Assessment of heterosis for yield and quality traits of fine grain rice genotypes of Uttarakhand hills

J.P. ADITYA and ANURADHA BHARTIYA

Crop Improvement Division, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263 601 (Uttarakhand)

ABSTRACT : Thirty six rice hybrids developed through line x tester crossing programme involving nine lines and four testers were evaluated for yield and its component traits. Significantly higher heterosis was observed in most of the hybrids for grain yield and components traits with few exceptions. In general, the estimated of heterosis values were low for quality traits as compared to yield and yield components. The magnitude of heterosis for all yield traits was not expressed in single hybrid combination and varied from cross to cross due to diverse genetic background of the parents. Crosses VL 30928 x Pusa Sugandh 3, VL 31486 x Pusa Sugandh 3, VL 30929 x Pusa Sugandh 3 manifested significant heterosis for grain yield as well as important quality characteristics in the desirable range whereas parent VL 30925, VL 30926, VL 30928, VL 30929, VL 31486 were the best parent for both quality characters and grain yield.

Key words: Rice, heterosis, yield, quality

Rice is one of the world's most important food crops, and staple food for 65% of the global population and forms the cheapest source of food, energy and protein (Khush, 1997). India produces 105.24 million tons from an area of 42.75 million hectares with a productivity of 2462 kg per hectare (Department of agricultural cooperation, 2012). In Uttarakhand, rice occupies 262.8 thousand ha area with annual production of 579.8 thousand ton and average productivity of 2206 kg/ha (Department of agricultural cooperation, 2012). Heterosis in rice was first reported by Jones (1926) who observed that some F1 hybrids had more culms and higher yields than their parents. However, heterosis in rice was first exploited and commercially utilized in China (Yuan *et al*., 1994).The most promising hybrids yielded 20-30% (Lin and Yuan, 1980) and 15-20% (Yuan, 1998) higher than the best hybrids and conventional rice varieties, respectively. In general, positive heterosis is desired for yield and negative heterosis for early maturity (Nuruzzaman *et al*., 2002). However, the success of hybrid rice program depends upon 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. Line x Tester analysis is one of the most powerful tools for estimating the general combining ability (GCA) of parents and selecting of desirable parents and crosses with high SCA for the exploitation of heterosis (Salgotra *et al*., 2009). Fine grain rice occupies an important position in the economy of India. The fine grain Basmati varieties of rice are considered high quality rice and fetch a high price in the national and international trade. However, yield per unit area of Basmati rice is very low due to tall plant habit and late maturity. So, broadening the genetic base of rice is an essential requirement for rice improvement programme. Although many studies have been reported on the hybrid vigour for yield and yield components, information on the heterosis for fine grain in Uttarakhand hills is limited. Hence, an attempt is made in the present investigation to estimate the heterosis over mid parent and better parent for 16 yield attributes.

