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RESEARCH ARTICLE

HETEROSIS IN DIVERSE ECOTYPES OF RICE UNDER SALINE-ALKALI ENVIRONMENT

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ABSTRACT

Moderate to high heterosis for yield and contributing characters was studied in 27 hybrids involving four tolerant (T) and three susceptible (S) varieties of rice under saline-alkali environments. The trend of magnitude of Mean, heterosis, heterobeltiosis and standard heterosis in inter and intra groups hybrid for days to 50% flowering and plant height were T/T >T/S > S/S hybrids. For Grain yield the trend was T/T >T/S > S/S for mean and standard heterosis and T/S > T/T > S/S for heterosis and heterobeltiosis. For protein content it was S/S > T/S > T/T. The mean standard heterosis estimates ranged from -31.56 to 51.78 having mean value of 14.22%. As regards to S/S hybrids, these estimates were much lower than those in T/T or T/S hybrids. Straw yield (high dry matter), 100 seed weight, spikelets per panicle, productive tillers per plant and short stature causes higher yields. Hybrids Usar 1/IR 24, Usar 1/IR 26, Jaya/Manhar and Jaya/ IR26 exhibited higher heterosis, heterobeltiosis and standard heterosis for yield and yield contributing traits.

INTRODUCTION

Rice (*Oryza sativa L.*) is a major staple food and is most important in Asia, where 90% of the world's rice is grown and consumed. Heterosis is a complex genetic phenomenon depending upon the balance of additive, dominance and interaction components of the genetic variance as well as distribution of genes in parental lines. Success of heterosis breeding in several cross fertilizing species prompted the scientists to study the prospects of its application in rice as well (Virmani, 1986). With the serious limitations of strictly self fertilizing nature of rice and the absence of a usable form of male sterility, research continue, however, with no tangible results until the Chinese scientists surprised the world by releasing in 1976 the first commercial hybrid. These hybrids were capable of out yielding the best non hybrid varieties by 25-30% under favorable irrigated environment (Lin and Yuan 1980).

Though research on the commercial utilization of heterosis in rice has seen tremendous achievement by dint of a number of stratagems during the last two decades, it is still in its infancy as the high yielding potential in rice has not yet been fully exploited in stress (saline-alkali) condition. The triumph of hybrid rice depends on the magnitude of heterosis, which also helps in the identification of potential cross combinations to be used in the conventional breeding program to create wide array of variability in the segregating generations. Heterosis provides useful information for choosing an approximate breeding methodology for the improvement of different characters. Yield heterosis is a variable trait and depends not only on the parental combinations alone but on the effect of the growing environment also (Virmani *et al*., 1982; Young and Virmani, 1990). Barlow (1981) stated that heterosis-growing condition interaction was the expectation rather than the exception. We present results on the nature and magnitude of heterosis involving diverse ecotypes of rice in a set of 21 hybrids under saline-alkali condition.

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MATERIAL AND METHODS

Seven rice varieties representing four salt tolerant (T) and three salt susceptible (S) (Table 1) were crossed in a half diallel fashion to develop 21 F_1. The materials comprising of 21 hybrids (7 T/T, 12 T/S and 3 S/S) and seven parental lines were grown in a randomized complete block design with three replications for field evaluation under saline-alkali environment. Thirty days old seedlings were transplanted. Each plot consisted of 3 m long three rows with spacing of 20 cm between the rows and 15 cm between the plants in a row. Recommended package and practices were applied in the experimental plots to raise the good crop. From the saline-alkali affected area, the field was selected to conduct the present experiment. The observation on soil status was analyzed in the Department of Soil Science of the university, which was found to be high pH=9.6 and E.C.=1.20 mmhos cm^{-1}. At flowering and maturity stages, observations were recorded on ten quantitative traits from ten randomly selected plants in parents and F_1s in each plot in a replication (Table 2). Data on days to 50% flowering was, however, taken on the whole plot basis. Plot means were computed from the data collected. Performance of the F_1s were evaluated on the basis of estimates of heterosis and heterobeltiosis (Fonseca and Patterson, 1968) and standard heterosis against the best high

