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Heterosis and inbreeding studies for agronomic and quality traits in rice (*Oryza sativa* L.)

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ABSTRACT

Heterosis and inbreeding depression was studied for twenty characters in seven parental lines and their eleven hybrids in rice. Significant positive average heterosis and heterobeltiosis was observed for effective tillers, grain yield /plant, panicle density ,filled grains /panicle, panicle length, length/breadth ratio, head rice recovery, milling percent and hulling percent. Significant negative heterosis was observed for days to 50 % flowering in desired direction. Among the crosses, Kavya × WGL-915, BPT-5024 × WGL-915, Kavya × HKR-08-62, BPT-5204 × MTU-1075 and BPT-5204 × Gontrabidhan recorded significant positive heterobeltiosis for grain yield/plant and also two to three important economic characters and showed significant positive inbreeding depression . The inheritance of yield, yield components and quality traits were mostly governed by non additive type of gene action as evident from high heterosis followed by high inbreeding depression and in such cases heterosis breeding is more feasible to achieve quantum jump in rice yield while, pedigree method in few specific crosses showing low inbreeding depression in order to improve characters like head rice recovery, kernel length, length/ breadth ratio, kernel length after cooking and days to 50% flowering etc. Selection of good parents was found to be most important for developing high yielding rice varieties with desirable characters.

Key words: Heterosis, Inbreeding depression, Quality traits, Rice, Yield.

Food security in India is closely linked to sustainable rice production as it contributes > 42% of the total food grain production and is the staple food for more than two thirds of population. Although rice is a naturally self pollinated crop, strong heterosis is observed in their F_1 hybrids.

Heterosis can be defined quantitatively as an upward deviation of the mid parent based on the mean values of the two parents (Johnson and Hutchinson, 1993). Heterosis may be positive or negative. In general heterosis is desired for yield and negative heterosis for early maturity, plant height and kernel width.

Heterosis is expressed in three ways, mid parent, better parent and standard variety. However from the plant breeders view point heterosis over better parent (Heterobeltiosis) and standard check (standard heterosis) are more effective. The genetic basis for manifestation of heterosis over better parent is mainly attributed to dominance (h) and epistatic gene actions of dominance x dominance (l) of complementary nature. Mid parental heterosis was mostly under genetic effects of partial dominance.

Inbreeding depression (ID) is usually defined as the lowered fitness or vigor of inbred individuals compared with their non inbred counterparts. Inbreeding depression, the depressive effect in the expression of traits arising from increasing homozygosity (Allard, 1960). In quantitative genetics theory inbreeding depression and heterosis are due to non additive gene action and are considered to be two aspects of the same phenomenon (Mather and Jinks, 1982) .

In this work heterosis and inbreeding depression were studied by using diverse parents for selecting good materials for developing superior rice varieties for future use.

The experimental material for the present study comprised of seven genotypes Kavya, BPT-5204, Gontrabidhan, MTU-1075, WGL-915, NLR-40024 and HKR-08-62, which were photo insensitive, varied in maturation, yield potential and quality traits The parents were crossed in diallel fashion to develop F_1s (without reciprocals) during *kharif*-2015 at Regional Agricultural Research Station, Warangal., Among these hybrids a set of 11 hybrids were selected to study heterosis and inbreeding depression for twenty yield, yield components and quality traits. The eleven hybrids along with seven parents and eleven F_2s were evaluated in randomized block design with three replications during *rabi*, 2016 at Regional Agricultural Research Station, Warangal.

Each entry consists of two rows of 3m length for each of the parents and F_1s and 45 rows of F_2s. Inter and intra row spacing adopted was 20 cm and 15 cm respectively. Recommended agronomic package of practices were

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Table 1: Range of heterosis over mid parent ,better parent and inbreeding depression for yield and quality traits in rice.

