achieved by China and other countries during the last two decades, it is felt that the maximum yield potential of hybrid rice not been fully studied and exploited as yet.

Heterosis breeding of crop plants incorporates both positive and negative heterosis depending on the breeding objectives. In general, positive heterosis is desired for yield and negative heterosis for reduced expression of a trait *viz*., flowering, maturity, disease susceptibility etc. (Nuruzzaman *et al.*, 2002). Heterosis breeding is an important genetic tool that can facilitate yield enhancement from between 30% to 400% and helps in enriching many other desirable quantitative and qualitative traits in crops (Srivastava, 2000).

MATERIALS AND METHODS

The present investigation was carried out during the Kharif 2013-14 at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The breeding material comprised of 13 rice genotypes and their 30 crosses. Out of 13 rice genotypes three genotypes *viz*, Jaya, Sarjoo 52 and NDR 359 were used as tester and 10 genotypes *viz*., Pant Dhan 4, NDR 97, Krishna Hamsha, IR 64, Malviya Dhan 36, HUR 3022, Sahbhagi Dhan, Pusa Basmati 1, Tarori Basmati 1 and Pant 12 were used as lines and sown at three different dates with an interval of 10 days of each sowing to ensure pollen availability for crossing during Kharif 2013. Depending upon flowering stage, 30 crosses were made between three tester (used as female parents) and 10 lines (used as male parents) according to line x tester mating design (Kempthorne, 1956). Seeds were harvested after 25 to 30 days of pollination. Nursery seedlings of 43 entries (30 crosses + 13 parents) were raised and then one month old seedlings were transplanted for recording observations in a compact family randomized block design with three replications in a well-puddled field, maintaining one seedling per hill. Each entry (cross/parent) was accommodated in three rows, each row had 1.5 m length. Inter-and intra-row spacing was 20 cm and 10 cm, respectively. Recommended crop management practices were followed. The observations were recorded on 10 plants from the middle row of each entry leaving border plants per replication in order to avoid competition effect of two different crosses/parents for days to 50% flowering, panicle length (cm), number of effective tillers per plant, number of grains per panicle, seed index (g) and grain yield per plant (g). The mean for observations of ten plants per replications obtained and recorded for statistical analyses. F1 hybrid performance was evaluated on the basis of the estimates of heterobeltiosis (Fonseca and Patterson, 1968) and Standard heterosis (Virmani et al., 1982; Subedi, 1982). In the present study, Pusa Basmati 1 was used as a standard check/variety.

RESULTS AND DISCUSSION

The hybrids showing high heterosis have good chances to identify desirable lines in succeeding generations as compared to hybrids having low heterotic effects (Patil *et al.* 2003). In present investigation, the performances of all the 30 F_1s were compared with better parent and one standard variety/check (Pusa basmati 1). The data presented in Table 1 revealed marked difference in the nature and magnitude of heterosis among F1s for all six traits.

For days to 50% flowering, negative value of heterosis is desirable as early flowering is usually associated with early maturity. It enhances the productivity per day per unit area. In present study, most of the F_1s flowered earlier as compared to best parent and standard check. The magnitude of heterobeltiosis varied from -22.30 (Jaya x Pant 12) to 6.23 (Jaya x Pant 4) percent and standard heterosis varied from -31.55 (NDR 359 x Pant 12) to 2.08 (Jaya x Tarori basmati 1) percent for days to 50% flowering. Out of 30 F1s, twenty seven F_1s was exhibited with negative and significant heterobeltiosis while, all 30 F1s, except Jaya x Tarori basmati 1 performed better than standard check. The top performing F1s, over better parent was Jaya x Pant 12 followed by NDR 359 x Pant 12, NDR 359 x NDR 97 and Sarjoo 52 x Pant 12. The top performing F_1s over standard check was NDR 359 x Pant 12 followed by NDR 359 x NDR 97, Jaya x Pant 12 and Jaya x Krishna hamsha. Similar findings for days to 50% flowering, were also reported by Lingaraju *et al.* (1999), Patil *et al.* (2003), Sen and Singh (2011), Sharma *et al.* (2013), Haque *et al*. (2014), Tiwari and Jatav (2016) and Srivastava and Jaiswal (2016). The earliness may be due to earliness nature of parental lines involved in these crosses.

