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Heterosis in mild pungent chilli (*Capsicum annuum* L.)

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Abstract

Field experiment was carried out to study heterosis for green fruit yield and its components of 28 F_1 hybrids generated by half diallel crosses of eight diverse mild pungent chilli cultivars. Among 28 F_1 hybrids, hybrids IVPBC-535 X SG-5, IVPBC-535 X ACS-03-14 and IVPBC-535 X ACS-03-13 were found to be most promising for green fruit yield and other desirable traits. Hence, they could be further evaluated to exploit the heterosis or utilized in future breeding programmes to obtain desirable segregants for the development of superior genotypes.

Keywords: chilli, heterobeltiosis, heterosis, standard heterosis

Introduction

Heterosis is expressed in three ways depending on the criteria used to compare the performance of the hybrids (Gupta 2000). These three ways are mid-parents heterosis, better parent heterosis or heterobeltiosis and standard heterosis. From a practical point of view, standard heterosis is the most important of the two levels of heterosis because it is aimed at developing desirable hybrids superior to the existing high yielding commercial varieties (Chaudhary 1984). Heterosis breeding is an important genetic tool that can facilitate yield enhancement from 30-400% and helps enrich many other desirable quantitative traits in crops (Srivastava 2000).

To study heterotic effects and magnitude of gene effects of green fruit yield, the knowledge of contribution of its component characters has immense value. Exploitation of heterosis in chilli (*Capsicum annuum* L.) has been recognized as a practical tool in providing the breeders a means of increasing yield and other economic traits (Patel *et al*. 2002; Shankarnag *et al.* 2006; Satish & Lad 2007). Standard heterosis and heterosis for better parent was reported by Sood & Kaul (2006) for green fruit yield plant^{-1}. The value ranged from -18.11-33.18 and -20.19-33.10 for better parent and standard heterosis, respectively. Tembhurne & Rao (2012) also reported significant and positive standard heterosis for dry as well as green fruit yield plant^{-1}.

The objective of this study was to identify desirable genotypes to exploit the heterosis and utilize in future breeding programme to obtain desirable segregants for the development of superior mild pungent chilli genotype.

Material and methods

The experimental material comprised of eight mild pungent diverse parents *viz.*, *Kumathi*, KTPL-19, IVPBC-535, ACS-01-1, AVNPC-131, ACS-03-13, ACS-03-14 and SG-5 along with its 28 F_1 hybrids generated by half-diallel in all possible combinations excluding reciprocals. The experiment was laid out in randomized block design with three replications at Research Farm of Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat (India) during *kharif-rabi* 2007–08. Each plot consisted of a single row of 10 plants. Inter and intra row spacing was kept at 60 cm. The observations were recorded on five randomly selected plants from each treatment and replication for 15 characters *viz.*, days to flowering, plant height (cm), primary branches plant^{-1}, secondary branches plant^{-1}, fruits plant^{-1}, fruit length (cm), fruit girth (cm), pedicel length (cm), fruit shape index, fruit weight (g), green fruit yield plant^{-1} (g), seeds fruit^{-1}, 100 seed weight (g), moisture content in fruits (%) and weight loss in fruits (%). The heterotic effects were computed as the proportion of deviation of F_1 mean values from the better parent (BP) *i.e.* heterobeltiosis and standard parent (SP) *i.e.* standard heterosis (Kumar & Lal 2001). The better parent was established individually for each character based on their superior mean performance and the commercial cultivar AVNPC-131 was used as standard parent.

Results and discussion

The analysis of variance indicated significant differences among the genotypes for all the traits studied. Partitioning of genotypes suggested that significant differences were observed among the parents as well as hybrids for all the traits under study (Table 1). This indicated that materials used for present investigation had adequate diversity for different traits. The finding of heterosis over better parent (BP) and standard parent (SP) AVNPC-131 are presented in Table 2.