MATERIALS AND METHODS

Nine lines *viz.,* VL 30925, VL 30926, VL 30928, VL 30929, VL 30938, VL 31486, VL 31632, VL 31634, VL 31638 were crossed with four tester *viz.,* Pusa Basmati 1, Pusa Sugandh 2, Pusa Sugandh 3, Pusa Sugandh 5 in line x tester fashion. 13 parents and 36 hybrids were grown in randomized block design with two replications at Experimental Farm of ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. The standard package and practices were followed for raising good crop. The seedling was planted at spacing of 20 x 15 cm with two meter row length. Observations were recording on five randomly selected competitive plants of the middle row of each plot for quantitative traits *viz.*, plant height, tillers per plant, flag leaf length, flag leaf width, panicles per plant, panicle length, grains per panicle, fertile grain per panicle, thousand grain weight, kernel length, kernel width, L/B ratio, grain yield per plant whereas days to 50 per cent flowering and days to maturity were recorded on plot basis. The mean values were utilized for calculating the heterosis as percent increase or percent decrease of F_1s over mid parent (average heterosis) and over better parent (heterobeltiosis) by statistical analysis using INDOSTAT software package. The combining ability analysis was carried out following the method as suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Among the thirty six hybrids studied, most of them exhibited significantly positive heterosis over mid parent (MP) and better parent (BP) for most of the yield related traits with few exceptions (table 1). The maximum expression of heterobeltiosis (46.69%) and relative heterosis (60.21%) for grain yield per plant were observed for the hybrid VL 30929 x Pusa Sugandh 3 followed by VL 31632 x Pusa Sugandh 5(39.62% and 46.73%) which may be due to the cumulative favourable heterotic effects of some other yield attributing traits like highly significant and desirable heterosis for different quantitative traits like grains per panicle, fertile grains per panicle and tillers per plant. Tiwari *et al*. (2011) and Aditya *et al*. (2012) reported heterosis for most of yield and yield contributing characters. Short plant stature is an important character of hybrid to withstand lodging. Cross VL 31634 x Pusa Sugandh 3 showed highest significant heterosis for plant height in desired direction followed by cross VL 31638 x Pusa Sugandh 2. The highest significant heterobeltiosis and relative heterosis was observed in cross VL 30925 x Pusa Basmati 1 followed by VL 30938 x Pusa Basmati 1 for days to 50% flowering and days to maturity. Similar findings were reported by earlier workers Deoraj *et al*. (2007), Eradasappa *et al*. (2007) and Rosamma and Vijayakumar (2007) for days to 50% flowering and plant height. Cross VL 31634 x Pusa Sugandh 2 did not reach to the maturity and its value is zero in calculation of heterosis therefore, exhibited maximum heterosis otherwise, cross VL 30925 x Pusa Basmati 1 and VL 30938 x Pusa Basmati 1 showed significant maximum heterobeltiosis and relative heterosis for this trait. The significant maximum heterobeltiosis and relative heterosis was recorded by the cross VL 31632 x Pusa Sugandh 2 (52.63% & 70.59%) for tiller per plant and VL 30925 x Pusa Basmati 1(18.99% & 19.19%) for flag leaf length. Cross VL 30938 x Pusa Basmati 1 (20.12% & 20.73%) showed significant maximum heterobeltiosis and relative heterosis for panicle length followed by cross VL 31638 x Pusa Basmati 1 (18.71% & 22.28%) and VL 30926 x Pusa Sugandh 2 (18.40% & 19.38%). Grains per panicle and fertile grains per panicle are important attribute for grain yield. Cross VL 31632 x Pusa Sugandh 5 exhibited significant maximum heterobeltiosis and relative heterosis for grains per panicle and fertile grains per panicle followed by cross VL 30928 x Pusa Sugandh 3 and VL 30926 x Pusa Sugandh 3. Deoraj *et al*. (2007), Eradasappa *et al*. (2007) and Rosamma and Vijayakumar (2007) reported similar reports for productive tillers, panicle length and filled grain per panicle. For 1000 grain weight, significant maximum heterobeltiosis and relative heterosis was observed by the cross VL 30926 x Pusa Basmati 1 (21.98% & 22.73%) followed by VL 30938 x Pusa Sugandh 3 (16.85% & 16.98%), VL 30928 x Pusa Sugandh 2 (16.49% & 17.36%), VL 30925 x Pusa Basmati 1 (16.30% & 17.16%) and VL 30925 x Pusa Sugandh 2 (15.02% & 22.23%). Reduced plant height, moderate tillering, large and compact panicles, increased kernel number per panicle, increased thousand kernel weight and higher yield are the most important rice characters to be improved in breeding programs (Paterson *et al*.,2005 ; Wayne & Dilday,2003). Kernel length and L/B ratio are one of the important parameters for quality attributes in rice. In general, the estimates of heterosis values were found to be low for quality traits when compare to yield and yield components (Krishnaveni *et al*, 2005). Only one cross VL 30925 x Pusa Sugandh 2 (6.09% & 7.08%) recorded significant maximum heterobeltiosis and relative heterosis for kernel length however, three crosses *viz.,* VL 31638 x Pusa Sugandh 2 (16.90% & 21.92%), VL 31632 x Pusa Sugandh 2 (9.28% & 16.65%) and VL 30938 x Pusa Sugandh 2 (9.28% & 13.43%) showed significant maximum heterobeltiosis and relative heterosis for L/B ratio. Heterotic crosses for grain yield per plant were accompanied by heterosis for two or more component traits. This may be due to the fact that metabolic substances which favoured the development of one component had adverse effect on the other (Parihar and Pathak, 2008).

The mean performance of lines and testers for various traits are given in table 2. Among parents, VL 31486 recorded high flag leaf length, panicle length, kernel length accompanied with good grain yield per plant and 1000 grain weight. The highest grain yield per

Table 1: Heterosis over mid parent (MP) and better parent (BP) for grain yield and other traits