Number of effective tillers per plant contributes to higher grain yield. The magnitude of heterosis over better parent for number of effective tiller per plant varied from 15.84 (NDR 359 x Pant 12) to -30.90 (Sarjoo 52 x Sahabhagi dhan) percent. During present study most of the F_1s exhibited positive and non-significant heterobeltiosis while, only three F_1s, was found to have positive and significant heterobeltiosis. The magnitude of heterobeltiosis varied from 35.84 (NDR 359 x Pant Dhan 4) to -31.90 (Sarjoo 52 x Sahbhagi Dhan) percent. The magnitude of standard heterosis varied from 36.83 (Jaya x NDR 97) to -40.06 (Sarjoo 52 x Sahabhagi dhan) percent. Four F_1s showed positive and significant standard heterosis. In present study, seven hybrids also showed negative and significant heterosis over better parent and standard check. Although heterosis is low probably due to presence of genes with lack of dominance and epistasis. While Sarawgi *et al.* (2000) observed high significant heterosis for effective tiller per plant in number of hybrids with highest standard heterosis of 33.33% in the hybrid R 302-111 x Pusa Basmati-1.

The result are disagreement with Ram (1992), Vivekanandan *et al.* (1992), Thirumeni and Subramanian (2000), Patil *et al.* (2003), Sharma *et al.* (2013), Singh *et al.* (2013) and Haque *et al*., (2014) for number of effective tillers per plant, they reported good heterosis.

Panicle length with positive and significant heterosis may contribute to enhance the number of spikelets / panicle, subsequently boost the grain yield / plant. For panicle length the magnitude of heterobeltiosis varied from 10.42 (Sarjoo 52 x Pant 12) to -15.36 (Sarjoo 52 x Pusa basmati 1) percent and of standard heterosis varied from -5.79 (NDR 359 x Sahabhagi dhan) to -23.84 (Jaya x Pant dhan 4) percent. Four crosses exhibited positive and significant heterosis for Panicle length over better parent. The top crosses for heterobeltiosis were Sarjoo 52 x Pant 12 followed by Sarjoo 52 x Sahabhagi dhan and Sarjoo 52 x Krishna hamsha. None of the crosses showed positive and significant standard heterosis for Panicle length. Roy *et al.* (2009) have obtained highly positively significant heterosis for panicle length in several hybrids with highest significant standard heterosis of 26.23% in the F_1 IET 6441 x Basmati 385. Mistry *et al.* (2015) have found significant standard heterosis of 29.02% in Krishna kamod x GNR-2 cross combination.

Table 1. Estimates of Heterobeltiosis (Hetbl.) and Standard heterosis (SH) for yield and some yield components in rice