Character	Range of perse performance			Average heterosis (F_1-MP / MP)	Heterobeltiosis (F_1-BP / BP)	Inbreeding Depression(F_1-F_2 / F_1)
	Parents	F_1s	F_2s			
Days to 50% flowering	93 - 118	89 - 100	92 - 101	-12.71**- -4.33**	-16.04** - - 9.18**	-5.65 - 7.46
Plant height(cm)	102.4 -124.0	105 - 137.9	100.8 -136.0	-15.42 - 8.88**	-22.59** - 3.47	-25.91** - 12.01**
Effective tillers	8 - 13.5	7.5 - 18.5	7.7 -10.2	-28.57** - 88.89**	-29.63** - 54.17**	-8.67 - 38.06*
Panicle length (cm)	20.4-29.8	24.4 – 31.5	24.1- 28.3	-13.43** - 27.31**	-24.76**- 17.04**	-13.43 – 27.31**
Panicle density	5.1 - 11.9	7.4 – 11.5	6.2-12.1	-6.92 – 47.27**	-19.53** - 43.12**	-25.00** - 16.75**
Filled seeds /Panicle	147- 259	184-331	162-306	1.69 – 29.55**	-17.16** - 28.54**	-15.69- 21.60*
Test weight(g)	15.5- 29.7	18.1-29.5	18.8-20.0	-10.42**- 21.57**	-27.49**- 2.22	-19.77**- 18.09*
Yield/Plant (g)	22.5- 32.7	28.4-47.4	15.1-26.9	-2.94 - 70.87**	-3.77 - 50.72**	5.46 - 60.86**
Hulling percent	75.7- 78.1	68.0-81.1	73.9- 80.3	-12.90** - 5.04**	-12.93**- 4.80*	-18.01* - 6.99*
Milling percent	63.4- 67.0	57.3-69.7	59.5- 68.5	-13.44**- 7.29**	-13.57* - 4.90*	-17.10*- 10.53*
Head rice recovery(%)	55.3- 62.6	30.9-66.2	28.7- 63.1	-47.13**- 6.52*	-49.88**- 5.76*	-58.67** - 8.77
Kernel length(mm)	4.7 - 6.4	4.7-6.1	4.6 - 6.1	-15.55**- 6.92**	-25.71**- 4.98	-25.37* - 3.19
Kernel width (mm)	1.54 - 1.79	1.60-1.79	1.59 - 1.76	-6.76**- 8.18**	-10.45**- 3.37	- 8.75* - 6.92
L/B ratio	2.71- 3.63	2.89-3.34	2.85 - 3.49	-11.15**- 12.72**	-18.59** - 7.95*	-16.44 - 6.11
Kernel length after cooking(mm)	5.8- 7.4	5.8-6.7	6.0- 6.8	- 8.33 - 3.42	-18.24**- 2.54	-10.78 - 6.79
Kernel breadth after cooking (mm)	2.1-2.8	2.1-2.7	2.0 - 2.4	-15.46**- 7.07	-25.45**- 6.82	-18.29 - 8.49
Kernel elongation ratio	1.2 - 1.3	1.11 - 1.28	1.03 - 1.34	-4.31 - 5.60	-5.67- 4.70	-7.23 - 11.25
Alkali spreading value	2.5 - 4.9	2.1 - 5.0	4.1-5.5	-51.72**- 23.07	-53.33** - 19.05	104.76 -16.67
Volume expansion ratio	1.55 - 3.00	1.70 - 2.90	1.85-2.30	-12.50 - 27.27	-22.22 - 27.27	-24.32-31.03
Water uptake	240- 420	208 - 403	248- 340	-13.99 - 38.94	-17.26 - 25.60	-23.64 -25.47*

***,** Significant at P=0.005 and P=0.001respectively.**

followed to raise crop successfully. Observations were recorded on five randomly selected plants in parents and F_1s and 40 plants in F_2s. Heterosis was estimated as the percent change in F_1 over the midparent(heterosis) and better parent (Heterobeltiosis) following standard methods. Inbreeding depression was computed as the percent change in F_2 over the F_1.

The range of mean performance of parents, F_1s and F_2s, heterotic effects and inbreeding depression for the characters studied are presented in Table 1. The range of mean performance was wide for most of the characters studied except hulling percent, milling percent and kernel elongation ratio.

