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Heterosis for Yield and Yield Components in Basmati Rice

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ABSTRACT

Basmati rice varieties are well known for their pleasant aroma and good grain and cooking quality characteristics. These varieties are in general, poor yielders. The yield potential of basmati varieties can be enhanced by the exploitation of heterosis as also reflected by the huge success of PRH 10. Keeping in view, the significance of heterosis, 28 F_1 S excluding reciprocals were developed using 8x8 diallel. Mid parent, better parent and standard heterosis were estimated for yield and its components. Crosses Pant Sugandh Dhan 15 x UPR 2845-6-3-1, Pant Sugandh Dhan 15 x UPR 3003-11-1-1 and Pant Sugandh Dhan 17 x UPR 3003-11-1-1 had shown high standard heterosis for grain yield (309.53, 244.45 and 255.56%), biological yield (158.47, 150 and 124.58%) and for harvest index (58.6, 37.8 and 58.4%).

Key words: Basmati rice, diallel analysis, mid parent heterosis, heterobeltiosis, standard heterosis

INTRODUCTION

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 and/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 and 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). The magnitude of heterosis depends on the degree of genetic distinctiveness of the parental lines used (Akhter *et al.*, 2003) while, both positive and negative heterosis is useful for crop improvement, depending on objectives of the breeding. In general, positive heterosis is desired for yield and negative heterosis for earliness (Nuruzzaman *et al.*, 2002). The hybrid vigour is the manifestation of heterosis which is percent increase (positive) or decrease (negative) in the average performance of hybrid or cross over the mid-parent (relative heterosis), better parent (heterobeltiosis) and the check variety (standard/useful heterosis). Basmati rice, because of its unique aroma, flavour and cooking quality is the pride of India. The cultivation of basmati rice is very economical for farmers, but the yield potential of present varieties is very poor. Among the hybrids released, Pusa RH10 is the world's first and only superfine grained aromatic rice hybrid.

So, to increase the number of high yielding hybrids with basmati quality, it is important to know the heterotic potential of crosses between different basmati parents. Keeping this in view, 8x8 half diallel of basmati rice varieties was attempted and mid parent heterosis, heterobeltiosis and standard heterosis were estimated.

MATERIALS AND METHODS

The material was comprised of eight basmati rice varieties namely; Pant Sugandh Dhan 15, Basmati 370, Type 3, Pant Sugandh Dhan 17, Pusa Basmati 1, Pusa Sugandh 4, UPR 2845-6-3-1 and UPR 3003-11-1-1. The popular cultivar Pusa Basmati 1 was also used as check. The 36 entries (28 F_{1s} and eight parents) were grown in a randomised block design with two replications along with check at the Dr. N.E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). A single seedling per hill was transplanted at a spacing of 20x15 cm. The F_1 S and parents were planted in a two rows plot of 2 m length. Data were collected from 5 random but competitive plants, leaving border plant on each side of rows. Observations were recorded on 16 agronomical and quality traits viz., days to 50% flowering, plant height, flag leaf length, flag leaf breath, panicle length, panicles per plant, grain number per panicle, 1000-grain weight, grain yield per plant (EY), biological yield per plant (BY), Harvest Index (HI), Kernel length, Kernel breath, Kernel L/B ratio, amylose content and alkali spreading value. The mid parent heterosis, heterobeltiosis and standard heterosis were worked out as suggested by Hays *et al.* (1955) and Fonseca and Patterson (1968). However, data of standard heterosis only is given in the manuscript.

RESULTS AND DISCUSSION

The extent of heterosis depends on the genetic diversity between parents and the specific combining ability of parents viz., the extent of non-additive genetic variance. The crosses showing high degree of heterosis along with significant specific combining ability (SCA) and good general combining ability (GCA) are expected to yield superior hybrids (Bagheri *et al.*, 2008). In present study apart from measuring the extent of exploitable level of heterosis, evaluation was also done for quality and basmati standards of the hybrids.