	Day to 50% flowering		**Panicle length (cm)**		**No. of effective tillers per plant**	
Hybrids	**Hetbl**	**SH**	**Hetbl**	**SH**	**Hetbl**	**SH**
Jaya X Pant Dhan 4	6.23 **	-3.57 *	-11.92**	-23.84**	1.19	-19.24*
Sarjoo 52 X Pant Dhan 4	-11.68**	-18.45**	-3.77	-19.05**	-5.45	-34.38**
NDR 359 X Pant Dhan 4	-3.53 *	-16.07**	-2.67	-15.37**	35.84**	-26.18**
Jaya X NDR 97	-19.35 **	-26.79**	-6.21	-18.91**	-7.9	36.83**
Sarjoo 52 X NDR 97	-18.13**	-24.40**	6.67	-16.17**	-11.11	33.05**
NDR 359 X NDR 97	-20.29**	-30.65**	0.48	-12.63**	-13.51	19.21*
Jaya X Krishna Hamsha	-19.02**	-26.49**	3.98	-10.09**	-1.05	-11.04
Sarjoo 52 X Krishna Hamsha	-15.23**	-21.73 **	8.77*	-11.46**	1.75	-8.52
NDR 359 X Krishna Hamsha	5.71**	-8.04**	3.47	-10.03**	2.81	-7.57
Jaya X Sahabhagi Dhan	-9.18 **	-17.56**	-2.8	-15.95**	-15.77	-25.87**
Sarjoo 52 X Sahabhagi Dhan	-15.87**	-22.32**	9.17*	-14.21**	-31.90**	-40.06**
NDR 359 X Sahabhagi Dhan	-14.14**	-25.30**	8.34*	-5.79	-20.43*	-29.97**
Jaya X Tarori Basmati 1	-2.93*	2.08	-4.83	-17.29**	-5.93	9.89
Sarjoo 52 X Tarori Basmati 1	-12.84**	-8.33**	-0.1	-13.18**	-19.54*	-16.09
NDR 359 X Tarori Basmati 1	-17.93**	-13.69**	3.2	-10.26**	-23.17**	-19.87*
Jaya X Pusa Basmati 1	-15.48**	-15.48 **	-12.04**	-12.04**	-19.24*	-19.24*
Sarjoo 52 X Pusa Basmati 1	-15.48**	-15.48 **	-15.36**	-15.36**	-29.34**	-29.34**
NDR 359 X Pusa Basmati 1	-5.95**	-5.95 **	-10.77**	-10.77**	-12.62	-12.62
Jaya X IR 64	-16.07**	-23.81**	-6.81	-19.43**	0	-12.3
Sarjoo 52 X IR 64	-17.81**	-24.11**	3.38	-14.18**	-9.35	-20.50*
NDR 359 X IR 64	-3.53*	-16.07**	-0.76	-13.71**	-2.88	-14.83
Jaya X Malviya Dhan 36	-7.96**	-13.99 **	-0.5	-13.96**	-5.14	-24.29**
Sarjoo 52 X Malviya Dhan 36	-8.92**	-14.88 **	0.11	-21.33**	32.28**	-19.24*
NDR 359 X Malviya Dhan 36	-10.83**	-16.67 **	1.06	-12.13**	6.58	-23.34**
Jaya X HUR 3022	-12.13**	-20.24 **	-2.43	-15.63**	-26.39*	-37.54**
Sarjoo 52 X HUR 3022	-18.13**	-24.40**	5.96	-12.19**	17.06*	-9.15
NDR 359 X HUR 3022	5.36**	-8.33 **	-2.52	-15.23**	5.58	-10.41
Jaya X Pant 12	-22.30**	-29.46 **	2.21	-11.62**	0.73	25.15**
Sarjoo 52 X Pant 12	-19.74**	-25.89 **	10.42*	-7.55*	-11.68	-7.89
NDR 359 X Pant 12	-21.32**	-31.55 **	4.82	-8.86**	-6.84	-2.84
SE	±1.67	±1.67	±0.99	±0.99	±0.89	±0.89

*Significant at p= 0.05, ** significant at p=0.01.