Cross combination	Plant height		Days to 50% flowering		Days to maturity		Tillers per plant		Flag leaf length		Flag leaf width		Panicles per plant		Panicle length	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
VL 30925 x P. Bas 1	-1.20	-4.58	-17.79**	-20.24**	-13.34**	-15.71**	31.82	11.54	19.19**	18.99**	-3.70	-7.14	30.23	12.00	0.40	-0.40
VL 30925 x P. Sug 2	-1.47	-6.33	-3.14**	-3.75**	-1.52**	-2.01**	35.14	31.58	3.95	-0.96	-12.28	-13.79	29.73	26.32	12.80*	11.01
VL 30925 x P. Sug 3	5.40	-1.89	-4.82**	-5.42**	-3.87**	-4.67**	45.45	33.33	-3.63	-4.28	3.33	-3.13	39.39	27.78	8.78	7.01
VL 30925 x P. Sug 5	7.03	3.21	-1.69**	-2.11**	-1.86**	-2.03**	26.32	20.00	4.82	4.47	8.77	6.90	26.32	20.00	4.56	1.25
VL 30926 x P. Bas 1	11.11**	3.88	-6.61**	-13.10**	-5.26**	-10.58**	-6.67	-19.23	11.47*	8.04	10.71	3.33	-9.09	-20.00	7.57	5.84
VL 30926 x P. Sug 2	6.01	-2.38	-12.04**	-16.25**	-8.17**	-11.41**	0.00	0.00	4.53	-3.47	-11.86	-13.33	0.00	0.00	19.38**	18.40*
VL 30926 x P. Sug 3	17.33**	5.87	-2.41**	-7.08**	-2.25**	-6.00**	47.06	31.58	0.89	-1.74	3.23	0.00	47.06	31.58	5.48	1.34
VL 30926 x P. Sug 5	14.76**	7.15	2.21**	-1.70**	1.57**	-1.69**	7.69	5.00	-6.16	-8.90	1.69	0.00	7.69	5.00	12.58	11.64
VL 30928 x P. Bas 1	7.50*	2.82	-9.84**	-12.70**	-8.05**	-10.26**	-4.35	-15.38	-7.15	-9.52	5.45	0.00	-6.67	-16.00	14.45*	10.49
VL 30928 x P. Sug 2	13.08**	6.48	-16.39**	-17.08**	-11.60**	-11.74**	7.69	5.00	-11.5*	-17.86**	-10.34	-10.34	7.69	5.00	3.03	-1.31
VL 30928 x P. Sug 3	8.38*	-0.05	-2.94**	-3.75**	-3.18**	-3.67**	31.43	15.00	0.98	-1.12	-4.92	-9.38	25.71	10.00	14.02*	12.73
VL 30928 x P. Sug 5	8.82*	3.94	-5.31**	-5.51**	-4.89**	-5.05**	-5.00	-5.00	-0.60	-2.98	6.90	6.90	-5.00	-5.00	17.18**	10.49
VL 30929 x P. Bas 1	4.34	2.75	-12.87**	-13.04**	-10.22**	-10.51**	-4.00	-7.69	3.87	1.77	11.54	11.54	-6.12	-8.00	4.06	2.33
VL 30929 x P. Sug 2	15.68**	12.09**	-6.29**	-8.70**	-5.23**	-7.64**	20.93	8.33	4.75	-2.26	1.82	-3.45	16.28	4.17	5.88	3.31
VL 30929 x P. Sug 3	8.19*	2.61	-6.69**	-9.09**	-5.54**	-7.64**	64.10**	33.33	9.75	8.06	0.00	-9.37	64.10	33.33	10.04	9.20
VL 30929 x P. Sug 5	4.25	2.51	-6.97**	-10.28**	-5.90**	-8.60**	13.64	4.17	8.79	6.77	-5.45	-10.34	4.55	-4.17	13.88*	9.34
VL 30938 x P. Bas 1	9.87**	1.55	-17.79*	-20.24**	-12.97**	-15.06**	-7.41	-10.71	-6.93	-8.59	5.45	0.00	-5.66	-10.71	20.73**	20.12**
VL 30938 x P. Sug 2	12.15**	2.11	-8.18**	-8.75**	-6.22**	-6.38**	-10.64	-25.00	2.25	-4.38	-13.79	-13.79	-10.64	-25.00	3.98	3.66
VL 30938 x P. Sug 3	26.42**	12.82**	-2.73**	-3.33**	-2.18**	-2.67**	-2.33	-25.00	5.58	4.21	4.92	0.00	-6.98	-28.57	16.37**	13.03
VL 30938 x P. Sug 5	9.14*	0.73	-1.27**	-1.69**	-1.18*	-1.35*	-16.67	-28.57	3.29	1.62	-3.45	-3.45	-20.83	-32.14	18.13**	15.85*
VL 31486 x P. Bas 1	11.73**	5.09	-10.79**	-13.10**	-8.52**	-10.58**	-17.39	-26.92	0.72	-3.82	-1.75	-9.68	-22.73	-32.00	8.99	3.83
VL 31486 x P. Sug 2	5.93	-1.88	-9.39**	-9.58**	-7.05**	-7.05**	-2.56	-5.00	11.17*	1.22	-10.00	-12.90	0.00	0.00	9.25	3.28
VL 31486 x P. Sug 3	10.49**	0.27	-9.39**	-9.58**	-7.02**	-7.33**	48.57*	30.00	-1.20	-5.20	-7.94	-9.38	52.94	36.84	7.19	4.55
VL 31486 x P. Sug 5	7.37*	0.85	-0.84*	-1.67**	-1.35**	-1.68**	30.00	30.00	2.16	-2.29	-6.67	-9.68	28.21	25.00	6.46	-0.91
VL 31632 x P. Bas 1	17.05**	16.99**	-4.51**	-7.54**	-4.11**	-6.41**	36.59	7.69	-1.69	-5.57	-7.41	-10.71	48.57	4.00	16.95**	15.90*
VL 31632 x P. Sug 2	16.55**	14.72**	-7.14**	-7.92**	-5.21**	-5.37**	70.59**	52.63*	14.62*	4.95	8.77	6.90	93.10	47.37	7.47	7.36
VL 31632 x P. Sug 3	16.76**	12.44**	-1.26**	-2.08**	-1.51**	-2.00**	13.33	13.33	-7.78	-10.99	-13.33	-18.75*	36.00	13.33	8.91	5.36
VL 31632 x P. Sug 5	25.25**	25.13**	-1.06**	-1.27**	-1.52**	-1.68**	60.00*	40.00	5.39	1.39	12.28	10.34	86.67	40.00	15.92*	14.14
VL 31634 x P. Bas 1	-2.93	-9.43*	-4.44**	-5.95**	-3.91**	-5.45**	8.33	0.00	-3.69	-5.71	8.00	3.85	6.38	0.00	25.00**	11.67
VL 31634 x P. Sug 2	39.99**	32.65**	-9.92**	-10.66**	-100.00**	-100.00**	17.07	9.09	10.57	7.37	5.66	-3.45	17.07	9.09	24.09**	11.66
VL 31634 x P. Sug 3	-16.53**	-19.19**	4.96**	4.10**	4.32**	3.97**	18.92	0.00	-6.23	-8.65	10.71	-3.13	8.11	-9.09	-18.51**	-28.74**
VL 31634 x P. Sug 5	1.31	-5.34	-3.13**	-4.92**	-2.34**	-3.31**	-14.29	-18.18	9.51	7.04	9.43	0.00	-19.05	-22.73	22.45**	11.84
VL 31638 x P. Bas 1	20.27**	12.79**	-3.87**	-6.35**	-3.12**	-5.45**	41.67*	30.77	7.12	4.87	5.88	3.85	47.83	36.00	22.28**	18.71*
VL 31638 x P. Sug 2	-4.86	-12.12**	0.21	0.00	0.17	0.00	-7.32	-13.64	7.68	4.56	14.81	6.90	-5.00	-9.52	-1.99	-4.09
VL 31638 x P. Sug 3	9.42*	-0.98	-1.88**	-2.08**	-1.17*	-1.67**	2.70	-13.64	4.87	2.16	-8.77	-18.75*	5.56	-9.52	-2.42	-7.47
VL 31638 x P. Sug 5	10.57**	3.55	-0.84*	-1.67**	-0.51	-0.67	9.52	4.55	10.54	8.04	-11.11	-17.24	12.20	9.52	13.50*	12.90
SEm(±)	3.68	4.25	0.45	0.52	0.66	0.77	2.04	2.36	1.61	1.86	0.12	0.14	1.92	2.22	1.48	1.71
CD (P=0.05)	7.47	8.63	0.91	1.05	1.35	1.56	4.15	4.79	3.27	3.78	0.25	0.29	3.90	4.50	3.01	3.47