For days to 50% flowering, crosses Pant Sugandh Dhan 17x Pusa Sugandh 4 and Pusa Sugandh 4 x UPR 2845-6-3-1 showed significant negative relative heterosis, better parent heterosis and standard heterosis over check while crosses Pusa Sugandh 4 x UPR 3003-11-1-1 and Pusa Basmati 1 x Pusa Sugandh 4 showed significant negative relative heterosis and better parent heterosis as reported by Selvaraj *et al.* (2011) for other varieties (Table 1). Days to 50% flowering of two crosses viz., Pant Sugandh Dhan 17 x Pusa Sugandh 4 and Pusa Sugandh 4 x UPR 2845-6-3-1 (-7.95, -7.01) were significantly different from check and can be used for developing early maturing hybrids as observed by Dwivedi *et al.* (1998) for other parents. For plant height, cross Type 3x UPR 3003-11-1-1 showed significant negative estimate of relative heterosis (-28.87), better parent heterosis (-40.13) and standard heterosis (-22.91) which indicated that this cross can be used for breeding dwarf hybrid. Cross Basmati 370 x Type 3 showed significant negative value of mid parent and better parent heterosis.

Cross Pusa Basmati 1xPusa Sugandh 4 showed significant positive estimate of relative, better parent and standard heterosis over check for flag leaf length and most of the crosses showed significant positive standard heterosis. This cross showing significantly high value of standard heterosis (102.70) can be utilised to develop more productive hybrids because flag leaf length and breadth contribute significantly in total photosynthate.

Crosses Pant Sugandh Dhan 15 x Basmati 370, Pant Sugandh Dhan 15 x Type 3, Pant Sugandh Dhan 15 x Pusa Basmati 1, Basmati 370 x Pant Sugandh Dhan 17 and Basmati 370 x Pusa Basmati 1 showed significant positive estimate of relative heterosis, better parent heterosis and standard heterosis for panicle length. However, crosses Basmati 370 x UPR 2845-6-3-1 (13.17), Type 3 x UPR 2845-6-3-1 (12.84), Pant Sugandh Dhan 17 x UPR 2845-6-3-1 (12.50) and Pusa Basmati 1 x UPR 2845-6-3-1 (12.33) showed significant positive value of standard heterosis. These cross combinations can be utilised for development of hybrids having longer panicles. More number of effective panicles per plant is an essential trait for developing more productive hybrids, in our study all hybrids except Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17, Type 3 x Pusa Sugandh 4 and Pant Sugandh Dhan 17 x UPR 2845-6-3-1 showed high value of relative, better parent and standards heterosis for panicles per plant (Liang *et al.*, 2003).

Crosses, Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17, Pant Sugandh Dhan 15 x Pusa Basmati 1, Pant Sugandh Dhan 15 x UPR 2845-6-3-1, Type 3 x Pusa Basmati 1, Pant Sugandh Dhan 17 x Pusa Sugandh 4 and UPR 2845-6-3-1 x UPR 3003 -11-1-1 showed significant positive estimate of relative heterosis, better parent heterosis and standard heterosis over the check for grain number per panicle. Test weight is an essential trait of basmati variety which ranged from 20-26 g. Crosses, Pant Sugandh Dhan 15x Pusa Sugandh 4, Pant Sugandh Dhan 15x UPR 2845-6-3-1, Pant Sugandh Dhan 15 x UPR 3003-11-1-1, Pusa Sugandh 4 x UPR 2845-6-3-1 and Pusa Sugandh 4 x UPR 3003-11-1-1 showed significant positive value of standard heterosis (Table 1) and also the mean value within the range of 20-26 g as observed by Suresh and Anbuselvam (2006) for other variety.

Out of 28 crosses, 23 crosses (Table 1) showed significant positive standard heterosis for grain yield per plant. This indicates that materials used in the study were quite diverse and all 23 crosses can be used for developing good hybrids as reported by Tiwari *et al.* (2011a) for other parents. All 28 crosses showed significant standard heterosis for biological yield per plant. Crosses having high grain yield per plant (economic yield per plant) and high biological yield per plant indicate that these crosses may be utilized in developing high yield potential hybrids (Akinwale *et al.*, 2011). For harvest index also 20 out of 28 crosses showed significant and positive standard heterosis. Crosses Pant Sugandh Dhan 15 x UPR 2845-6-3-1, Pant Sugandh Dhan 15 x UPR 3003-11-1-1 and Pant Sugandh Dhan 17 x UPR 3003-11-1-1 had shown high standard heterosis for grain yield (309.53, 244.45 and 255.56%) (Tiwari *et al.*, 2011a, b), biological yield (158.47, 150 and 124.58%) and for harvest index (58.6, 37.8 and 58.4%) which further support the concept that high biological yield leads to high economical yield and finally high harvest index (Bansal *et al.*, 2000).