Table-1 Cont…

Hybrids	No. of grains per panicle		Seed index (g)		Yield per plant (g)	
	Hetbl	SH	Hetbl	SH	Hetbl	SH
Jaya X Pant Dhan 4	-9.75	6.89	-9.75	6.89	17.24*	26.76**
Sarjoo 52 X Pant Dhan 4	-16.56	-1.18	-16.56	-1.18	-52.16**	-33.21**
NDR 359 X Pant Dhan 4	-25.88**	-12.22	-25.88**	-12.22	0.43	30.40**
Jaya X NDR 97	-19.06*	-5.96	-19.06*	-5.96	16.32*	39.41**
Sarjoo 52 X NDR 97	-5.87	-0.78	-5.87	-0.78	-44.70**	-22.80**
NDR 359 X NDR 97	43.54**	28.88*	43.54**	18.88	-6.43	-4.48
Jaya X Krishna Hamsha	-13.47	0.53	-13.47	0.53	30.65**	34.46**
Sarjoo 52 X Krishna Hamsha	29.31**	36.31**	29.31**	36.31**	-37.11**	-12.23
NDR 359 X Krishna Hamsha	13.36	-4.06	13.36	-4.06	-10.18	19.99*
Jaya X Sahabhagi Dhan	-10.58	3.89	-10.58	3.89	-9.27	8.75
Sarjoo 52 X Sahabhagi Dhan	18.14	24.53*	18.14	24.53*	-52.78**	-34.10**
NDR 359 X Sahabhagi Dhan	-6.75	-2.29	-6.75	-2.29	47.10**	7.6
Jaya X Tarori Basmati 1	-7.17	7.85	-7.17	7.85	19.78**	43.52**
Sarjoo 52 X Tarori Basmati 1	-21.67*	-17.44	-21.67*	-17.44	-34.75**	-8.95
NDR 359 X Tarori Basmati 1	-0.46	-22.09*	-0.46	-22.09*	33.95**	17.33*
Jaya X Pusa Basmati 1	-10.56	3.92	-10.56	3.92	-9.64	16.61
Sarjoo 52 X Pusa Basmati 1	-9.45	-4.55	-9.45	-4.55	-15.65*	17.70*
NDR 359 X Pusa Basmati 1	-30.05**	-30.05**	-30.05**	-30.05**	15.22*	48.67**
Jaya X IR 64	-16.32	-2.78	-16.32	-2.78	-16.30*	0.31
Sarjoo 52 X IR 64	18.67	25.09*	18.67	25.09*	27.04**	1.82
NDR 359 X IR 64	25.11*	-2.07	25.11	-2.07	30.37**	37.27**
Jaya X Malviya Dhan 36	-4.01	30.22**	-4.01	30.22**	0.71	27.28**
Sarjoo 52 X Malviya Dhan 36	-3.64	30.71**	-3.64	30.71**	21.11**	10.1
NDR 359 X Malviya Dhan 36	-23.53**	3.74	-23.53**	3.74	-35.18**	-18.06*
Jaya X HUR 3022	-0.31	15.83	-0.31	15.83	-18.51**	0.88
Sarjoo 52 X HUR 3022	24.12*	30.83**	24.12*	30.83**	37.21**	-12.39
NDR 359 X HUR 3022	-15.56	-20.71	-15.56	-20.71	49.39**	12.18
Jaya X Pant 12	-22.44*	-9.89	-22.44*	-9.89	-29.25**	-1.2
Sarjoo 52 X Pant 12	-29.54**	-25.73*	-29.54**	-25.73*	-26.38**	2.81
NDR 359 X Pant 12	7.86	-15.58	21.86*	-15.58	-30.74**	-3.28
SE	±13.13	±13.13	±0.15	±0.15	±1.64	±1.64

*Significant at p= 0.05, ** significant at p=0.01.

Table2: Top five crosses on the basis of heterobeltiosis and standard check with their respective SCA effect and parental GCA effect.