Average heterotic effects were high for effective tillers (88.89**), grain yield / plant (70.87**), panicle density (47.27**) and test weight (21.57**), where as high and significant heterobeltiosis was observed for effective tillers (54.17**), yield per plant (50.72**), panicle density (43.12**), filled seeds per panicle (28.54**) panicle length (17.04**), length/breadth ratio (7.95**), head rice recovery (5.76**), milling percent (4.90**) and hulling percent (4.80**).

A perusal of crosses with heterotic effects revealed that none of the crosses were superior for all the traits studied (Srinivas *et al.*, 2014) Table 2. Out of eleven crosses evaluated eight crosses expressed significant average heterosis and seven crosses were significantly superior to their respective better parents for grain yield/plant. The crosses Kavya × WGL-915 (50.7**),BPT 5204 ×WGL915 (46.4**), Kavya ×HKR08-62 (44.6**), BPT5204 × MTU1075 (36.09**), BPT5204 × Gontrabidhan (35.6**), Kavya × NLR40024 (18.2**) and Gontrabidhan × WGL915 (17.7**) with higher magnitude of heterobeltiosis and also significant positive inbreeding depression indicating inbreeding resulted in loss of hybrid vigor. High degree of heterosis in F_1 and significant inbreeding depression in F_2 would be attributed to high magnitude of non additive gene effects controlling the traits, hence breeding would be more feasible and intensive selection should be practiced in large segregating populations for isolating several high yielding homozygous lines. Association of high heterosis with inbreeding depression for seed yield per plant and some of its component traits were observed by Venkanna *et al.*, (2014).

However some crosses in addition to yield per plant exhibited significant heterobeltiosis in desired direction with low or negative inbreeding depression *viz.*, Kavya× WGL-915 for filled grains/panicle and hulling percent, BPT-5204 × WGL-915 for panicle density, effective tillers, days to 50% flowering and kernel width, Kavya × HKR-08-62 for plant height, BPT-5204 × MTU-1075 for effective tillers and day to 50% flowering, BPT-5204 × Gontrabidhan for day to 50% flowering, kernel width and length/breadth ratio, whereas

Table 2: Extent of Average Heterosis (H1), Heterobeltiosis (H2) and Inbreeding depression (ID)in eleven crosses for yield , yield components and quality traits in rice.

Characters	Heterosis	Crosses										
		Kavya × Gontrabidhan	Kavya × WGL915	Kavya × NLR40024	Kavya × HKR08-62	BPT5204 × Gontrabidhan	BPT5204 × MTU1075	BPT5204 × WGL915	Gontrabidhan × WGL915	MTU1075 × NLR40024	WGL915 × NLR40024	NLR40024 × HKR08-62
Days to 50% flowering	H_1	-7.14**	-9.31**	-4.33**	-7.84**	-4.29**	-12.72**	-8.72**	-4.28**	-7.13**	-10.55**	-8.53**
	H_2	-12.08**	-10.38**	-9.18**	-9.18**	-14.47**	-15.32**	-13.19**	-10.38**	-14.48**	-16.04**	-11.94**
	ID	0	0	0	0	7.46	-1.01	1.96	0	1.59	0	-5.65
Plant Height (cm)	H_1	2.14	8.88**	6.08**	6.38**	-1.11	-1.67	-15.42**	7.84**	3.31	8.03**	2.23
	H_2	-0.34	1.32	-0.64	3.47	-1.77	-4.50**	-22.59**	-1.91	-4.25**	-5.36**	-6.69**
	ID	-0.43	8.67*	-2.71	1.56	0.05	12.01**	-25.91**	-1.84	1.35	5.47	-0.26
Effective tillers	H_1	-28.57*	5.26	-22.45	-11.11	55.00**	68.18**	88.89**	22.22	-25.49*	20.93	8
	H_2	-31.82*	-9.09	-29.63*	-13.04	55.00**	54.17**	70.00**	10	-29.63*	-3.7	0
	ID	-8.67	23.5	-6.84	11.5	38.06*	0	0	21.82	0	28.85	35.93
Panicle length (cm)	H_1	9.13*	9.32*	27.31**	2.84	8.61	10.67*	-13.43**	14.74**	15.70**	9.44*	2.04
	H_2	4.15	-3.79	17.01**	-5.56	5.13	8.4	-24.76**	-3	5.74	-10.41**	-13.19**
	ID	-1.2	8.2	9.22*	-0.92	0	3.02	-13	12.03*	3.29	7.39	-5.2
Panicle density	H_1	-6.64**	4	-7.24	20.50**	12.89**	12.39**	47.27**	8.31*	4.14	-6.92	13.08*
	H_2	-10.97**	-9.30*	-19.53**	-11.16**	-7.59*	3.33	43.12**	-9.28*	-2.22	-7.5	-6.96
	ID	-14.22*	-7.69	-17.34	16.75*	6.39	7.53	12.23	10.70*	-16.48	-25.00*	-16.33
Filled grains per panicle	H_1	2.52	16.21**	16.51**	28.15**	24.28	23.99**	27.06**	29.55**	19.95**	1.69	19.93*
	H_2	2.32	15.09**	-5.8	0.39	4.85	12.1	7.89	28.54**	3.65	-17.16**	15.05
	ID	-15.69	1.18	-6.57	16.38	-6.85	10.18	1.1	21.60*	-12.38	-15.71	11.72