Table 1. Salient features of genotypes used in the study

S.No.	Name	Parentage	Origin	Stature	Duration	Grain Characters	Ecological conditions
1.	Usar 1	Getu /Jaya	India	Tall	140	Bold	Salt tolerant/irrigated
2.	NDR 5024	Jaya/NDR 502	India	Semi-dwarf	130	Medium bold	Salt tolerant/irrigated
3.	Jaya	TN(1)/T141	India	Semi-dwarf	135	Bold	Salt tolerant/irrigated
4.	Saket 4	TKM6/IR8	India	Dwarf	115	Long slender	Salt tolerant/Early upland
5.	IR24	IR 8/ IR 127-2-2	IRRI	Dwarf	120	Long slender	Upland/irrigated/salt susceptible
6.	Manhar	IR 20/Cavery	India	Dwarf	120	Long slender	Upland/irrigated/salt susceptible
7.	IR 26	IR 24/ TKM 6	IRRI	Dwarf	125	Long slender	Irrigated/salt susceptible

Table 2. Analysis of variance for different characters in a 7 parents-diallel mating design in rice

Source of variation	d.f.	Mean square									
		Days to 50% flowering	Plant height (cm)	Tillers per plant	Productive tillers per plant	Spikelets per panicle	Sterile spikelets per panicle	Straw yield per plant (g)	100 grain weight (g)	Protein content (%)	Grain yield per plant (g)
Replication	2	0.62	2.67	3.93	2.85	8.38	0.74	1.50	0.002	0.06	0.35
Treatments	48	108.14^{**}	199.28^{**}	32.83^{**}	24.13^{**}	611.48^{**}	63.69^{**}	114.14^{**}	0.11^{**}	3.45^{**}	35.97^{**}
Parents	6	134.74^{**}	210.03^{**}	20.60^{**}	20.78^{**}	990.49^{**}	87.89^{**}	123.30^{**}	0.11^{**}	3.24^{**}	43.26^{**}
F_1s	20	78.53^{**}	180.32^{**}	22.43^{**}	19.32^{**}	320.04^{**}	67.91^{**}	81.29^{**}	0.07^{**}	3.55^{**}	34.97^{**}
Parents vs F_1s	1	494.48^{**}	682.50^{**}	105.33^{**}	79.71^{**}	3381.86^{**}	4.79^{*}	819.25^{**}	0.46^{**}	0.07	95.79^{**}
Error	96	2.14	2.16	0.90	0.71	3.74	0.71	0.87	0.002	0.04	0.71

*,** Significant at 5 and 1 per cent level, respectively.

Table 3. Mean of various traits and mean and range of heterosis in diverse ecotypes of rice under saline-alkali environment

