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Research Article

Heterosis for yield and yield contributing characters in inter sub-specific crosses of rice

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Abstract :

Forty two inter and intra sub-specific hybrids were studied utilising seven wide compatible varieties (WCVs) including two *indicas* (Dular and ASD 16) and five tropical *japonicas* (WCR 6, IR 65600-32-4-6-1, IR 65601-120-3-5, IR 66158-38-3-2-1 and IR 67323-46-2-1) for nine biometrical characters including grain yield. For most of the characters, the mean heterosis per cent are in the order of *indica* / *japonica* F_1> tropical *japonica* / *indica* F_1> *indica* / *indica* F_1> tropical *japonica* / *japonica* F_1.The combinations with significant standard heterosis over local variety MDU 5 for grain yield along with important yield components recommended for heterosis breeding were Dular x IET 16114 (*indica* / *japonica*); IR 65601-120-3-5 x ADT 43, IR 67323-46-2-1 x ADT 43 (tropical *japonica* / *indica*) and IR 66158-38-3-2-1 x Odaebayeo (tropical *japonica* / *japonica*).

Key words:

Hybrid rice, Inter sub-specific, *indica* (I), *japonica* (J), Standard heterosis, tropical *japonica* (TJ)

In plant breeding programme, exploitation of heterosis is vital and considered to be one of the greatest outstanding achievements. The F_1 hybrids can be exploited commercially (or) can be used for selecting promising recombinants in the subsequent generations to release the best variety when it attained homozygosity. Heterosis in rice was first reported by Jones (1926). The expression of heterosis varied with the crosses, so also with characters (Lokaprakash, *et al* 1992). To know the potentiality of hybrids, the magnitude and direction of heterosis are important (Singh *et al.,* 1995).

Rice, being a self-pollinated crop, the commercial exploitation of hybrid vigour depends on magnitude of heterosis for grain yield. The prospects of exploiting hybrid vigour in rice catapulated the rice growing countries following the suggestions for its commercial exploitation by several researchers (Virmani, *et al.,* 1982). The magnitude of heterosis depends on the degree of genetic distinctiveness of the parental lines used. Naturally, the *indica* / *japonica* hybrids would be expected to be the ideal cross combinations from the viewpoints of adaptation and heterosis. Inter sub-specific hybrids showed increased hybrid vigour in total dry matter and spikelet number.

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However, heterosis for grain yield is difficult to realize because of high degree of spikelet sterility (Butany, *et a.,l* 1961). Development of *indica* / *japonica* inter sub-specific hybrid, therefore, assumes greater significance in realizing higher magnitude of heterosis, which is a prerequisite for widespread adoption of hybrid rice technology.

Seven 'lines' (WC genotypes) (two *indica*s namely Dular and ASD 16 and five tropical *japonica*s *viz*., WCR 6, IR 65600-32-4-6-1, IR 65601-120-3-5, IR 66158-38-3-2-1 and IR 67323-46-2-1), and all six 'testers' (MDU 5, ASD 18, ADT 43, IET 16114, IET 16920 and Odaebayeo) were sown staggered manner at ten days interval for the purpose of synchronization in flowering. Twenty nine days old seedlings were transplanted in the main field in a three row plot of 3 metre length with wider spacing between female parents and they were crossed in a line x tester fashion. Recommended packages of practices were adopted. Here, the wet cloth method of emasculation and pollination was employed for hybridization. Crossed seeds were collected separately from 42 crosses. Shade dried seeds obtained from 42 cross combinations along with their parents (seven WCVs, three *japonica*s and three *indica*s) were sown in raised nursery bed. Twenty nine days old seedlings were transplanted in the main field. The 42 hybrids were raised in a Randomized block design with two replications, whereas parents were raised adjacent to hybrid plot replicated twice and randomized separately in the same block to make it statistically more acceptable (Arunachalam, 1974). In the main field, single seedling per hill was planted with an inter and intra row spacing of 20 and 15 cm respectively. Each genotype in a replication was accommodated in a single row of 3 m length with 20 plants. Ten competitive plants were selected randomly from each genotype and from each replication to measure biometrical traits. All the recommended agronomical practices were followed throughout the crop period. Biometrical observations were recorded for nine traits *viz.,* days to 50 per cent flowering, pollen fertility per cent, plant height, productive tillers per plant, panicle length, number of grains per panicle, test weight, spikelet fertility per cent and grain yield.