*, ** Significant at 5% and 1% levels of probability, respectively.

Cross combination	Grains per panicle		Fertile grains per panicle		Spikelet Sterility %		1000 grain weight		Kernel length		Kernel width		L/B ratio		Grain yield per plant	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
VL 30925 x P. Bas 1	-8.55	-18.38*	-0.77	-15.35	-19.08	-27.40	17.16*	16.30*	-8.96**	-10.76**	10.29**	7.49*	-17.48**	-21.12**	-17.93	-18.71
VL 30925 x P. Sug 2	8.44	-5.92	-3.59	-17.54	23.97	19.05	22.23**	15.02*	7.08**	6.09*	-5.78*	-14.25**	12.42**	1.47	-8.27	-18.32
VL 30925 x P. Sug 3	9.23	8.72	33.17**	22.37*	-42.03**	-50.00**	19.59**	13.57	-1.59	-6.02*	6.93*	6.65*	-7.90*	-11.87**	0.75	-4.77
VL 30925 x P. Sug 5	28.78**	11.53	44.42**	21.93*	-27.42	-31.82	16.67*	14.22	-0.94	-4.99*	12.19**	8.29*	-11.91**	-18.32**	-23.34	-36.12*
VL 30926 x P. Bas 1	11.31	-2.38	30.52*	24.84	-37.82*	-49.32**	22.73**	21.98**	-2.82	-7.93**	13.29**	12.50**	-14.23**	-19.22**	-38.27**	-39.30**
VL 30926 x P. Sug 2	5.16	-5.08	4.21	-0.62	4.59	-9.52	2.08	-5.15	7.47**	4.74	2.45	-8.33**	3.73	-5.06	-37.73**	-44.19**
VL 30926 x P. Sug 3	76.38**	40.88**	104.14**	80.63**	-28.57	-43.75**	16.69*	9.41	-1.84	-9.30**	14.13**	11.70**	-14.01**	-18.92**	6.09	0.97
VL 30926 x P. Sug 5	51.53**	37.02**	73.03**	67.52**	-33.93	-43.94*	2.29	-1.17	-8.11**	-14.74**	14.97**	13.06**	-20.16**	-27.02**	23.90	3.86
VL 30928 x P. Bas 1	7.66	1.77	18.16	10.22	-18.31	-20.55	10.71	2.75	-1.77	-4.22	-6.34*	-13.40**	4.14	-5.92	9.03	1.20
VL 30928 x P. Sug 2	-9.44	-16.96	5.75	-1.08	-36.36*	-39.13*	17.36**	16.49*	-9.04**	-9.40**	5.95*	1.54	-14.14**	-18.01**	-9.66	-25.20*
VL 30928 x P. Sug 3	60.73**	51.89**	107.96**	105.24**	-50.34**	-53.75**	6.88	5.07	-0.28	-5.25 *	-2.52	-7.42*	1.80	-7.95*	-9.56	-20.96
VL 30928 x P. Sug 5	46.72**	34.28**	83.09**	68.82**	-49.63**	-50.72**	23.06**	17.34	-1.45	-5.96*	2.61	-5.98*	-5.07	-16.65**	-19.83	-37.47**
VL 30929 x P. Bas 1	10.40	-7.51	20.19*	-3.40	-20.61	-28.77	18.68**	13.83	-1.64	-1.89	7.53**	2.83	-8.67**	-12.85**	13.44	10.69
VL 30929 x P. Sug 2	15.60	-5.63	5.39	-15.09	20.66	15.87	8.05	5.15	6.53**	3.73	-1.30	-8.55**	6.94*	-3.32	-2.81	-15.98
VL 30929 x P. Sug 3	21.85**	12.87	38.16**	18.87*	-26.09	-36.25*	0.00	-1.75	-13.81**	-16.28**	9.28**	7.46*	-21.22**	-24.75**	60.21**	46.69**
VL 30929 x P. Sug 5	-3.62	-21.45**	7.11	-14.72	-25.81	-30.30	14.02*	12.47	-8.36**	-10.59**	8.55**	2.83	-15.95**	-22.20**	-13.41	-29.76*
VL 30938 x P. Bas 1	35.15**	18.25	56.25**	55.28**	-39.05*	-56.16**	16.38*	9.87	1.88	-4.66	1.48	-9.67**	-1.99	-17.65**	-15.10	-15.67
VL 30938 x P. Sug 2	58.12**	42.37**	66.36**	64.81**	-13.68	-34.92	3.47	2.36	4.13	0.20	-8.01**	-8.11**	13.43**	9.28*	-24.93	-34.09*