Table 2: Continue.....

Table 2: Continue.....

Test weight (g)	H_1	6.14*	21.57**	1.48	-6.35*	0.84	11.80**	9.86**	2.9	2.47	-10.42**	-7.51*
	H_2	2.22	-0.67	0.27	-14.81**	-11.08**	-1	-16.36**	-13.32**	-1.99	-27.49**	-16.78**
	ID	3.61*	11.71*	0.27	-17.14*	-9.42*	18.09*	1.61	8.37*	0	-19.77*	-11.26
Grain yield per plant (g)	H_1	1.97	62.75**	23.21**	49.55**	52.68**	61.38**	70.87**	22.62**	9.85	14.43**	-2.94
	H_2	-1.73	50.72**	18.15*	44.60**	35.64**	36.09**	46.42	17.65*	3.98	10.33	-3.77
	ID	5.46	60.86**	38.26*	55.66**	32.91*	57.08**	54.29**	30.14*	42.79	50.14*	46.26**
Hulling percent	H_1	3.12	5.04*	4.86*	4.11*	4.53*	-12.90**	5.26*	2.03	3.56	2.65	3.69
	H_2	2.55	4.80*	4.17	3.46	3.46	-12.93**	3.84	1.7	2.63	2.22	3.65
	ID	1.85	-0.5	1.82	-1.32	0.93	-18.01*	3.58	-2.96	5.68	-0.32	6.99*
Milling percent	H_1	3.11	3.2	4.40*	0.46	4.26*	-13.44**	7.29**	-3.77	4.77*	3.07	1.29
	H_2	2.84	2	2.76	0.08	3.39	-13.57**	4.90*	-5.14*	4.11	0.3	-0.67
	ID	1.57	-1.97	3.2	-3	0.15	17.10*	5.54	-7.6	7.89	2.01	10.53*
Head rice recovery %	H_1	0.74	-2.54	6.52*	-14.18**	5	-14.18**	-3.93	-40.89**	-1.67	5.81*	-47.13**
	H_2	-2.24	-8.15**	5.76*	-19.18	-4.73	-15.05**	-7.02*	-42.65**	-4.62	0.41	-49.88**
	ID	0.65	-35.81	8.77	-10.48*	-1.86	-17.51	-4.73	-58.67**	1.28	2.18	7.12
Kernel length (mm)	H_1	0.66	-2.24	-2.21	6.92**	5.26*	-3.83	-15.55**	-5.21**	2.39	-3.08	-3.83*
	H_2	-1.79	-12.30**	-5.36*	-4.39*	4.98*	-6.56*	-25.71**	-16.80**	-1.57	-15.54**	-16.44**
	ID	-6.77*	-9.8	2.52	3.19	-0.89	-9.33	-25.37*	-6.82	2.49	-0.28	-9.75*
Kernel width (mm)	H_1	0.6	3.76	4.46*	8.18*	-6.76**	-0.61	-4.54*	-5.20**	4.33**	2.51	-4.76*
	H_2	-5.93**	-3.36	2.5	1.42	-10.45**	-0.61	-8.68**	-5.60*	3.37	-2.8	-9.09**
	ID	0.3	-2.03	0	5.04	-7.57	0	-7.67	0.59	5.64	6.92	-8.75*
Length/ Breadth ratio	H_1	1.02	-4.09	-5.07	0.59	12.72**	-3.28	-11.15**	0.08	-1.97	-4.85	1.52
	H_2	-6.46*	-9.15**	-8.50*	-5.66*	7.95*	-6.06	-18.59**	—11.83**	-4.94	-12.96**	-8.00**
	ID	-7.07	-7.6	2.07	-1.9	6.11	-6.79	-16.44	0	-3.36	-7.61	-0.9
Kernel length after cooking (mm)	H_1	3.42	0.38	1.28	0	0	-6.45	-7.12	-8.33	4.49	-3.03	-2.66
	H_2	2.54	-9.8	0.42	-9.86	-1.26	-10.08	-16.22**	-18.24**	-0.78	-13.51	-12.93*
	ID	-0.83	-1.87	-4.64	6.79	-2.55	-10.78	-6.45	-3.72	3.91	-2.34	2.34
Kernel breadth after cooking (mm)	H_1	-2.33	-4.12	-2.33	-3.49	4.65	-4.55	-15.46**	7.07	2.22	-5.05	6.82