Cross, Pant Sugandh Dhan 15 x Pusa Sugandh 4 showed the significant value for mid parent and better parent heterosis while crosses Pant Sugandh Dhan 15x Basmati 370, Pant Sugandh Dhan 15 x Type 3, Basmati 370 x UPR 2845-6-3-1 and Basmati 370 x UPR 3003-11-1-1 showed significant relative heterosis for kernel length an important quality trait of basmati rice. For kernel breadth, the cross Type 3 x UPR 2845-6-3-1 (17.65) showed significant positive value of standard heterosis while crosses Pant Sugandh Dhan 15 x UPR 3003-11-1-1 and Pusa Sugandh 4 x UPR 3003-11-1-1 showed significant positive value of relative and better parent heterosis. Crosses Basmati 370 x UPR 2845-6-3-1 (22.32) showed significant positive value of mid-parent heterosis for L/B ratio.

Table 1: Mean value and standard heterosis percent for yield and its components in 28 basmati rice hybrids

	Days to 50% flowering		Plant height (cm)		Flag leaf length (cm)		Flag leaf breath (cm)		Panicle length (cm)	
Crosses	F1 (Mean)	SH	F1 (Mean)	SH	F1 (Mean)	SH	F1 (Mean)	SH	F1 (Mean)	SH
Pant Sugandh Dhan 15 x Basmati 370	107.5	0.467	153.75	19.836**	37.4	68.468**	1.53	42.991**	32.2	8.784*
Pant Sugandh Dhan 15 x Type 3	112.5	5.14	164.4	28.137**	39.6	78.378**	1.53	42.991**	33.1	11.824**
Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17	105.5	-1.402	135.7	5.768	44.5	100.45**	1.7	58.879**	33.8	14.189**
Pant Sugandh Dhan 15 x Pusa Basmati 1	108.5	1.402	130.8	1.949	39.4	77.477**	1.52	42.056**	33.1	11.824**
Pant Sugandh Dhan 15 x Pusa Sugandh 4	114.5	7.009	149.55	16.563**	32.25	45.27*	1.175	9.813	32	8.108
Pant Sugandh Dhan 15 x UPR 2845-6-3-1	110.5	3.271*	127.25	-0.828	33.835	52.41**	1.345	25.701*	31.5	6.419
Pant Sugandh Dhan 15 x UPR 3003-11-1-1	109.5	2.336	127.25	-0.818	42	89.189**	1.525	42.523**	33	11.486*
Basmati 370 x Type 3	112.5	5.14	150.3	17.147**	33.875	52.59**	1.255	17.29	30.5	3.041
Basmati 370 x Pant Sugandh Dhan 17	118	10.280**	171.25	33.476**	29.335	32.14	1.4	30.841**	32.55	9.966*
Basmati 370 x Pusa Basmati 1	120	12.150**	171.7	33.827**	39.4	77.477**	1.21	13.084	31.9	7.77
Basmati 370 x Pusa Sugandh 4	117.5	9.813**	161.2	25.643**	34.1	53.604**	1.22	14.019	30.1	1.689
Basmati 370 x UPR 2845-6-3-1	114.5	7.009*	169	31.723**	35.25	58.784**	1.35	26.168*	33.5	13.17**
Basmati 370 x UPR 3003-11-1-1	109.5	2.336	160.7	25.253**	41.8	88.288**	1.48	38.318**	32.4	9.459*
Type 3 x Pant Sugandh Dhan 17	118	10.280**	167	30.164**	31	39.64*	1.38	28.972*	32.4	9.459*
Type 3 x Pusa Basmati 1	121.5	13.551**	167.4	30.475**	37	66.667**	1.31	22.43	32.8	10.811*
Type 3 x Pusa Sugandh 4	123	14.953**	148.5	15.744**	36.1	62.613**	1.45	35.514**	32.1	8.446
Type 3 x UPR 2845-6-3-1	117	9.346**	172	34.061**	38.9	75.225**	1.48	38.318**	33.4	12.84**
Type 3 x UPR 3003-11-1-1	104.5	-2.336	98.9	-22.915**	30.04	35.315	1.16	8.411	27.6	-6.757
Pant Sugandh Dhan 17 x Pusa Basmati 1	112	4.673	174.1	35.698**	38.2	72.072**	1.5	43.925**	32.6	10.135*
Pant Sugandh Dhan 17 x Pusa Sugandh 4	98.5	-7.944*	123.9	-3.429	37.4	68.468**	1.56	45.794**	32.6	10.135*
Pant Sugandh Dhan 17 x UPR 2845-6-3-1	98.5	-7.944*	124.75	-2.767	37.925	70.833**	1.21	13.084	33.3	12.50**
Pant Sugandh Dhan 17 x UPR 3003-11-1-1	103	-3.738	127	-1.013	31.125	40.203*	1.215	13.551	31.35	5.912
Pusa Basmati 1 x Pusa Sugandh 4	103	-3.738	117.65	-8.301	45	102.703**	1.4	30.841**	33	11.486*
Pusa Basmati 1 x UPR 2845-6-3-1	104.5	-2.336	149	16.134**	37.75	70.045**	1.45	35.514**	33.25	12.331**
Pusa Basmati 1 x UPR 3003-11-1-1	100.5	-6.075	146.05	13.835**	39	75.676**	1.47	37.383**	33.35	12.669**
Pusa Sugandh 4 x UPR 2845-6-3-1	99.5	-7.009*	133	3.663	40.7	83.33**	1.35	26.168*	30.8	4.054
Pusa Sugandh 4 x UPR 3003-11-1-1	101.5	-5.14	137.7	7.327	38.7	74.324**	1.41	31.776**	32.3	9.122*
UPR 2845-6-3-1 x UPR 3003 -11-1-1	106	-0.935	129.1	0.624	41.66	87.658**	1.535	43.458**	32.05	8.277