VL 30938 x P. Sug 3	17.95	-5.97	25.71*	15.18	-5.36	-33.75*	16.98**	16.85*	2.16	-6.74**	3.97	-5.05	-3.46	-18.81**	-11.86	-17.94
VL 30938 x P. Sug 5	44.34**	30.21*	57.59**	56.60**	-24.49	-43.94*	10.28	7.02	-0.10	-8.42**	4.11	-8.13**	-6.78*	-23.66**	32.77*	9.23
VL 31486 x P. Bas 1	47.26**	38.49**	50.00**	49.07**	-2.33	-13.70	6.03	-9.58	-0.50	-5.99*	2.92	-2.76	-3.29	-3.35	-49.76**	-50.84**
VL 31486 x P. Sug 2	16.59	13.14	2.18	1.23	29.41	22.22	10.38	0.00	4.57*	-3.86	-8.07**	-13.82**	12.56**	-2.46	5.72	-8.40
VL 31486 x P. Sug 3	2.96	-12.58	31.43**	20.42	-51.47**	-58.75**	6.30	-4.53	-1.01	-4.03	-0.39	-3.26	-0.50	-0.67	-1.63	-9.70
VL 31486 x P. Sug 5	15.54	12.34	18.99	18.24	-6.56	-13.64	0.70	-12.02*	-4.06	-7.39**	3.35	-3.26	-7.29*	-10.16**	-15.87	-31.61*
VL 31632 x P. Bas 1	54.68**	40.87**	89.12**	72.67**	-40.69**	-41.10*	3.59	-2.40	1.87	-7.55**	9.93**	-1.77	-9.60**	-25.81**	-23.60	-34.13*
VL 31632 x P. Sug 2	19.64	12.29	36.95**	24.69	-28.89	-33.33*	-24.89**	-25.54**	8.63**	1.27	-6.73**	-7.24**	16.65**	9.28*	-12.88	-15.26
VL 31632 x P. Sug 3	13.14	-6.60	25.31*	6.28	-17.11	-21.25	3.39	3.28	-3.16	-14.19**	-0.85	-9.09**	-4.16	-21.28**	-29.84*	-35.84*
VL 31632 x P. Sug 5	108.14**	95.74**	153.10**	133.76**	-42.03**	-44.44**	1.01	-2.18	-4.90*	-15.40**	9.64**	-2.88	-15.89**	-32.67**	46.73**	39.62*
VL 31634 x P. Bas 1	9.52	0.00	-10.06	-18.27	30.56*	28.77	-4.87	-6.24	-7.44**	-16.17**	0.00	-10.99**	-9.99**	-26.48**	16.17	5.59
VL 31634 x P. Sug 2	57.49**	39.67**	-100.00**	-100.0**	198.51**	181.69**	-100.00**	-100.00**	-100.0**	-100.0**	-100.0**	-100.0**	-100.0**	-100.0**	-100.00**	-100.0**
VL 31634 x P. Sug 3	-13.32	-15.09	-23.20*	-24.37*	19.21	12.50	-7.09	-11.16	-16.32**	-26.00**	9.27**	-0.22	-25.21**	-38.86**	-69.59**	-70.56**
VL 31634 x P. Sug 5	24.07*	9.84	41.81**	27.41*	-27.01	-29.58	-2.84	-4.20	-21.04**	-29.90**	3.86	-8.35**	-26.41**	-41.36**	-70.17**	-73.15**
VL 31638 x P. Bas 1	69.07**	30.16*	38.24**	16.77	55.96**	16.44	8.05	-7.99	5.04*	4.34	0.63	-8.90**	3.17	-7.15*	41.11*	8.14
VL 31638 x P. Sug 2	-12.37	-30.93*	-2.56	-17.90	-23.23	-39.68*	11.90*	1.22	4.31	1.98	-14.54**	-16.23**	21.92**	16.90**	-43.18*	-51.84**
VL 31638 x P. Sug 3	-18.06	-41.51**	5.96	-16.23	-51.72**	-65.00**	7.26	-3.82	-4.78*	-7.87**	12.29**	4.34	-15.97**	-24.30**	-22.91	-37.96*
VL 31638 x P. Sug 5	-6.20	-25.96*	7.46	-8.28	-33.33	-48.48**	19.20**	3.99	-0.87	-3.67	13.23**	1.60	-13.82**	-24.61**	14.94	4.27
SEm(±)	12.21	14.10	9.29	10.72	4.94	5.70	1.39	1.60	0.17	0.20	0.05	0.05	0.12	0.14	1.91	2.21
CD (P=0.05)	24.80	28.63	18.86	21.77	10.03	11.58	2.82	3.26	0.35	0.41	0.10	0.11	0.25	0.29	3.88	4.48