The magnitude of heterosis for yield and other agronomic traits depends to a large extent on genetic differences between parents (Renhua, *et al.,* 1998 and Li, *et al.,* 1998) opined that genetic diversity between parents, within limits, has profound influence on the magnitude of heterosis for yield and other traits. In the present study, a characterwise comparative study of standard heterosis in different types of crosses was taken up with an idea to choose the best crossing type, which further raise the levels of heterosis and to make hybrid rice more remunerative and sustainable. The results are briefly discussed hereunder. Heterosis studies for days to 50 per cent flowering revealed that inter sub-specific hybrids (tropical *japonica* / *indica* and *indica* / *japonica*) are early maturing when compared to intra sub-specific ones (tropical *japonica* / *japonica* and *indica* / *indica*).

The magnitude of standard heterosis for pollen fertility per cent was in the order of I/I > TJ/I > I/J > TJ/J. Distant crosses will realize less pollen fertility per cent than closer ones is the probable reason for this behaviour. For desirable plant height (semi-dwarf), the mean heterosis per cent was in the order of TJ/I > I/I > I/J > TJ/J; TJ/I > TJ/J > I/I > I/J and TJ/I > TJ/J > I/J > I/I respectively. The probable explanation for the poor heterosis expression of I/J crosses is due to semi dwarf and dwarf nature of parents used in this investigation. For productive tillers per plant, the level of standard heterosis was high for inter sub-specific crosses than the intra sub-specific crosses with the order of I/J > I/I > TJ/I > TJ/J. The characters *viz.,* panicle length and number of grains per panicle also exhibited high standard heterosis level in inter sub-specific crosses than intra sub-specific crosses with the order of I/J > TJ/I > I/I > TJ/J. High level of heterosis for spikelet fertility is observed in I/J followed by TJ/J, I/I and TJ/I crosses in that order. The well known plant breeder's adage that more the diversity between parents more is the spikelet sterility. But in the present study because of presence of WCG *viz*., S_5^n reduces the spikelet sterility thereby the level of heterosis was high in inter sub-specific crosses than the intra sub-specific crosses. However, in test weight for standard heterosis, the comparison is projected in the order of I/J > TJ/J > I/I > >TJ/I. In general, tropical *japonica*s and *japonica*s are of bold grain types when compared to *indica*s. But the present anomaly of less grain weight of TJ/I and TJ/J can be explained in the light of medium slender nature of the *indica* and *japonica* testers used in the crosses. These hybrids outweighted by some of the *indica* hybrids developed from Dular, which possess good test weight. In case of standard heterosis studies, the order is I/J > I/I > TJ/J > TJ/J.

In general for all the characters, the mean heterosis per cent seems to be in the order of I/J > TJ/I > I/I > TJ/J. Almost similar results were reported earlier by Yuan (1994) as I/J > I/TJ > J/TJ > I/I > J/J, Ikehashi, *et al.,* (1994) as I/J > I/I > J/J and Viraktamath, *et al.,* (1999) as I/J > I/TJ > J/TJ > I/I.

Many workers have emphasized the usefulness of heterosis per cent as an important criterion for evaluation of hybrids. Therefore, the knowledge about the magnitude of heterosis would help in selection of best cross combination. Among the three types of heterosis, standard heterosis is mainly considered by plant breeders for evaluation of hybrids with a view to get superior hybrids performing well over the local standard varieties. Therefore, in the present study also, standard heterosis value was taken into account for evaluation of hybrids. The hybrids with significant standard heterosis for all the four types of cross combinations *viz* , tropical *japonica* / *indica*, tropical *japonica* / *japonica*, *indica* / *indica* and *indica* / *japonica* are discussed hereunder.

In the present study, none of the hybrids of tropical *japonica* / *indica* combination recorded superior heterotic effect for days to 50 per cent flowering in both categories, while five, two and six hybrids of tropical *japonica* / *japonica*, *indica* / *indica*, *indica* / *japonica* showed appreciable amount of heterosis over standard variety, respectively.

None of the hybrids of all four cross combinations showed significant positive heterosis for pollen fertility per cent. The non significance of all hybrids can be well supported by the fact that hybrids with distant parents realizes less pollen fertility per cent compared to closer ones.

Four hybrids *viz*., IR 65601-120-3-5 x MDU 5, IR 65601-120-3-5 x ASD 18, IR 66158-38-3-2-1 x MDU 5 and IR 66158-38-3-2-1 x ASD 18 of tropical *japonica* /*indica* type registered significant negative heterosis for plant height. Whereas, IR 66158-38-3-2-1 x ADT 43 showed desirable heterosis over standard variety alone. IR 65600-32-4-6-1 x Odaebayeo and IR 67323-46-2-1 x IET 16114, the two tropical *japonica* / *japonica* hybrids, recorded negative significant heterosis for plant height over standard variety. None of the hybrids of *indica* / *indica*, *indica* / *japonica* showed negative heterosis.