Particular	Parameter	Hybrid /Parent	No	Traits			
				Days to 50% Flowering	Plant height	Protein content (%)	Grain yield per plant
Absolute value	Mean	T/T	6	102.8	68.07	7.03	15.48
		T/S	12	99.74	61.66	8.04	15.42
		S/S	3	95.44	55.53	8.48	9.57
		Parent	7	94.42	56.03	7.89	12.14
	Range	T/T		99.67 to 105.67	60.66 to 71.51	6.25 to 8.97	12.62 to 19.03
		T/S		88.67 to 105	51.70 to 71.83	6.69 to 9.84	9.24 to 20.49
		S/S		89.67 to 100.33	46.56 to 63.37	7.75 to 9.32	8.81 to 10.26
		Parent		84.00 to 103.33	44.35 to 70.49	6.63 to 9.52	7.17 to 18.26
Heterosis(%)	Mean	T/T	6	7.07	13.58	-9.49	7.93
		T/S	12	5.60	11.33	2.86	31.33
		S/S	3	3.83	9.27	13.44	5.56
	Range	T/T		-0.66 to 16.18	5.90 to 21.34	-30.32 to 16.60	-7.33 to 20.25
		T/S		-2.45 to 11.88	-4.79 to 25.1	-14.99 to 21.05	-9.29 to 55.28
		S/S		-0.74 to 8.08	-4.37 to 17.7	8.59 to 18.93	5.56 to 27.05
Heterobetiosis (%)	Mean	T/T	6	13.60	24.61	-21.31	-3.29
		T/S	12	11.28	23.39	-4.06	8.64
		S/S	3	5.77	17.41	6.85	-8.12
	Range	T/T		2.4 to 25.79	12.42 to 34.08	-34.35 to 2.44	-24.75 to 13.76
		T/S		5.15 to 19.93	-4.39 to 61.98	-23.84 to 16.16	-36.85 to 41.96
		S/S		-0.37 to 10.66	5.00 to 27.75	2.87 to 14.54	-28.19 to 20.22
Standard heterosis (%)	Mean	T/T	6	3.40	-24.56	-6.87	14.68
		T/S	12	0.25	-31.66	6.51	14.22
		S/S	3	-4.08	-38.46	12.41	-29.09
	Range	T/T		0.17 to 6.20	-32.77 to -20.75	-17.22 to 18.81	-6.52 to 40.96
		T/S		-10.88 to 5.53	-42.7 to -20.39	-11.39 to 30.33	-31.56 to 51.78
		S/S		-9.88 to 0.83	-48.4 to -29.77	2.65 to 23.44	-34.74 to -24
Inbreeding depression	Mean	T/T	6	1.36	4.51	-1.36	-6.17
		T/S	12	0.93	5.26	3.14	17.14
		S/S	3	3.31	0.39	18.83	-13.86
	Range	T/T		-3.68 to 7.89	-5.06 to 18.06	-34.08 to 29.74	-20.34 to 34.54
		T/S		-9.56 to 6.85	-8.88 to 20.21	-27.11 to 34.62	-15.9 to 47.06
		S/S		0.69 to 5.58	-7.11 to 12.13	8.42 to 28.72	-44.02 to 14.57
No. of hybrids showing significant better performance over Sarjoo 52		T/T	6	0 (0%)	6 (100%)	1 (16.6%)	3 (50%)
		T/S	12	4 (33.3%)	12 (100%)	6 (50%)	8 (66.6%)
		S/S	3	2 (66.6%)	3 (100%)	2 (66.6%)	0 (0%)

Table 4: Magnitude of heterosis (%) for grain yield and its components in top ten hybrids