*, ** Significant at 5% and 1% levels of probability, respectively.

Table 2: Mean performance of grain yield per plant and yield components of the parents used in the crossing programme

Parents	Plant height (cm)	Days to 50% flowering	Days to maturity	Tillers per plant	Flag leaf length (cm)	Flag leaf width (cm)	Panicles per plant	Panicle length (cm)	Grains per panicle	Fertile grains per panicle	Spikelet Sterility %	1000 grain weight (g)	Kernel length (cm)	Kernel width (cm)	L/B ratio (cm)	Grain yield per plant (g)
Lines																
VL 30925	105.85	118.50	147.50	9.00	29.65	1.40	9.00	25.25	160.50	114.00	29.01	20.55	7.63	1.87	4.08	16.15
VL 30926	113.35	108.50	138.50	9.50	31.70	1.50	9.50	24.05	95.00	73.50	23.00	20.00	7.11	1.80	3.95	15.92
VL 30928	108.00	118.00	148.50	10.00	31.35	1.45	10.00	26.70	141.50	93.00	34.34	23.65	7.55	2.09	3.61	19.23
VL 30929	101.70	126.50	157.00	12.00	31.00	1.30	12.00	25.70	186.50	132.50	28.98	22.05	7.91	1.95	4.06	17.31
VL 30938	116.20	118.50	148.50	14.00	30.85	1.45	14.00	24.60	94.50	79.50	15.89	22.80	6.93	2.28	3.04	16.69
VL 31486	111.90	119.50	149.00	10.00	32.70	1.55	9.50	27.45	111.00	79.50	28.31	28.70	8.93	2.00	4.48	17.21
VL 31632	98.50	118.00	148.50	7.50	32.30	1.40	5.00	24.40	103.50	66.50	35.81	22.90	6.48	2.26	2.87	11.92
VL 31634	85.40	122.00	151.00	11.00	28.50	1.20	11.00	19.55	152.50	98.50	35.14	20.85	6.45	2.28	2.83	13.46
VL 31638	112.60	119.50	148.50	11.00	28.50	1.25	10.50	23.40	68.00	55.50	18.20	28.80	7.84	2.19	3.58	8.77
Testers																
Pusa Basmati 1	98.60	126.00	156.00	13.00	29.75	1.30	12.50	24.85	126.00	80.50	36.11	20.25	7.95	1.78	4.48	16.46
Pusa Sugandha 2	95.40	120.00	149.00	9.50	26.85	1.45	9.50	24.45	118.00	81.00	31.41	23.30	7.49	2.28	3.28	12.62
Pusa Sugandha 3	91.20	120.00	150.00	7.50	30.05	1.60	7.50	26.10	159.00	95.50	40.06	22.85	8.39	1.88	4.46	14.38
Pusa Sugandha 5	98.30	117.50	148.00	10.00	29.85	1.45	10.00	23.65	117.50	78.50	32.82	21.45	8.31	1.74	4.78	10.77