Traits	Hetrobeltiosis		SCA effect	Parental GCA effect	Standard heterosis		SCA effect	Parental GCA effect
DF	1. Jaya x Pant 12	-22.30**	NS	Poor x Good	1. NDR 359 X Pant 12	-31.55**	**	Poor x Good
	2. NDR 359 x Pant 12	-21.32**	**	Poor x Good	2. NDR 359 X NDR 97	-30.65**	**	Poor x Good
	3. NDR 359 x NDR 97	-20.29**	**	Poor x Good	3. Jaya x Pant 12	-29.46**	NS	Poor x Good
	4. Sarjoo 52 x Pant 12	-19.74**	NS	Good x Good	4. Jaya X NDR 97	-26.79**	NS	Poor x Good
	5. Jaya x NDR 97	-19.35**	NS	Poor x Good	5. Jaya X Krishna Hamsha	-26.49**	**	Poor x Poor
PL	1. Sarjoo 52 X Pant 12	10.42*	NS	Poor x Good	1. NDR 359 X Sahabhagi Dhan	-5.79	NS	Good x Poor
	2. Sarjoo 52 X Sahabhagi Dhan	9.17*	NS	Poor x Poor	2. Sarjoo 52 X Pant 12	-7.55*	NS	Poor x Good
	3. Sarjoo 52 X Krishna Hamsha	8.77*	NS	Poor x Good	3. NDR 359 X Pant 12	-8.86**	NS	Good x Good
	4. NDR 359 X Sahabhagi Dhan	8.34*	NS	Good x Poor	4. NDR 359 X Krishna Hamsha	-10.03**	NS	Good x Good
	5. Sarjoo 52 X NDR 97	6.67	NS	Poor x Poor	5. Jaya X Krishna Hamsha	-10.09**	*	Poor x Good
NETP	1.NDR 359 X Pant Dhan 4	35.84**	*	Poor x Poor	1.Jaya X NDR 97	36.83**	*	Poor x Good
	2.Sarjoo 52 X Malviya Dhan 36	32.28**	NS	Poor x Poor	2.Sarjoo 52 X NDR 97	33.05**	NS	Poor x Good
	3.Sarjoo 52 X HUR 3022	17.06*	**	Poor x Poor	3. Jaya X Pant 12	25.15**	*	Poor x Good
	4.NDR 359 X Malviya Dhan 36	6.58	NS	Poor x Poor	4. NDR 359 X NDR 97	19.21*	NS	Poor x Good
	5.NDR 359 X HUR 3022	5.58	NS	Poor x Poor	5. Jaya X Tarori Basmati 1	9.89	NS	Poor x Poor
NGP	1. NDR 359 X NDR 97	43.54**	**	Poor x Poor	1. Sarjoo 52 X Krishna Hamsha	35.89**	*	Good x Good
	2. Sarjoo 52 X Krishna Hamsha	29.31**	*	Good x Good	2. Sarjoo 52 X HUR 3022	31.12**	*	Good x Poor
	3. NDR 359 X IR 64	25.11*	NS	Poor x Poor	3. Sarjoo 52 X Malviya Dhan 36	29.99**	NS	Good x Good
	4. Sarjoo 52 X HUR 3022	24.12*	*	Good x Poor	4. Jaya X Malviya Dhan 36	28.45*	*	Poor x Good
	5. Sarjoo 52 X IR 64	18.67	NS	Good x Poor	5. NDR 359 X NDR 97	28.88*	**	Poor x Poor
SI	1. NDR 359 X NDR 97	43.54**	*	Good x Poor	1. Sarjoo 52 X Krishna Hamsha	36.31**	NS	Poor x Poor
	2. Sarjoo 52 X Krishna Hamsha	29.31**	NS	Poor x Poor	2. Sarjoo 52 X HUR 3022	30.83**	NS	Poor x Poor
	3. NDR 359 X IR 64	25.11**	NS	Good x Poor	3. Sarjoo 52 X Malviya Dhan 36	30.71**	NS	Poor x Poor
	4. Sarjoo 52 X HUR 3022	24.12*	NS	Poor x Poor	4. Jaya X Malviya Dhan 36	30.22	NS	Poor x Poor
	5. NDR 359 X Pant 12	21.86*	NS	Good x Poor	5. Sarjoo 52 X IR 64	25.09*	NS	Poor x Poor
GY	1. NDR 359 X HUR 3022	49.39**	*	Good x Good	1. NDR 359 X Pusa Basmati 1	48.67**	*	Good x Good
	2. NDR 359 X Sahabhagi Dhan	47.10**	NS	Good x Poor	2. Jaya X Tarori Basmati 1	43.52**	**	Good x Good
	3. Sarjoo 52 X HUR 3022	37.21**	NS	Poor x Good	3. Jaya X NDR 97	39.41**	*	Good x Poor
	4. NDR 359 X Tarori Basmati 1	33.95**	NS	Good x Good	4. NDR 359 X IR 64	37.27**	**	Good x Poor
	5. Jaya X Krishna Hamsha	30.65**	NS	Good x Poor	5. Jaya X Krishna Hamsha	34.46**	NS	Good x Poor