Heterotic hybrids	Grain yield per plant	Days to 50% flowering	Plant height	Tillers per plant	Productive tillers per plant	Spikelets per panicle	Sterile Spikelets per panicle	Straw yield	100-grain weight	Protein content
Heterosis										
Saket 4/Manhar	55.28**	11.88**	3.98	19.17*	58.97**	23.09**	10.64**	65.57**	9.97**	5.44**
Usar 1/ IR 24	53.44**	-1.72	21.13**	35.44**	33.23**	15.4**	11.17**	57.99**	16.76**	21.05**
Usar 1/IR 26	51.48**	5.88**	4.25**	26.00**	18.23**	36.69**	24.72**	69.56**	16.08**	-7.38**
Jaya/Manhar	50.93**	-2.45*	16.58**	26.07**	15.98**	18.27**	4.22**	106.83**	18.31**	9.52**
Jaya/IR 26	46.92**	5.96*	-2.01	-1.51	4.08	34.07**	12.43**	81.19**	7.04**	12.18**
NDRK5024/Manhar	39.00	11.39**	25.10**	21.58**	13.87**	33.26**	-24.82**	69.79**	12.19**	13.07**
NDRK5024/IR 24	31.97**	7.80**	9.37**	17.85*	19.45**	6.29**	-52.39**	4.67	4.36	-8.59**
Manhar/IR 26	27.05**	4.14**	14.47**	3.96	34.49**	40.13**	38.97**	84.87**	20.85**	18.93**
Usar 1/ Manhar	26.55**	7.93**	23.76**	35.46**	67.08**	22.56**	-7.75*	35.50**	0.50	-14.99**
NDRK5024/Jaya	20.25**	1.68	6.78**	17.15*	2.88	0.48	-9.44**	-4.40	10.80**	-9.49**
Heterobeltiosis										
Usar 1/ IR 24	41.96**	5.15**	32.24**	28.33**	24.54**	5.05**	46.24**	49.15**	5.80**	3.40*
Saket 4/Manhar	32.35**	15.87**	16.59**	7.40	35.42**	5.79**	26.32**	62.14**	2.29	-0.93
Jaya/Manhar	20.71**	8.52**	26.47**	19.92**	7.37	3.16	9.66**	90.61**	7.06**	1.90*
Manhar/IR 26	20.22**	7.04**	27.75**	0.00	31.02**	40.01**	42.21**	79.00**	7.78**	14.54**
Saket 4/IR 24	15.53**	5.56**	12.37**	9.23*	15.12**	7.64**	13.83**	-1.77**	4.79*	16.16**
Jaya/IR 24	13.96**	15.07**	16.50**	14.20**	15.92**	-20.81**	-21.28**	51.50**	-1.96	-10.74**
Usar 1/ Jaya	13.76**	3.97**	34.08**	20.16**	23.28**	20.11**	83.15**	36.18**	0.17	-33.12**
Usar 1/IR 26	13.35**	10.53**	12.00**	24.60**	12.37	17.59**	37.46**	33.33**	10.24**	-14.11**
Jaya/IR 26	12.77**	9.12**	0.60	-9.70*	-5.94	17.03**	15.52**	62.13**	5.31*	8.23**
Jaya/Saket 4	10.45**	25.79**	16.94**	4.85	5.32	11.88**	39.00**	70.35**	9.41*	2.44*
Standard heterosis										
Usar 1/ IR 24	51.78**	-4.19**	-22.27**	20.41**	9.14	18.65**	23.64**	39.67**	18.29**	30.33**
NDRK5024/IR 24	49.26**	1.84	-25.14**	28.82**	25.00**	20.60**	-30.45**	9.79**	2.29	-11.39**
NDRK5024/Jaya	40.96**	1.18	-27.60**	30.71**	6.29	2.24	18.50**	-7.00*	12.57**	-0.26
NDRK5024/Manhar	35.33**	4.85**	-20.39**	29.82**	10.5*	20.35**	-5.45**	56.13**	3.43**	15.50**
Usar 1/ Jaya	21.63**	5.20**	-22.92**	18.29**	4.79	11.35**	54.86**	27.50**	12.00**	-15.63**
Usar 1/IR 26	21.19**	5.53**	-32.17**	4.59	-14.36**	9.01**	16.23**	24.83**	22.86**	8.34**
Usar 1/ NDRK5024	20.67**	0.17	-21.80**	28.29**	29.71**	16.32**	28.27**	15.67**	18.29**	-17.22**
Jaya/Manhar	19.78**	-1.84	-37.84**	18.06**	-8.71	-7.62**	6.68*	29.46**	4.00	18.15**
Jaya/IR 24	13.04*	4.85**	-33.03**	12.41**	1.57	-10.56**	-15.77**	26.00**	-4.57*	3.44
Jaya/IR 26	11.85*	4.19**	-42.16**	-11.12*	-20.07**	4.80**	17.64**	10.13**	5.71**	25.43**

*,** Significant at 5 and 1 per cent level, respectively.

yielding variety, Sarjoo 52 (Virmani *et al*., 1982). Statistical significance of heterosis were tested by comparing these values with the critical difference values.