For productive tillers per plant, IR 66158-38-3-2-1 x ASD 18 and IR 66158-38-3-2-1 x ADT 43 are the two tropical *japonica* / *indica* hybrids which recorded positive significant heterosis. All (six) hybrids of *indica* / *japonica* registered significant positive heterosis. While none of the *indica* / *indica* crosses showed positive heterosis.

Two hybrids of tropical *japonica* / *indica viz*., IR 67323-46-2-1 x ADT 43 and IR 65601-120-3-5 x ADT 43 expressed significant heterosis for panicle length over standard variety. But in tropical *japonica* / *japonica* group, WCR 6 x IET 16920 and WCR 6 x IET 16114 recorded significant heterosis. None of the *indica* / *indica* hybrids expressed positive significance, whereas four hybrids of *indica* / *japonica* showed positive significant heterosis over standard variety, respectively.

For number of grains per panicle, hybrids IR 65601-120-3-5 x ADT 43, IR 67323-46-2-1 x ADT 43 of tropical *japonica* / *indica* realized superior heterosis over standard variety, Inter sub-specific hybrids developed by WC parents realizing more yield through number of grains per panicle could explain the above results. None of the hybrids of tropical *japonica* / *japonica* and *indica* / *indica* recorded positive heterosis.

Only one hybrid of *indica* / *japonica* group namely ASD 16 x IET 16114 expressed significant positive heterosis for spikelet fertility, whereas all the hybrids of all other groups failed to register positive heterosis.

Thirteen hybrids of tropical *japonica* / *indica* expressed positive significant heterosis for test weight over standard variety. In case of tropical *japonica* / *japonica*, *indica* / *indica* and *indica* / *japonica*, thirteen, six and six recorded significant positive heterosis over standard variety, respectively.

For grain yield, six (WCR 6 x MDU 5, WCR 6 x ADT 43, IR 65600-32-4-6-1 x ADT 43, IR 65601-120-3-5 x ADT 43, IR 66158-38-3-2-1 x ASD 18 and IR 67323-46-2-1 x ADT 43) hybrids of tropical *japonica* / *indica* group recorded significant positive heterosis over standard variety. The results are well supported by the work of Vijayakumar, *et al*., (1999) where they enunciated with utility of wide compatible tropical *japonica* lines as female to realize higher yields in distant crosses. In case of *indica* / *indica,* Dular x ASD 18, ASD 16 x MDU 5, ASD 16 x ASD 18 all the hybrids showed significant positive heterosis over standard variety. Four hybrids *viz*., Dular x IET 16114, Dular x IET 16920, Dular x Odaebayeo, ASD 16 x IET 16114 of *indica* / *japonica* recorded significant positive heterosis, whereas ASD 16 x IET 16920 and ASD 16 x Odaebayeo expressed positive heterosis over standard variety alone.

Swaminathan *et al* (1972) stressed the need for calculating standard heterosis for commercial exploitation of hybrid vigour. The hybrid which is likely to be released for commercial scale should surpass the yield level of locally cultivated superior variety / hybrid. Hence, in practical breeding programme, standard heterosis would alone be taken into consideration for selection of hybrids rather than mid and better parental heterosis.

The TJ /I hybrid IR 65600-32-4-6-1 x ADT 43 recorded highest standard heterosis (34.98%) followed by TJ /I hybrids viz., IR 65601-120-3-5 x ADT 43 (33.42%), IR 67323-46-2-1x ADT 43 (18.31%), WCR 6x MDU 5 (11.58%) and IR 65600-32-4-6-1 x MDU 5 (6.49).

The hybrids viz., IR 65600-32-4-6-1 x ADT 43 and IR 65601-120-3-5 x ADT 43 exhibited high (>30%); the hybrids viz., IR 67323-46-2-1x ADT 43 and WCR 6x MDU 5 recorded medium (>20%) and the hybrid IR 65600-32-4-6-1 x MDU 5 showed the low (<10%) standard heterosis for grain yield.