Table 3: Range of different yield and its component characteristics in parents and hybrids

Character	Heterosis range (%)		Range		Based on mean performance Best Parents	Best Hybrids
	Average heterosis	Heterobeltiosis	Parents	Hybrids		
Plant height	-16.53 to 39.99	-19.19 to 32.65	81.50 to 121.40	71.60 to 132.60	VL 31634, P. Sug 3	VL 31634 x P. Sug 3, VL 31634 x P. Bas 1
Days to 50% flowering	-17.79 to 4.96	-20.24 to 4.10	108.00 to 127.00	99.00 to 127.00	VL 30926, Pusa Sug 5	VL 30928 x P. Sug 2
Days to maturity	-100 to 4.32	-100 to 3.97	138.00 to 158.00	0.00 to 157.00	VL 30926, VL 30925, VL 30928	VL 30925 x P. Bas 1, VL 30926 x P. Sug 2, VL 30928 x P. Sug 2
Tillers per plant	-17.39 to 70.59	-28.57 to 52.63	7.00 to 17.00	7.00 to 19.00	VL 30938, Pusa Bas1	VL 30929 x P. Sug 3, VL 31638 x P. Bas 1
Flag leaf length	-11.51 to 19.19	-17.86 to 18.99	26.30 to 37.00	24.40 to 40.70	VL 31632, VL 31486	VL 30925 x P. Bas 1, VL 30926 x P. Bas 1
Flag leaf width	-13.79 to 14.81	-18.75 to 11.54	1.10 to 1.80	1.10 to 2.00	VL 31486, P. Sug 3	VL 30926 x P. Sug 3, VL 31634 x P. Sug 3, VL 30938 x P. Sug 3
Panicles per plant	-22.73 to 86.67	-32.14 to 47.37	4.00 to 17.00	7.00 to 19.00	VL 31486, VL 30928,	VL 30928 x P. Sug 3, VL 30928 x P. Bas 1, VL 30928 x P. Sug 5
Panicle length	-18.51 to 25.00	-28.74 to 20.12	18.50 to 29.00	17.70 to 31.30	VL 30928, VL 31486	VL 30928 x P. Bas 1, VL 30928 x P. Sug 3, VL 30938 x P. Bas 1
Grains per panicle	-18.06 to 108.14	-41.51 to 95.74	66.00 to 191.00	76.00 to 250.00	VL 30929, VL 30925, VL 31634, P. Sug 3	VL 30928 x P. Sug 3, VL 31632 x P. Sug 5, VL 30926 x P. Sug 3, VL 30929 x P. Sug 3, VL 31634 x P. Sug 2
Fertile grains per panicle	-100 to 153.10	-100 to 133.76	53.00 to 138.00	0.00 to 205.00	VL 30929, VL 30925,	VL 30928 x P. Sug 3, VL 30929 x P. Sug 3, VL 31632 x P. Sug 5, VL 30926 x P. Sug 3
Spikelet Sterility %	-51.72 to 198.51	-65 to 181.69	12.12 to 47.57	8.57 to 100.00	VL 31638, VL 30938, VL 30926	VL 30938 x P. Bas 1, VL 31638 x P. Sug 3, VL 31486 x P. Sug 3,VL 30928 x P. Sug 5, VL 31638 x P. Sug 5
1000 grain weight	-100 to 23.06	-100 to 21.98	19.10 to 30.80	0.00 to 31.10	VL 31486, VL 31638	VL 31638 x P. Sug 5, VL 31638 x P. Sug 2, VL 31486 x P. Sug 2
Kernel length	-100 to 8.63	-100 to 6.09	6.43 to 9.02	0.00 to 8.75	VL 31486, Pusa Sug 3, Pusa Sug 5	VL 31486 x P. Sug 2, VL 31486 x P. Bas 1, VL 31486 x P. Sug 3
Kernel width	-100 to 14.97	-100 to 13.06	1.73 to 2.33	0.00 to 2.40	Pusa Sug 5, P. Bas 1, VL 30926	VL 30928 x P. Bas 1, VL 30928 x P. Sug 3
L/B ratio	-100 to 21.92	-100 to 16.90	2.80 to 4.85	0.00 to 4.68	Pusa Sug 5, VL 31486, P. Bas 1	VL 31486 x P. Sug 3, VL 31486 x P. Sug 2, VL 31486 x P. Sug 5, VL 31486 x P. Bas 1
Grain yield per plant	-100 to 60.21	-100 to 46.69	7.23 to 22.46	0.00 to 26.15	VL 30928, VL 30929, VL 31486, VL 30938	VL 30929 x P. Sug 3, VL 30928 x P. Bas 1, VL 30929 x P. Bas 1

plant was observed in VL 30928. VL 31634 was the least short statured plant whereas VL 30926 was the first to mature. Grains per panicle and fertile grains per panicle was maximum in VL 30929 accompanied by kernel length and grain yield per plant.