RESULTS AND DISCUSSION

Analysis of variance indicated that mean squares due to parents, F_1s and F_2s were highly significant (Table 2) which indicated the presence of wide differences among genotypes (parental lines and hybrids) under saline-alkali condition. Mean of T/T (6), T/S (12) and S/S (3) and heterosis estimates for yield and associated traits are given in Table 3.

Heterosis for days to 50% flowering

In general, hybrids were late flowering than parents and standard variety. Mean estimates of heterosis, heterobeltiosis and standard heterosis were all positive except for standars heterosis in case of S/S hybrids (Table 3). Among T/S hybrids, heterosis ranged between -2.45 to 11.88 % with a mean of 5.60%, heterobeltiosis from 5.15 to 19.93% with a mean of 11.28% and standard heterosis from -10.88 to 5.53% with a mean of 0.25%. Similar values of heterosis were reported for S/S hybrids but the magnitude of positive values being slightly lower for heterosis and heterobeltiosis and negative for standard heterosis. Among T/T hybrids, heterosis ranged between -0.66 to 16.18% with a mean of 7.07%, heterobeltiosis 2.4 to 25.79% with a mean of 13.60% and standard heterosis 0.17 to 6.20% with a mean of 3.40%. The relative magnitude of heterosis in inter and intra-group of hybrids indicated that S/S group exhibited higher values of heterosis for early flowering than T/T and T/S hybrids. Long duration of inter and intra-group hybrids involving medium to late flowering duration parents has been considered as the major barrier in exploiting high yield potential of these hybrids to increase the per day productivity (Ikahashi *et al*., 1994; Khush & Aquino, 1994). Results indicated that 29% of the hybrids with significant standard heterosis for flowering were heterotic for early flowering. Interestingly, early heterotic combinations were involving tolerant/susceptible parents over mid parent (Usar 1/IR 24 and Jaya/Manhar), better parent (Usar 1/IR 24) and standard variety (Usar 1/IR24). These hybrids also recorded higher heterosis for maximum grain yield (Table 3 & 4). Negative heterosis for days to flowering combined with high heterosis for grain yield over Sarjoo 52 is highly encouraging as the hybrids would not only be superior in their yield potential but also exhibit much higher per day productivity. Similar reports have been made with inter-varietal hybrids (Virmani *et al*., 1981; Kim & Rutger, 1988; Young & Virmani, 1990) and intersubspecific hybrids (Dwivedi *et al*., 1998).

Heterosis for plant height

Most of the T/S hybrids were taller than the parental lines which indicated heterosis as well heterobeltiosis for plant height. Mean height of parental lines ranged between 44.56 to

70.49 cm indicating dwarf stature (Table 3). Hybrids recorded relative heterosis values ranging between 5.90 to 21.34% in T/T, -4.79 to 25.1% in T/S and -4.37 to 17.7 % in S/S hybrids with the respective means of 13.58, 11.33 and 9.27%. As regards with heterobeltiosis, hybrids T/T, T/S and S/S ranged between 12.42 to 34.08, -4.39 to 61.98 and 5.00 to 27.75% with the mean value of 24.61, 23.39 and 17.41%, respectively. For standard heterosis, T/T hybrids ranged between -32.77 to -20.75% with mean of -24.56%, T/S hybrids between -42.7 to -20.39% with mean of -31.66 % and S/S hybrids -48.4 to -29.77% with mean of -38.46%. These results indicated maximum mean height as well as the magnitude of heterosis for S/S followed by T/T and T/S hybrids. Hybrids recoded mean height between 46.56 to 71.83 cm. For T/T hybrids, it was only slightly higher as compared to other groups. It indicated that the plant type of F_1 rice hybrids fall within the useful range, only some were very dwarf. Therefore, height did not change useful range to non-useful range. Jennings *et al*. (1979) reported this range to be useful in rice. This showed better prospects of selecting parental combinations having optimum plant height for higher yield. Hybrids Usar 1/ IR 24, NDRK5024/IR 24 and NDRK5024/Jaya exhibiting higher grain yield also combined significant standard heterosis for plant height (Table 4).