	H_2	-4.55	-15.45**	-4.55	-5.68	2.27	-8.7	-25.45**	-3.64	0	-14.55**	-6.82
	ID	-11.9	3.87	2.38	-4.62	3.33	3.57	-18.29	8.49	0	3.19	-2.77
Kernel elongation ratio	H_1	5.6	2.56	3.53	-4.31	-2.31	-2.8	1.46	-1.29	2	-0.62	0.63
	H_2	4.7	2.56	0.81	-5.13	-5.67	-3.95	-1.21	-2.14	0.79	-3.24	-2.83
	ID	3.67	7.08	-7.23	0	-1.29	-2.06	8.61*	10.48	1.18	-2.51	11.25
Alkali spreading value	H_1	-19.75	-1.18	-51.72**	-10.59	21.31	-16.22	23.08	-2.63	-4.4	21.95	-3.66
	H_2	27.78	-6.67	-53.33**	-15.56	2.78	-36.73**	0	-7.5	-11.22	19.05	-5.95
	ID	-7.69	16.67	-104.76*	-10.53	-48.65	-6.45	0	0	-12.64*	0	0
Water uptake	H_1	-0.9	6.34	-13.99	20.17	38.94**	19.7	7.18	15.02	5.3	17.65	-5.49
	H_2	-12	0.93	-4.43	1.42	25.6	-4.17	3.7	7.2	-17.26	11.11	-20.57
	ID	-23.64	2.75	0	6.29	15.29	25.47*	6.25	16.42	23.74	1.67	11.61
Volume expansion ratio	H_1	27.27	13.16	1.49	12.33	8.82	11.83	-10.26	-12.5	20.83	-8.64	-5.13
	H_2	20	-4.44	5.56	-2.38	5.71	-13.33	22.22	-22.22	-3.33	-17.78	-11.9
	ID	-4.76	-6.98	-17.65	-9.76	-5.41	21.15	-5.71	-8.57	31.03	-24.32	-16.22

***,** Significant at P=0.005 and P=0.001respective.**

Kavya × NLR-40024 exhibited significant positive heterobeltiosis for head rice recovery. High heterosis for grain yield / plant and its contributing traits has been reported by Rukmini Devi *et al.,* (2014). These crosses were identified as the most desirable combinations for developing high yielding rice varieties because they showed significant positive heterosis for grain yield/ plant and other contributing traits. Hence it would be possible to spot high yielding segregants through pedigree selection in crosses having low or desirable negative inbreeding depression for improvement of yield in rice. In general the magnitude of heterosis was low for plant height, test weight and grain quality characters when compared to heterosis for yield and yield attributes. The characters head rice recovery, kernel length, kernel width, length/breadth ratio, kernel length after cooking kernel width after cooking, kernel elongation ratio, alkali spreading value and volume expansion ratio showed positive inbreeding depression in F_2 generation resulted in loss of hybrid vigor. The positive inbreeding depression indicated the presence of dominance effects for most of the characters..