The positive effects of heterosis were considered favourable for all the characters except days to flowering, moisture content in fruits and weight loss in fruits for which negative effects were considered favourable. The number of significant hybrid over better parent were 19

Table 1. Analysis of variance for various characters in chilli

Sources of variation	d.f.	Days to flowering	Plant height	Primary branches plant^{-1}	Secondary branches plant^{-1}	Fruits plant^{-1}	Fruit length	Fruit girth	Pedicel length	Fruit Shape index	Fruit weight	Green fruit yield plant^{-1}	Seeds fruit^{-1}	100 seed weight	Moisture content in fruits	Weight loss in fruits
Replications	2	32.48**	21.95*	1.06**	0.62*	317.25*	0.05	0.06	0.16**	0.01	0.09	20669.08	196.60**	0.012**	0.12	7.79
Genotypes	35	31.69**	436.43**	0.16**	0.58**	1255.13**	9.96**	1.53**	0.21**	0.68**	11.76**	69735.27**	2103.71**	0.718**	9.77**	70.83**
Parents	7	11.41**	666.16**	0.17**	0.79**	351.57**	15.73**	3.97**	0.40**	1.38**	4.31**	8584.86**	3101.04**	1.281**	18.95**	65.85**
Hybrids	27	20.01**	392.11**	0.16**	0.51**	1268.03**	8.22**	0.89**	0.17**	0.48**	13.69**	61709.36**	1851.32**	0.581**	7.63**	73.60**
Parents Vs hybrids	1	489.15**	19.45	0.07	0.99*	7231.92**	17.43**	1.58**	0.00	1.08**	11.70**	714487.70**	1936.64**	0.453**	3.27**	30.75**
Error	70	1.69	5.75	0.04	0.15	100.46	0.67	0.03	0.29	0.03	0.11	7139.09	20.26	0.002	0.05	6.11

*,** Significant at P<0.05 and P<0.01, respectively

Table 2. Heterosis in percentage in F_1 hybrids over Better Parent (BP) and Standard Check (SC) for various characters in chilli