Out of 42 hybrids as a whole, the hybrid ASD 16 x IET 16114 recorded superior heterotic expression for days to 50 per cent flowering, productive tillers per plant, panicle length, spikelet fertility, test weight and grain yield. Whereas, hybrids *viz*., Dular x IET 16920, Dular x Odaebayeo, ASD 16 x IET 16920 showed superior expression of standard heterosis for five traits each including grain yield. A total of five hybrids *viz*., Dular x IET 16114, ASD 16 x Odaebayeo, IR 65601-120-3-5 x ADT

43, IR 66158-38-3-2-1 x ASD 18, IR 67323-46-2-1 x ADT 43 had significantly superior standard heterosis for four traits each including grain yield. The remaining hybrids expressed superior value for less than four traits. The above mentioned nine hybrids exhibited superior heterotic values than the standard variety including grain yield. Therefore, these hybrids can be utilized for heterosis breeding.

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Table 1. Standard heterosis per cent for yield and its components in inter and intra sub-specific rice hybrids

Sl. No.	Hybrids	Cross type	Days to 50% flowering	Pollen fertility %	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility %	Test weight (g)	Grain yield (g)
1.	WCR 6x MDU 5	TJxI	1.28	-1.40	0.36	-14.86*	-4.19*	-1.82*	-13.76*	6.93*	11.58*
2.	WCR 6 x ASD 18	TJxI	3.21*	2.09	2.55	-8.78*	-8.72*	-28.40*	-9.56*	7.92*	1.72
3.	WCR 6 x ADT 43	TJxI	3.85*	0.61	3.55	-10.81*	-10.94*	-40.35*	-14.27*	10.89*	-16.91*
4.	IR 65600-32-4-6-1 x MDU 5	TJxI	7.69*	0.76	3.04	-11.49*	-4.62*	-16.54*	0.76	1.98	6.49*
5.	IR 65600-32-4-6-1 x ASD 18	TJxI	1.28	-0.21	2.68	-16.22*	-5.47*	-47.71*	-8.78*	8.91*	-35.47*
6.	IR 65600-32-4-6-1 x ADT 43	TJxI	5.77*	-2.49	6.41*	-24.32*	-4.87*	17.41*	-7.75*	10.89*	34.98*
7.	IR 65601-120-3-5 x MDU 5	TJxI	3.85*	-0.36	-10.08*	-17.57*	0.43	-43.59*	-5.13*	0.00	-40.39*
8.	IR 65601-120-3-5 x ASD 18	TJxI	5.77*	-2.44	-15.22*	-23.65*	-4.62*	-37.97*	-1.98	17.82*	-20.28*
9.	IR 65601-120-3-5 x ADT 43	TJxI	6.41*	-0.21	-0.61	-22.97*	4.70*	10.84*	-13.07*	10.89*	33.42*
10.	IR 66158-38-3-2-1 x MDU 5	TJxI	5.13*	-0.47	-8.88*	-36.49*	-13.16*	-42.09*	-7.16*	7.92*	-39.98*
11.	IR 66158-38-3-2-1 x ASD 18	TJxI	4.49*	-1.50	-7.25*	2.03*	-16.24*	-28.16*	-6.86*	45.54*	12.15*
12.	IR 66158-38-3-2-1 x ADT 43	TJxI	7.69*	-1.36	-5.23*	3.38*	-12.39*	-16.06*	-14.86*	8.91*	-5.99*
13.	IR 67323-46-2-1 x MDU 5	TJxI	0.64	-1.33	6.84*	-36.49*	-13.85*	-40.51*	-7.24*	9.90*	-42.86*
14.	IR 67323-46-2-1x ASD 18	TJxI	1.28	-0.93	7.99*	-44.59*	7.61*	5.62*	-9.12*	2.97*	-9.77*
15.	IR 67323-46-2-1x ADT 43	TJxI	4.49*	-0.36	8.91*	-29.05*	3.42*	10.44*	-6.40*	16.83*	18.31*
16.	WCR 6 x IET 16114	TJxJ	-5.77*	-9.54*	4.52*	-27.70*	3.33*	-26.74*	-7.68*	7.92*	-16.42*
17.	WCR 6 x IET 16920	TJxJ	-5.13*	-8.87*	15.04*	-33.78*	7.69*	-25.40*	-10.41*	2.97	-25.45*
18.	WCR 6 x Odaebayeo	TJxJ	-4.49*	-10.94*	1.94	-31.76*	-4.10*	-19.23*	-8.17*	24.75*	-10.67*
19.	IR 65600-32-4-6-1 x IET 16114	TJxJ	0.00	-6.53*	1.00	-34.46*	-9.66*	-8.86*	-1.33	5.94*	-15.68*
20.	IR 65600-32-4-6-1 x IET 16920	TJxJ	1.92	-5.27*	2.94	-42.57*	-26.15*	-20.81*	-4.22*	14.85*	-20.28*
21.	IR 65600-32-4-6-1 x Odaebayeo	TJxJ	2.56	-7.35*	-6.36*	-38.51*	-25.21*	-10.44*	-3.02*	20.79*	-13.22*
22.	IR 65601-120-3-5 x IET 16114	TJxJ	-0.64	-9.90*	-6.13	-44.59*	-9.23*	-31.80*	-8.34*	3.96*	-49.26*
23.	IR 65601-120-3-5 x IET 16920	TJxJ	-1.92	-12.72*	-2.25	-43.92*	-18.21*	-29.51*	-6.88*	10.89*	-39.98*
24.	IR 65601-120-3-5 x Odaebayeo	TJxJ	0.64	-5.40*	-2.45	-45.27*	-17.69*	-25.16*	-2.22	13.86*	-33.50*