Strong root system and thicker culms of hybrid may be responsible for their lodging resistance and higher yields. Similarly, Virmani *et al*. (1982), Ikehashi *et al*. (1994) and Dwivedi *et al*. (1998) also noted that hybrid derived from semi-dwarf parents was almost equal to or slightly taller than the parents. Lin & Yuan (1980) reported better lodging resistance in hybrids than parents despite their little taller stature. Therefore, to develop inter ecosystem hybrid rice possessing semi-dwarf plant type, observations that both the parents of the hybrids should be semi-dwarf possessing the same dwarfing gene. Such a gene has been identified in variety MD-2 and Shen Nung 89-336 gene for developing hybrids at IRRI (Khush & Aquino, 1994). Tolerant and susceptible parents involved in this study had allelic Sd_1 gene. This had overcome only partially the problem of increased heterosis in plant height but not completely as also reported by Yuan (1994 and Dwivedi *et al*. (1998).

Heterosis for grain yield per plant

Mean grain yield of six T/T, 12 T/S and three S/S hybrids and heterosis estimates are given in Table 3. Hybrids of T/T and T/S group were superior to respective parents in mean yield per plant revealing substantial heterosis for grain yield. As expected, the absolute yield of T/T and T/S hybrids were higher than that of S/S. The magnitude of yield differences between the hybrids was also higher in T/T and T/S than that of S/S. The results indicated better adoption of T/T and T/S hybrids under saline-alkali situation. The mean heterosis for T/T hybrids ranged from -7.33 to 20.25% with an average of 7.93% , heterobeltiosis ranged from -24.75 to 13.76% with an average of -3.29% and standard heterosis ranged from 6.52 to 40.96% with an average of 14.68%. Among T/S hybrids, mean heterosis ranged from -9.29 to 55.28% with the average of 31.33%. Heterobeltiosis also ranged from -36.85 to 41.96% with average value of 8.64%. The mean standard heterosis estimates ranged from -31.56 to 51.78 having mean value of 14.22%. As regards to S/S hybrids, these estimates were much lower than those in T/T or T/S hybrids. The mean heterosis ranged from 5.56 to 27.05% with average of 5.56%, heterobeltiosis from -28.19 to 20.22% with average of -8.12% and standard heterosis ranged from -34.74 to -24% with average of -29.09%. The maximum estimates of heterosis in the T/S group of hybrids ranged between 11.88 to 25.10%, heterobeltiosis 16.16 to 61.98% and standard heterosis -20.29 to 30.33% which were much higher as compared to ranges for T/T and S/S hybrids indicating thereby greater importance of genetically diverse parents involving in heterotic expression (Khush & Aquino, 1994; Dwivedi *et al*., 1998). From the plant breeding viewpoint, standard heterosis is of practical significance. In this study the standard heterosis was calculated over Sarjoo 52, a medium duration variety, which yielded significant higher than other varieties used in this study. Sarjoo 52 is also presently the most popular cultivar with maximum acreage in the state of Uttar Pradesh and are salt tolerant. Data represented higher frequency of T/S hybrids showing significant heterosis and heterobeltiosis for grain yield than T/T and S/S hybrids and standard heterosis at par with T/T and much higher than the S/S hybrids. In general, the frequency of hybrids depicting significant and positive standard heterosis for grain yield was 50% in T/T, 66.6% in T/S and 0% in S/S hybrids. It indicated predominant role of diverse genotypes in determining the heterotic combinations as also supported by Dwivedi *et al*. (1998) and Tiwari *et al*. (2011). Straw yield (high dry matter), 100 seed weight, spikelets per panicle, productive tillers per plant and short stature causes higher yields. Hybrid Usar 1/IR 24, Usar 1/IR 26, Jaya/Manhar and Jaya/ IR26 (Table 4) exhibited higher heterosis, heterobeltiosis and standard heterosis.