*, **: Significant at 5 and 1% probability level, respectively. Sh: Standard heterosis over the check

Table 1: Continued

Crosses	Panicles per plant		Grains per panicle		1000-grain weight (gm)		Grain yield per plant (gm)		Biological yield per plant (gm)	
	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH
Pant Sugandh Dhan 15 x Basmati 370	32.375	111.601**	57.79	5.901	21.65	13.351	40.5	157.143**	107.5	82.203**
Pant Sugandh Dhan 15 x Type 3	24.50	60.131**	70.655	29.47*	22.45	17.539	38.75	146.032**	115.0	94.915**
Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17	15.90	3.922	115.895	112.379**	24.2	26.702*	44.5	182.540**	116.5	97.458**
Pant Sugandh Dhan 15 x Pusa Basmati 1	24.10	57.516**	85.385	56.469**	22.85	19.634	47.0	198.413**	120.45	104.153**
Pant Sugandh Dhan 15 x Pusa Sugandh 4	35.75	133.66**	56.705	3.912	23.7	24.084*	48.0	204.762**	132.5	124.576**
Pant Sugandh Dhan 15 x UPR 2845-6-3-1	22.455	46.765**	122.040	123.639**	23.6	23.560*	64.5	309.524**	152.5	158.475**
Pant Sugandh Dhan 15 x UPR 3003-11-1-1	24.50	60.131**	93.46	71.266**	23.7	24.084*	54.25	244.444**	147.5	150.00**
Basmati 370 x Type 3	21.15	38.235**	35.67	-34.634*	20.13	5.393	15.15	-3.810	76.5	29.661**
Basmati 370 x Pant Sugandh Dhan 17	31.5	105.882**	57.20	4.819	23.15	21.204	41.45	163.17**	157.5	166.949**
Basmati 370 x Pusa Basmati 1	30.90	101.961**	74.855	37.172*	20.30	6.283	46.75	196.825**	137.5	133.051**
Basmati 370 x Pusa Sugandh 4	26.30	71.895**	30.380	-44.328**	21.90	14.660	18.2	15.556	67.5	14.407*
Basmati 370 x UPR 2845-6-3-1	29.0	89.542**	26.465	-51.503**	20.125	5.366	15.45	-1.905	69.0	16.949*
Basmati 370 x UPR 3003-11-1-1	23.80	55.556**	35.545	-34.863*	16.250	-14.921	13.75	-12.698	47.5	-19.492**
Type 3 x Pant Sugandh Dhan 17	21.60	41.176**	39.040	-28.459	21.25	11.257	17.90	13.651	77.5	31.356**
Type 3 x Pusa Basmati 1	22.60	47.712**	90.705	66.218**	19.35	1.309	39.45	150.476**	105.0	77.966**
Type 3 x Pusa Sugandh 4	19.4	26.797*	61.895	13.423	20.65	8.115	24.75	57.43**	117.5	99.153**
Type 3 x UPR 2845-6-3-1	31.55	106.209**	64.585	18.353	21.75	13.874	44.25	180.952**	127.5	116.102**
Type 3 x UPR 3003-11-1-1	19.855	28.007*	68.55	25.618	19.55	2.356	26.05	65.397**	69.0	16.949*
Pant Sugandh Dhan 17 x Pusa Basmati 1	29.75	94.444**	57.835	5.983	19.25	0.785	33.10	110.159**	142.5	141.25**
Pant Sugandh Dhan 17 x Pusa Sugandh 4	19.25	25.817*	107.47	96.940**	22.15	15.969	45.75	190.476**	140.0	137.288**
Pant Sugandh Dhan 17 x UPR 2845-6-3-1	17.55	14.706	128.91	236.229**	21.35	11.780	47.40	200.952**	127.5	116.102**
Pant Sugandh Dhan 17 x UPR 3003-11-1-1	36.50	138.562**	72.270	32435*	21.45	12.304	56.00	255.556**	132.5	124.576**
Pusa Basmati 1 x Pusa Sugandh 4	19.65	28.431*	105.180	92.743**	21.10	10.471	43.3	174.921**	112.5	90.678**
Pusa Basmati 1 x UPR 2845-6-3-1	32.585	112.974**	72.46	32.784*	17.20	-9.948	39.25	149.206**	120.0	103.390**
Pusa Basmati 1 x UPR 3003-11-1-1	26.90	75.817**	67.210	23.163	20.20	5.759	36.30	130.476**	110.0	86.441**
Pusa Sugandh 4 x UPR 2845-6-3-1	19.60	28.105*	80.610	47.719.**	24.60	28.796*	38.70	145.714**	92.5	56.780**
Pusa Sugandh 4×UPR 3003-11-1-1	21.80	42.484**	44.66	-18.160	24.70	29.319*	23.75	50.794**	80.0	35.593**
UPR 2845-6-3-1×UPR 3003 -11-1-1	21.58	41.046**	109.935	101.457**	22.30	16.754	52.75	234.921**	132.5	124.576**