*Significant at P = 0.05, ** Significant at P = 0.01 NS= Non-significant,

SCA= Specific combining ability, GCA= General combining ability, DF= Day to 50% flowering, PL= Panicle length, NETP= Number of effective tillers per plant, NGP= Number of grains per panicle, SI= Seed index, GY=Grain yield per plant.

Number of grains per panicle is the major yield attributing trait and probably this trait will be helpful in breaking the yield ceiling (Sing and Maurya, 1999), hence significant positive heterosis is desirable. The magnitude of heterobeltiosis for number of grains per panicle varied from 43.54 (NDR 359 x NDR 97) to -30.05 (NDR 359 x Pusa basmati 1) percent and of heterosis over standard check varied from 35.89 (Sarjoo 52 x Krishna hamsha) to -30.05 (NDR 359 x Pusa basmati) percent. Four F_1s exhibited positive and significant heterobeltiosis for number of grains per panicle, while seven F_1s exhibited negative and significant heterobeltiosis. Seven F_1s exhibited positive and significant standard heterosis for number of grains per panicle. The top performing F_1s over better parent in present study was, NDR 359 x NDR 97 followed by Sarjoo 52 x Krishna hamsha and Sarjoo 52 x HUR 3022 and for standard heterosis was, Sarjoo 52 x Krishna hamsha followed by Sarjoo 52 x HUR 3022 and Sarjoo 52 x Malviya dhan 36 and were desirable F_1s for large number of grains per panicle as they exhibited higher magnitude of heterosis. Sharma *et al.* (2013) have also obtained highly significant positive heterosis for number of grains per panicle in several F_1s with highest significant standard heterosis of 14.58% in the F_1 IR 68897A x Malviya 36. The findings are in accordance with Davis and Rutger (1976), Tseng and Huang (1987), Raja Babu *et al.* (2004), Saravanan *et al.* (2008), Singh *et al.* (2013) and Mistry *et al.* (2015).

Seed index is one of the important yield related traits. The hybrids with positive heterosis are desirable for this trait. The magnitude of heterobeltiosis for seed index varied from 43.54 (NDR 359 x NDR 97) to -30.05 (NDR 359 X Pusa basmati 1) percent. Out of 30 F_1s only five F_1s exhibited positive and significant heterobeltiosis. The top performing F_1s over better parent were, NDR 359 x NDR 97, Sarjoo 52 x Krishna hamsha and Sarjoo 52 x HUR 3022. The magnitude of standard heterosis varied from 36.31 (Sarjoo 52 x Krishna hamsha) to -30.05 (NDR 359 X Pusa basmati 1) percent. Six crosses exhibited positive and significant standard heterosis during present study. The top performing F_1s over standard check were, Sarjoo 52 x Krishna hamsha, Sarjoo 52 x HUR 3022 and Sarjoo 52 x Malviya dhan 36. Rahimi *et al.* (2010) obtained upto 18.10% standard heterosis in hybrid P4 x P6 for 1000 grain weight in rice. Tiwari *et al.* (2011), Sharma *et al.* (2013), Singh *et al.* (2013), Ali *et al.*, (2014) and Bhati *et al.*, (2015) also reported highly significant positive heterosis for this trait in rice as in case of present study.