Crosses	Days to flowering		Plant height		Prim. branches pl^{-1}		Sec. branches pl^{-1}		Fruits $plant^{-1}$	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
Kumathi × KTPL-19	-8.63 *	-7.50	-19.35 **	12.35 **	0.00	-11.11	-7.80	9.24	100.04 **	64.61 **
Kumathi × IVPBC-535	-2.41	0.00	-7.81 **	28.43 **	-16.88	-26.11 **	-6.43	10.85	-0.67	24.09
Kumathi × ACS-01-1	1.24	3.75	-24.63 **	5.00	-8.13	-18.33 *	-2.53	15.47 *	72.10 **	82.68 **
Kumathi × AVNPC-131	-1.27	-1.27	-9.85 **	25.59 **	3.89	3.89	-3.90	13.86	34.38 *	34.38 *
Kumathi × ACS-03-13	2.45	4.99	-8.23 **	27.84 **	-12.5	-22.22 *	-15.59 *	0.00	13.38	31.04 *
Kumathi × ACS-03-14	1.24	3.75	-20.69 **	10.49 **	-7.51	-11.11	-5.07	12.47	-3.56	5.14
Kumathi × SG-5	-28.03 **	-26.25 **	-10.62 **	24.51 **	3.59	-3.89	-14.23 *	1.62	40.40 **	54.37 **
KTPL-19 × IVPBC-535	-24.70 **	-23.77 **	5.73	-3.13	5.26	-22.22 *	-4.06	9.24	-31.40 **	-14.30
KTPL-19 × ACS-01-1	-11.11 **	-10.01 *	-10.94 **	-4.22	5.26	-22.22 *	-8.11	4.62	-26.66 *	-22.16
KTPL-19 × AVNPC-131	-8.77 *	-8.77 *	5.19	5.19	-26.11 **	-26.11 **	-12.17	0.00	-16.90	-16.90
KTPL-19 × ACS-03-13	-3.70	-2.51	-3.05	2.84	-15.04	-37.22 **	-12.87 *	3.23	-10.47	3.47
KTPL-19 × ACS-03-14	0.00	1.24	-18.85 **	-3.34	-7.51	-11.11	-4.06	9.24	-22.00	-14.97
KTPL-19 × SG-5	-6.19	-5.02	0.37	-8.04 **	-28.14 **	-33.33 **	9.53	24.71 **	-19.89	-11.92
IVPBC-535 × ACS-01-1	-24.71 **	-20.02 **	-26.53 **	-20.99 **	4.72	-26.11 **	0.00	4.62	41.63 **	76.93 **
IVPBC-535 × AVNPC-131	-18.75 **	-18.75 **	-15.63 **	-15.63 **	-26.11 **	-26.11 **	-1.39	-1.39	-9.78	12.71
IVPBC-535 × ACS-03-13	-21.18 **	-16.27 **	-7.49 **	-1.87	41.73 **	0.00	-16.76 **	-1.39	57.58 **	96.86 **
IVPBC-535 × ACS-03-14	-25.87 **	-21.26 **	-31.69 **	-18.63 **	-19.08 *	-22.22 *	15.00	6.24	21.20	51.42 **
IVPBC-535 × SG-5	-30.57 **	-26.25 **	-0.57	-15.29 **	0.00	-7.22	16.22 *	9.24	27.05 *	58.72 **
ACS-01-1 × AVNPC-131	-11.25 **	-11.25 **	-15.49 **	-9.12 **	-22.22 *	-22.22* *	-13.25	-9.24	1.90	8.16
ACS-01-1 × ACS-03-13	-23.33 **	-13.76 **	29.91 **	39.71 **	36.22 **	-3.89	-18.13 **	-3.00	28.21 *	48.18 **
ACS-01-1 × ACS-03-14	-21.10 **	-11.25 **	2.56	22.16 **	-15.03	-18.33 *	0.00	4.62	25.72 *	37.05 **
ACS-01-1 × SG-5	-16.10 **	-8.77 *	8.67 **	16.87 **	15.57	7.22	16.34 *	21.71 **	41.53 **	55.62 **
AVNPC-131 × ACS-03-13	-8.77 *	-8.77 *	-23.37 **	-18.72 **	-33.33 **	-33.33 **	-14.23 *	1.62	59.64 **	84.51 **
AVNPC-131 × ACS-03-14	-3.75	-3.75	-18.77 **	-3.24	-11.11	-11.11	21.71 **	21.71 **	17.54	28.13 *
AVNPC-131 × SG-5	-16.27 **	-16.27 **	-6.66 *	-6.66 *	0.00	0.00	20.09 **	20.09 **	40.98 **	55.01 **
ACS-03-13 × ACS-03-14	-33.32 **	-22.50 **	1.57	20.99 **	-3.47	-7.22	3.90	23.09 **	52.46 **	76.21 **
ACS-03-13 × SG-5	-13.79 **	-6.26	-16.91 **	-11.87 **	11.98	3.89	6.63	26.33 **	3.43	19.54
ACS-03-14 × SG-5	-31.03 **	-25.01 **	-19.51 **	-4.12	11.56	7.22	27.76 **	20.09 **	42.12 **	56.27 **
S. Ed. (±)	1.06	1.06	1.96	1.96	0.16	0.16	0.32	0.32	8.18	8.18
Range	-33.32 to 2.45	-26.25 to 4.99	-31.69 to 29.91	39.71 to -20.99	-33.33 to 41.73	-37.22 to 7.22	-18.13 to 27.76	-9.24 to 26.33	-31.40 to 100.04	-22.16 to 96.86

*,** Significant at P<0.05 and P<0.01, respectively

Table 2. contd...