*, **: Significant at 5 and 1% probability level, respectively. Sh: Standard heterosis over the check

Table 1: Continued

Crosses	Harvest index (%)		Kernel length (mm)		Kernel breath (mm)		Kernel L/B ratio (mm)		Amylose content		Alkali spreading value	
	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH	F_1 (Mean)	SH
Pant Sugandh Dhan 15 x Basmati 370	37.68	41.124**	6.8	-5.556	1.8	5.882	3.775	-12.005	23.025	-4.023	6.0	-7.692
Pant Sugandh Dhan 15 x Type 3	33.78	26.517**	6.8	-5.556	1.7	0.000	3.995	-6.876	23.045	-3.522	5.75	-11.538*
Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17	38.195	43.052**	6.9	-4.167	1.75	2.941	3.94	-8.159	22.885	-4.606*	6.835	5.154
Pant Sugandh Dhan 15 x Pusa Basmati 1	39.025	46.161**	7.3	1.389	1.7	0.000	4.29	0.000	22.500	-6.211**	6.755	3.923
Pant Sugandh Dhan 15 x Pusa Sugandh 4	36.225	35.674**	7.8	8.333	1.7	0.000	4.61	7.459	23.775	-0.896	6.0	-7.692
Pant Sugandh Dhan 15 x UPR 2845-6-3-1	42.345	58.596**	7.25	0.694	1.7	0.000	4.26	-0.699	24.075	0.354	6.585	1.308
Pant Sugandh Dhan 15 x UPR 3003-11-1-1	36.80	37.828**	7.05	-2.083	1.9	11.76	3.705	-13.636	22.700	-5.377*	6.17	-5.077
Basmati 370 x Type 3	19.82	-25.678**	6.4	-11.12*	1.65	-2.941	3.895	-9.207	23.150	-3.501	6.75	-11.538*
Basmati 370 x Pant Sugandh Dhan 17	26.335	-1.367	7.0	-2.778	1.85	8.824	3.775	-12.005	23.350	-2.668	6.42	-1.231
Basmati 370 x Pusa Basmati 1	34.050	27.528**	6.85	-4.861	1.8	5.882	3.8	-11.422	23.750	-1.000	6.755	3.923
Basmati 370 x Pusa Sugandh 4	27.010	1.161	6.2	-13.889*	1.9	11.765	3.255	-24.126**	23.250	-3.085	6.42	-1.231
Basmati 370 x UPR 2845-6-3-1	22.375	-16.19**	7.55	4.861	1.7	0.000	4.44	3.497	23.425	-2.355	6.50	0.000
Basmati 370 x UPR 3003-11-1-1	29.050	8.801	7.65	6.250	1.8	5.882	4.245	-1.049	21.25	-11.421**	6.75	3.846
Type 3 x Pant Sugandh Dhan 17	23.125	-13.39*	7.35	2.083	1.85	8.824	3.985	-7.11	22.5	-6.211**	6.585	1.308
Type 3 x Pusa Basmati 1	37.570	40.712**	6.75	-6.250	1.65	-2.941	4.085	-4.779	21.5	-10.379**	6.835	5.154
Type 3 x Pusa Sugandh 4	21.060	-21.124**	6.30	-12.50*	1.75	2.941	3.30	-23.077**	22.43	-6.503**	6.42	-1.231
Type 3 x UPR 2845-6-3-1	34.73	30.075**	6.35	-11.806*	2.0	17.647**	3.175	-25.991**	22.785	-5.023*	6.005	-7.615