* Significant at 5 per cent level

Contd..

Table 1. Contd..

Sl. No.	Hybrids	Cross type	Days to 50 % flowering	Pollen fertility %	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility %	Test weight (g)	Grain yield (g)
25.	IR 66158-38-3-2-1 x IET 16114	TJxJ	-0.64	-8.89*	6.10*	-29.05*	-12.82*	-42.48*	-13.34*	6.93*	-41.54*
26.	IR 66158-38-3-2-1 x IET 16920	TJxJ	0.64	-8.46*	2.60	-35.81*	-25.13*	-41.77*	-8.93*	0.99	-47.54*
27.	IR 66158-38-3-2-1 x Odaebayeo	TJxJ	0.00	-11.83*	2.94	-31.08*	-30.34*	-32.44*	-7.64*	28.71*	-12.73*
28.	IR 67323-46-2-1x IET 16114	TJxJ	-3.21*	-9.51*	-7.58*	-42.57*	-5.13*	-32.20*	-7.52*	17.82*	-38.01*
29.	IR 67323-46-2-1x IET 16920	TJxJ	-5.13*	-12.70*	2.27	-50.00*	-26.58*	-22.39*	-9.25*	23.76*	-33.50*
30.	IR 67323-46-2-1x Odaebayeo	TJxJ	-1.92	-7.49*	3.52	-41.89*	-26.41*	-6.49*	-7.62*	27.72*	-4.76*
31.	Dular x MDU 5	I x I	-5.13*	0.77	32.93*	-18.24*	-5.47*	-31.65*	-10.60*	14.85*	-4.68*
32.	Dular x ASD 18	I x I	-3.21*	-0.21	25.43*	-10.81*	-9.23*	-27.29*	-6.19*	21.78*	6.08*
33.	Dular x ADT 43	I x I	-1.28	2.09	22.77*	-19.59*	-13.85*	-25.16*	-8.99*	13.86*	-15.19*
34.	ASD 16 x MDU 5	I x I	6.41*	-0.02	18.25*	-4.05*	-9.91*	-0.87	-1.82	5.94*	39.90*
35.	ASD 16 x ASD 18	I x I	7.69*	-1.61	8.20*	-31.08*	-9.57*	-11.23*	-13.15*	17.82*	9.69*
36.	ASD 16 x ADT 43	I x I	9.62*	1.04	24.13*	-17.57*	-9.74*	-22.31*	-5.53*	7.92*	0.08
37.	Dular x IET 16114	I x J	-8.97*	-2.67	29.00*	2.70*	-4.62*	-8.62*	-4.03*	26.73*	59.11*
38.	Dular x IET 16920	I x J	-9.62*	1.04	30.33*	23.65*	9.66*	0.71	1.39	20.79*	118.06*
39.	Dular x Odaebayeo	I x J	-10.90*	-0.76	31.76*	8.78*	2.99*	-32.44*	-2.22	29.70*	38.75*
40.	ASD 16 x IET 16114	I x J	-9.62*	2.09	15.29*	37.84*	3.59*	-0.95	3.00*	16.83*	84.32*
41.	ASD 16 x IET 16920	I x J	-7.05*	-3.07*	6.77*	43.92*	9.66*	-8.94*	-8.51*	32.67*	35.06*
42.	ASD 16 x Odaebayeo	I x J	-8.33*	-4.01*	9.55*	29.05*	-4.79*	-0.95	-2.20	21.78*	38.10*
	S. E.		**1.08**	**1.40**	**1.41**	**0.14**	**0.14**	**1.06**	**1.34**	**0.03**	**0.45**

* Significant at 5 per cent level
I – *indica*, J – *japonica*, Tj – tropical *japonica*