Crosses	Fruit length		Fruit grith		Pedicel length		Fruit shape index		Fruit weight	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
Kumathi × KTPL-19	-23.72 **	9.49	-33.44 **	-12.01 **	-9.00	13.85 *	10.73	24.05 **	-28.63 **	-10.35 **
Kumathi × IVPBC-535	-10.91 *	29.77 **	0.56	-21.39 **	-7.61	15.58 *	-18.75 **	64.56 **	19.53 **	11.64 **
Kumathi × ACS-01-1	1.31	9.73	3.92	-18.76 **	-1.73	22.94 **	-10.50	34.81 **	-1.25	-7.76 *
Kumathi × AVNPC-131	5.69	5.69	-14.58 **	-14.63 **	-16.96 **	3.90	10.17	23.42 **	-12.42 **	-12.42 **
Kumathi × ACS-03-13	6.75	-0.59	-9.72 **	-15.76 **	-17.99 **	2.60	5.08	17.72 *	-0.55	-7.12 *
Kumathi × ACS-03-14	13.06	-1.42	-31.73 **	-20.08 **	-31.14 **	-13.85 *	10.17	23.42 **	10.80 **	3.49
Kumathi × SG-5	-2.25	8.30	-20.31 **	-26.64 **	-23.30 **	2.60	22.63 **	47.47 **	-0.49	4.66
KTPL-19 × IVPBC-535	9.04	58.84 **	-30.46 **	-8.07 **	-10.14 *	7.36	-14.69 **	72.78 **	35.02 **	69.60 **
KTPL-19 × ACS-01-1	-4.05	37.72 **	-24.36 **	0.00	-9.78	7.79	-8.82	37.34 **	5.87 *	32.99 **
KTPL-19 × AVNPC-131	-8.76	30.96 **	-20.67 **	4.88	9.78	31.17 **	15.79	25.32 **	-5.25	19.02 **
KTPL-19 × ACS-03-13	-8.35	31.55 **	-15.28 **	12.01 **	-6.52	11.69	8.19	17.09	13.08 **	42.04 **
KTPL-19 × ACS-03-14	-24.71 **	8.07	-14.57 **	12.95 **	-11.23 *	6.06	-11.70	-4.43	42.84 **	79.43 **
KTPL-19 × SG-5	-25.87 **	6.41	-35.71 **	-15.01 **	-21.36 **	5.19	4.21	25.32 **	-12.26 **	10.22 **
IVPBC-535 × ACS-01-1	-9.69	31.55 **	11.91 **	-19.51 **	17.51 **	30.74 **	-19.06 **	63.92 **	10.65 *	-9.96 **
IVPBC-535 × AVNPC-131	-3.01	41.28 **	-14.39 **	-14.45 **	0.00	0.00	-18.44 **	65.19 **	6.73	6.73
IVPBC-535 × ACS-03-13	5.70	53.97 **	-3.28	-9.76 **	-2.41	5.19	-15.63 **	70.89 **	12.97 **	-6.47
IVPBC-535 × ACS-03-14	-5.94	37.01 **	-21.47 **	-8.07 **	12.95 *	9.52	-26.56 **	48.73 **	52.91 **	36.09 **
IVPBC-535 × SG-5	5.29	53.38 **	-13.38 **	-20.26 **	-5.83	25.97 **	-5.00	92.41 **	25.83 **	32.34 **
ACS-01-1 × AVNPC-131	-9.42	-1.90	-22.09 **	-22.14 **	-8.56	1.73	-16.39 **	25.95 **	-21.47 **	-21.47 **
ACS-01-1 × ACS-03-13	-1.97	6.17	-10.92 **	-16.89 **	-3.11	7.79	-15.55 **	27.22 **	-2.34	-19.15 **
ACS-01-1 × ACS-03-14	-9.42	-1.90	-20.67 **	-7.13 **	-13.23 *	-3.46	-29.83 **	5.70	4.65	-6.86
ACS-01-1 × SG-5	4.39	15.66 *	-11.75 **	-18.76 **	-8.41	22.51 **	-5.46	42.41 **	-11.56 **	-6.99 *
AVNPC-131 × ACS-03-13	33.69 **	33.69 **	-7.45 **	-7.50 **	-6.43	0.87	44.30 **	44.30 **	-31.05 **	-31.05 **
AVNPC-131 × ACS-03-14	-5.10	-5.10	-12.82 **	2.06	24.24 **	24.24 **	-6.96	-6.96	-7.24 *	-7.24 *
AVNPC-131 × SG-5	6.64	18.15 *	-16.46 **	-16.51 **	-16.18 **	12.12 *	17.37 *	41.14 **	-1.72	3.36
ACS-03-13 × ACS-03-14	3.18	-3.91	-13.14 **	1.69	2.01	9.96	-5.10	-5.70	-11.63 **	-21.35 **
ACS-03-13 × SG-5	-11.88	-2.37	-8.11 **	-14.26 **	-20.71 **	6.06	-5.79	13.29	-20.17 **	-16.04 **
ACS-03-14 × SG-5	-8.46	1.42	-23.56 **	-10.51 **	-20.06 **	6.93	-5.79	13.29	-19.07 **	-14.88 **
S. Ed. (±)	0.67	0.67	0.14	0.14	0.14	0.14	0.14	0.14	0.27	0.27
Range	-25.87 to 33.69	-5.10 to 58.84	-35.71 to 11.91	-26.64 to 12.95	-34.14 to 24.24	-13.85 to 31.17	-29.83 to 44.30	-6.96 to 92.41	-31.05 to 52.91	-31.05 to 79.43