Type 3 x UPR 3003-11-1-1	37.74	41.348**	6.10	-15.278**	1.6	-5.882	3.805	-11.305	22.565	-5.940*	6.250	-3.846
Pant Sugandh Dhan 17 x Pusa Basmati 1	23.26	-12.884*	5.9	-18.056**	1.8	5.882	3.27	-23.776**	23.940	-0.208	6.250	-3.846
Pant Sugandh Dhan 17 x Pusa Sugandh 4	32.74	22.622**	7.25	0.694	1.65	-2.941	4.395	2.448	23.90	-0.375	6.585	1.308
Pant Sugandh Dhan 17 x UPR 2845-6-3-1	37.17	39.213**	7.0	-2.778	1.65	-2.941	4.24	-1.166	23.475	-2.147	7.00	7.692
Pant Sugandh Dhan 17 x UPR 3003-11-1-1	42.295	58.408**	7.05	-2.083	1.75	2.941	4.025	-6.177	23.750	-1.000	7.00	7.692
Pusa Basmati 1 x Pusa Sugandh 4	38.480	44.120**	7.0	-2.778	1.75	2.941	4.0	-6.760	23.340	-2.709	5.92	-8.923*
Pusa Basmati 1 x UPR 2845-6-3-1	32.71	22.509**	6.65	-7.639	1.8	5.882	3.69	-13.986	23.410	-2.418	6.25	-3.846
Pusa Basmati 1 x UPR 3003-11-1-1	33.0	23.596**	6.95	-3.472	1.75	2.941	3.98	-7.226	23.575	-1.730	6.75	3.846
Pusa Sugandh 4 x UPR 2845-6-3-1	41.845	56.723**	7.1	-1.389	1.75	2.941	4.075	-5.012	23.200	-3.293	5.67	-12.769*
Pusa Sugandh 4 x UPR 3003-11-1-1	29.745	11.404*	7.1	-1.389	1.8	5.882	3.96	-7.692	22.925	-4.439	6.505	0.077
UPR 2845-6-3-1 x UPR 3003 -11-1-1	39.795	49.045**	6.9	-4.167	1.7	0.000	4.075	-5.012	23.500	-2.043	6.92	6.462

*, **: Significant at 5 and 1% probability level, respectively. Sh: Standard heterosis over the check

For amylose content, some crosses showed significant negative value of standard heterosis and better parent heterosis while crosses Pant Sugandh Dhan 17x UPR 3003-11-1-1, Pusa Basmati 1 x UPR 3003-11-1-1, Pusa Sugandh 4x UPR 3003-11-1-1, Pant Sugandh Dhan 15x UPR 2845-6-3- 1, UPR 2845-6-3-1x UPR 3003 -11-1-1 and Pant Sugandh Dhan 15x UPR 3003-11-1-1 showed significant positive value of relative heterosis. Amylose content in basmati rice is very important for the fluffiness of rice and it should range from 20-25%. No cross showed the significant positive deviation of amylose content from the check which means that the amylose content in crosses was in permissible limit. For alkali spreading value not a single cross showed significant deviation from the check while cross Basmati 370x UPR 2845-6-3-1 showed positive significant value of mid parent heterosis (20.99) and the better parent heterosis (20.03).