Heterosis for grain yield in positive direction is desirable as higher grain yield is the main objective for almost all the breeding programmes. Virmani *et al.* (1981) suggested that the yield advantage of 20% to 30% over best available standard variety should be sufficient to encourage farmers for adapting the hybrid rice varieties. In the present investigation, the magnitude of heterobeltiosis varied from 49.39 (NDR 359 x HUR 3022) to -52.78 (Sarjoo 52 X Sahabhagi dhan) percent and standard heterosis varied from 48.67 (NDR 359 X Pusa Basmati 1) to -34.10 (Sarjoo 52 X Sahabhagi dhan) percent for grain yield per plant. Out of 30 F_1s twelve F_1s over better parent and eleven F_1s even over standard check exhibited positive and significant heterosis. The top heterotic cross over better parent was, NDR 359 x HUR 3022 followed by NDR 359 X Sahabhagi dhan and Sarjoo 52 X HUR 3022 and top performing crosses over standard check were NDR 359 X Pusa Basmati 1, Jaya X Tarori Basmati 1 and Jaya X NDR 97 and were top heterotic combinations. A wide range of variations in the expression of heterosis for grain yield was reported by many workers. Bhave *et al.* (2002) observed 162.39% standard heterosis in the cross combination IR 58025A x RTN 68. Bhati *et al*. (2015) found highest heterobeltiosis 93.3% and standard heterosis 66.9% in Pusa 6A x Akshaya dhan for grain yield per plant. Singh *et al.* (2013) reported the highest standard heterosis of 20.60% in the cross combination IR 58025A x BPT 5204; and Latha *et al.* (2013) observed highest standard heterosis of 25.51% in the cross combination CRMS 32A x R1099-2569-1-1for grain yield per plant.

The present study showed that superior performance for all the characters was not expressed in a single cross combination. However, different cross combinations were found to be superior for various characters. Latha *et al.* (2013) also reported that the magnitude of heterosis varied from trait to trait and cross to cross and none of the cross combinations recorded significant heterosis for all the traits studied. Srivastva and Jaiswal (2016) also have suggested that desirable heterosis simultaneously all the traits was not expressed in any single cross combination. In the present study Jaya x Krishna hamsha (34.46%) exhibited significant and desirable standard heterosis for grain yield per plant along with for days to 50% flowering. and panicle length. Remaining promising crosses for yield per plant (on the basis of heterobeltiosis and standard heterosis) also recorded significant and desirable heterosis for some yield components. It was observed that the heterosis in the present set of desirable hybrids was influenced by yield related components which were studied. Earlier workers have reported high heterosis for grain yield in hybrids due to increased number of effective tillers per plant (Yamauchi and Yoshida, 1985 and Pandya and Tripathy, 2006), panicle length (Singh and Richarya, 1980), number of grains per panicle (Sarvanan *et al.* 2008) and 1000 grain weight (Alam *et al.* 2004, Reddy *et al.* 2013, Tiwari *et al.* 2015). Other yield contributing traits which were not mentioned in present study might have influenced grain yield per plant. Grain yield *per se* is a complex heritable character which is an end product of multiplicative interaction of various yield components and hence heterosis for yield may be attributed to heterosis of individual yield components or alternatively due to multiplicative effects of component characters.

Table 2 is presenting top five crosses on the basis of heterosis (heterobeltiosis and standard check) with their respective SCA effect and parental GCA effect. As per the accordance of Table 2, most of the crosses exhibiting desirable of heterobeltiosis/standard heterosis included poor x poor or poor x good general combiners while, few crosses included good x good general combiners. In general the crosses exhibiting desirable heterosis for yield traits were not necessarily related to their SCA effect. SCA effect of cross combinations, on the basis of heterobeltiosis and standard heterosis, was of both type *i.e.,* significant in desirable direction and non-significant (Table 2). Cross combinations showing high heterosis coupled with significant SCA effect would be suitable for heterosis breeding. On the other hand crosses with high heterosis but non-significant SCA effect would be desirable for exploitation of additive gene in segregating generations.

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