Early flowering is desirable when the breeding objective is to evolve short duration varieties.In the present study ,the extent of heterosis is high (16.04**) and all the crosses showed significant average heterosis and heterobeltiosis for earliness. The crosses NLR40024× HKR08-62 and BPT5204×MTU-1075showed negative inbreeding depression and heterobeltiosis in desired direction, hence selection in early segregating generations is fruitful to evolve purelines with earliness. Similar findings were reported earlier by Raju *et.al* (2005).

One of the most yield determining factor is tillering habit of the genotype. Usually prolific tillering will aid the production of higher leaf area, higher crop growth rate and the increased sink size. High amount of heterosis was evident in three F_1s manifesting superior performance over their respective better parents was observed for effective tillers per plant. One cross BPT 5204 ×Gontrabidhan (38.1*) exhibited positive significant inbreeding depression indicating prevalence of non additive gene action in its inheritance.

Heterosis for filled grains per panicle was positive and significant in 8 crosses over mid parent and two crosses (Gontrabidhan × WGL915 and Kavya × WGL915) over better parent. The cross Gontrabidhan × WGL915 had exhibited significant positive inbreeding depression indicating preponderance of non additive gene action.

Among the quality traits, hulling percent, milling percent, head rice recovery, kernel length, kernel width, kernel length after cooking, kernel width after cooking and kernel elongation ratio recorded low heterosis values. Similar reports were stated by Rukmini Devi *et al.,(*2017) and Venkateshan *et al.,(*2008). Significant average heterosis for hulling percent was expressed in 3 crosses BPT5204× WGL915, Kavya × WGL915 and BPT5204 × Gontrabidhan while Kavya × WGL915 exhibited significant heterobeltiosis and low negative inbreeding depression. Single plant selections in segregating populations might prove fruitful. Heterosis was mostly in negative direction for kernel length and length/breadth ratio. Significant positive heterobeltiosis for kernel length and length/breadth ratio was expressed by the cross BPT 5204 × Gontrabidhan and inbreeding depression was low and negative for kernel length, while significant and positive for length/breadth ratio. Significant heterobeltiosis with low or negative inbreeding depression ,single plant selections in segregating populations might prove fruitful to achieve genotypes with longer grains. . Similar results were reported by Alam *et al.*,(2004).The crosses with high heterosis followed by inbreeding depression, in F_2 involves dominance and epistatic components of gene interaction, hence these crosses would be effectively be utilized through heterosis breeding.

In this study, the extent of heterosis for 100 seed weight was low and mostly in negative direction when compared to better parent values .Mid parental heterosis was observed in 3 crosses Kavya× Gontrabidhan, Kavya× WGL915 and BPT5204 ×WG L915. Heterobeltiosis for test weight was very low and negative. The crosses BPT-5204 × MTU-1075, Kavya × WGL-915 and Gontrahidhan ×WGL-915 showed positive significant inbreeding depression for test weight and similar findings were earlier reported by Raju *et al.*, (2005)

From the foregoing discussion, it could be concluded that the inheritance of yield, yield components and quality traits were mostly governed by non additive type of gene action as evident from high heterosis followed by high positive inbreeding depression. The crosses showing high heterosis in F_1 and inbreeding depression in F_2 for grain yield *viz.*, Kavya × WGL-915, BPT 5204 × WGL915, Kavya × HKR08-62, BPT5204 × MTU-1075 and BPT5204 × Gontrabidhan could be advant ageously utilized for generating superior hybrid derivatives transg ressing the limits of parental expression for different yield components.

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