The hybrids which are likely to be released for commercial scale should surpass the yield level of locally cultivated superior variety/hybrid (Swaminathan *et al*., 1972). Hence, in practical breeding programme, standard heterosis would alone be taken into consideration for selection of hybrids rather than mid and better parental heterosis. Out of 28 hybrids and 16 characters as a whole (Table 2) most of the crosses showed significant value of standard heterosis for grain

Table 2: Crosses showing significant value of standard heterosis for different characters over check

Crosses	Characters /combination(s)
Pant Sugandh Dhan 15 x Basmati 370	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x Type 3	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x Pant Sugandh Dhan 17	Flag leaf length, flag leaf breath, panicle length, grain/panicle, test weight, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x Pusa Basmati 1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x Pusa Sugandh 4	Flag leaf length, panicles per plant, test weight, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x UPR 2845-6-3-1	Flag leaf length, flag leaf breath, panicles/plant, grains/panicle, test weight, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 15 x UPR 3003-11-1-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, test weight, grain yield, biological yield, HI
Basmati 370 x Type 3	Flag leaf length, panicles/plant, biological yield/plant
Basmati 370 x Pant Sugandh Dhan 17	Flag leaf breath, panicle length, panicles/plant, grain yield/plant, biological yield/plant
Basmati 370 x Pusa Basmati 1	Flag leaf length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Basmati 370 x Pusa Sugandh 4	Flag leaf length, panicles/plant, biological yield/plant
Basmati 370 x UPR 2845-6-3-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, biological yield/plant
Basmati 370 x UPR 3003-11-1-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant
Type 3 x Pant Sugandh Dhan 17	Flag leaf length, flag leaf breath, panicle length, panicles/plant, biological yield/plant
Type 3 x Pusa Basmati 1	Flag leaf length, panicle length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Type 3 x Pusa Sugandh 4	Flag leaf length, flag leaf breath, panicles/plant, grain yield/plant, biological yield/plant,
Type 3 x UPR 2845-6-3-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grain yield/plant, biological yield/plant, HI, kernel breath
Type 3 x UPR 3003-11-1-1	Plant height, panicles/plant, grain yield/plant, biological yield/plant, harvest index
Pant Sugandh Dhan 17 x Pusa basmati 1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grain yield/plant, biological yield/plant
Pant Sugandh Dhan 17 x Pusa Sugandh 4	Days to 50% flowering, flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, EY, BY, HI,
Pant Sugandh Dhan 17 x UPR 2845-6-3-1	Days to 50% flowering, flag leaf length, panicle length, grains/panicle, grain yield/plant, biological yield/plant, HI
Pant Sugandh Dhan 17 x UPR 3003-11-1-1	Flag leaf length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI

Table 2: Continued

Crosses	Characters /combination(s)
Pusa Basmati 1 x Pusa Sugandh 4	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Pusa Basmati 1 x UPR 2845-6-3-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI
Pusa Basmati 1 x UPR 3003-11-1-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, grain yield/plant, biological yield/plant, HI
Pusa Sugandh 4 x UPR 2845-6-3-1	Flag leaf length, flag leaf breath, panicles/plant, grains/panicle, test weight, grain yield/plant, biological yield/plant, HI
Pusa Sugandh 4 x UPR 3003-11-1-1	Flag leaf length, flag leaf breath, panicle length, panicles/plant, test weight, grain yield/plant, biological yield/plant, HI
UPR 2845-6-3-1 x UPR 3003 -11-1-1	Flag leaf length, flag leaf breath, panicles/plant, grains/panicle, grain yield/plant, biological yield/plant, HI

yield/plant, biological yield/plant and Harvest Index (HI) and also these crosses showed significant value of specific combining ability for these traits. Most of the crosses did not show significant deviation for quality traits from the standard check variety which means that these crosses can be utilised for the development of hybrids with the excellent basmati quality. So, the crosses showed significant value for standard heterosis and also the significant value of *sca* can be used for the development of the hybrids.

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