The range of parents, hybrids and range of heterosis for all the sixteen characters are given in table 3. In general, the magnitude of heterosis was low for grain quality characters as compared to the heterosis for grain yield and its component traits. Among yield components panicle length and 1000 grain weight manifested low heterosis. The hybrids recorded -100 to 60.21% average heterosis and -100 to 46.69% heterobeltiosis for grain yield per plant. For practical utility, a variety/hybrid with good yield potential combining with all quality characters in the desirable range is useful. If consider both yield and quality together crosses VL 30928 x Pusa Sugandh 3, VL 31486 x Pusa Sugandh 3, VL 30929 x Pusa Sugandh 3 manifested significant heterosis for grain yield as well as important quality characteristics in the desirable range whereas parent VL 30925, VL 30926, VL 30928, VL 30929, VL 31486, were the best parent for both quality characters and grain yield. Hence, these crosses and parents could be exploited for their yield potential and quality traits in the further breeding programme. Thus, the findings from the present study indicated that the higher and desirable magnitude of all yield related traits were not expressed in a single hybrid combination and varied from cross to cross due to diverse genetic background of their parents.

ACKNOWLEDGEMENTS

Authors are thankful to the Director, ICAR-VPKAS, Almora and Head, Crop Improvement Division for providing necessary facilities during the work carried out. We are also thankful to the technical staff of rice breeding for their help.

REFERENCES

Aditya K., Singh S. and Singh S.P. (2012). Heterosis for yield and yield components in basmati rice. *Asian J. of Agric. Res.,* 6: 21-29.

Deoraj S., Madhuviarya D.N. and Singh P. (2007). Heterosis in rain-fed transplanted rice. *Oryza,* 44 (3): 264-267..

Eradasappa E, Ganapathy K.N., Satish R.G., Shanthala J. and Nadarajan N. (2007). Heterosis studies for yield and yield components using CMS lines in rice (Oryza sativa). *Crop Res.,* 34(1&2): 152-155.

Jones, J.W. (1926). Hybrid Vigour in Rice. *J. Am. Soc. Agron.,* 18: 423-428.

Kempthorne O (1957). An introduction to genetic statistics. John Wiley and Sons, Inc: New York, Pp 453-471.

Khush GS (1997). Breaking the yield barrier of rice. *Geo J.,* 35:329-332.

Krishnaveni B, Shobha Rani N and Prasad ASR. (2005). Heterosis and inbreeding depression for yield and yield components in rice. *Oryza,* 42 (4): 256-259.

Lin, S.C. and I.P. Yuan. (1980). Hybrid rice breeding in China. In: Innovative approaches to rice breeding. pp. 35-51. IRRI, PO. Box 933, Manila, The Philippines.

Nuruzzaman, M., Alam, M.F., Ahmed, M.G., Shohael, A. M., Biswas, M. K., Amin, M. R. and Hossain, M. M. (2002). Studies on Parental Variability and Heterosis in *Rice. Pakistan J. Biol. Sci.*, 5(10): 1006-1009.

Parihar A. and Pathak A.R. (2008). Heterosis for various quantitative traits in rice. *Oryza,* 45 (3): 181-187.

Paterson A.H., Freeling M. and Sasaki T. (2005). Grains of knowledge:genomics of model cereals. *Genome Res.,*15 : 1643- 1650.

Rosamma C.A., Vijaya Kumar N.K. (2007). Variation in quantitative characters and heterosis in F1 rice (*Oryza sativa* L.) hybrids as affected by male sterile cytoplasm. *Indian J. Gent. Plant Breed.,* 67(1): 23-27.

Salgotra R.K., Gupta B.B., Praveen S. (2009). Combining ability studies for yield and yield components in basmati rice. *Oryza,* 46(1):12-16.

Tiwari D.K., Pandey P., Giri S.P., Dwivedi J.L. (2011). Prediction of gene action, heterosis and combining ability to identify superior rice hybrids. *Int. J. Bot.,* 7: 126-144.

Wayne S.C., Dilday R.H., (2003). Rice: Origin, History, Technology, and Production. Wiley Series in Crop Science, John Wiley & Sons, Inc., p. 324.

Yuan, L.P. (1998). Hybrid rice breeding in China. In: Virmani, S.S., E.A. Siddiq and K. Muratidharan. (ed.) Advances in Hybrid rice technology. International Rice Research Institute. Manila, The Philippines. Pp. 27-33.

Yuan, L.P., Z.Y. Yang and J. B. Yang (1994). Hybrid rice in China. In: Hybrid rice technology: New development and future prospects (SS Virmani, ed.). IRRI, Philippines, Pp.143-147.

Received: July 6, 2015
Accepted: February 2, 2017