Heterosis for protein content

Most of the T/S and S/S hybrids having higher protein content than the parental lines which indicated heterosis for the protein content among these two groups of hybrids. Mean protein content of parental lines ranged from 6.63 to 9.52% indicating medium protein content (Table 3). Hybrids recorded relative heterosis ranging between 30.32 to 16.60% in T/T, -14.99 to 21.05% in T/S and 8.59 to 18.93% in S/S with the respective mean of -9.49, 2.86 and 13.44%. As regards to heterobeltiosis, hybrids T/T, T/S and S/S ranged between -34.35 to 2.44, -23.84 to 16.16 and 2.87 to 14.54% with the mean values of -21.31, -4.06 and 6.85%, respectively. For standard heterosis, T/T hybrids ranged between -17.22 to 18.81 with mean of -6.87%, T/S hybrids between –11.39 to 30.33 with mean of 6.51% and S/S hybrids 2.56 to 23.44% with mean of 12.41%. These results indicated maximum mean protein content as well magnitude of heterosis for S/S hybrids followed by T/S and T/T hybrids. Hybrid recorded mean protein between 7.03 to 8.48%, it was at par to parents. Similar results have also been reported by the Verma el al. (2002). It indicated that the protein content of the F_1 rice hybrids fall within the parental range and improvement for protein content is genetically complex. It should be resolved by using molecular tools.

Heterosis and diverse ecotypes

Data revealed that most of the tolerant/susceptible crosses manifest heterosis for grain yield due to increased manifestation of heterosis in sink and source both (Table 4). Higher heterotic expression could be due to greater diversity between tolerant and susceptible germplasm that has largely remained distinct and there had been very little gene flow between them. They, therefore, could provide heterotic combinations if one of the parents had salt tolerant genes (Dwivedi *et al*., 1998). Also the tolerant lines used in the study were high yielding and widely adopted varieties in salinity situations. Such high yielding and adapted parents might produce larger proportion of heterotic hybrids for grain yield. Virmani (1994) and Dwivedi *et al*. (1998) also made similar observations and suggested that the parents taken to obtaining heterotic hybrids must be adapted to the prevailing conditions for which hybrids were developed. Previous reports using parents with narrow diversity in hybrids (Lu *et al*., 1993; Dwivedi *et al*., 1998) showed meager heterosis for various traits.

Trends of heterosis

Mean, heterosis, heterobeltiosis and standard heterosis in inter and intra groups hybrid in this study (Table 3-4) indicated following trends for days to 50% flowering and plant height: T/T >T/S > S/S hybrids. For Grain yield the trend was T/T >T/S > S/S for mean and standard heterosis and T/S>T/T> S/S for heterosis and heterobeltiosis. For protein content the trend was S/S>T/S>T/T. These observed trend were in agreement with the general trend of indica/japonica > indica/javanica > javanica/japonica > indica/indica > japonica/japonica reported by Yuan (1994) and Dwivedi *et al*. (1998) in their study involving different kinds of intersubspecific and intervarietal hybrids. We found that T/S and S/S hybrids involving salt tolerant and susceptible parents displayed high heterosis and also the *per se* performance over the best standard variety and therefore, we suggest them for immediate exploitation as hybrid varieties and T/T F_1 may be used for isolation of transgressive sergregants in the later generation for release of pure lines varieties for the salt affected area.

Conclusion

In summary hybrids Usar 1/IR 24, Usar 1/IR 26, Jaya/Manhar and Jaya/ IR26 exhibited higher standard heterosis for yield and yield contributing traits involved salinity tolerant and salinity susceptible genotypes with general combining ability of parents high/low indicated that these combinations are ideal for exploitation in breeding programme as hybrid varieties as well as isolating transgressive segregants for developing purelines.

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