*,** Significant at P<0.05 and P<0.01, respectively

Table 2. contd...

Crosses	Green fruit yield plant⁻¹		Seed fruit⁻¹		100 seed weight		Moisture content in fruits		Weight loss in fruits	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
Kumathi × KTPL-19	70.17 **	47.76 **	-39.90 **	-7.18 *	-41.89 **	-44.87 **	1.29 **	-1.63 **	40.73 **	63.39 **
Kumathi × IVPBC-535	39.62 **	38.71 **	-0.85	-14.96 **	-28.92 **	-32.56 **	-1.10 **	0.61 **	28.28 **	48.94 **
Kumathi × ACS-01-1	94.49 **	68.74 **	51.54 **	14.11 **	-9.46 **	-14.10 **	-3.74 **	-0.53 *	9.47	27.10 **
Kumathi × AVNPC-131	17.65	17.65	14.30 **	14.30 **	-18.72 **	-18.72 **	-0.59 **	-0.59 **	19.01 *	19.01 *
Kumathi × ACS-03-13	26.87	21.63	10.83 *	-16.54 **	-17.84 **	-22.05 **	-0.05	0.77 **	5.99	23.06 **
Kumathi × ACS-03-14	12.01	8.68	-13.19 **	-10.28 **	-34.86 **	-38.21 **	-1.55 **	-3.12 **	15.40	-8.48
Kumathi × SG-5	39.96 **	61.94 **	-9.75 **	-10.52 **	-7.57 **	-12.31 **	-0.88 **	-1.23 **	16.91 *	35.74 **
KTPL-19 × IVPBC-535	46.10 **	45.15 **	7.80 **	66.49 **	29.15 **	-26.15 **	-3.38 **	-1.71 **	8.43	38.45 **
KTPL-19 × ACS-01-1	19.25	3.54	-27.97 **	11.25 **	23.79 **	-21.28 **	-4.77 **	-1.59 **	6.32	44.62 **
KTPL-19 × AVNPC-131	-1.16	-1.16	-40.88 **	-8.70 **	-27.18 **	-27.18 **	-3.46 **	-3.46 **	72.19 **	72.19 **
KTPL-19 × ACS-03-13	53.73 **	47.39 **	-64.95 **	-45.87 **	-0.32	-20.77 **	-4.21 **	-3.42 **	-4.04	23.13 **
KTPL-19 × ACS-03-14	57.27 **	52.60 **	-29.93 **	8.21 *	21.50 **	-8.72 **	-2.46 **	-4.02 **	94.45 **	54.20 **
KTPL-19 × SG-5	-16.07	-2.90	-33.48 **	2.74	25.34 **	-6.15 **	-1.39 **	-1.74 **	41.95 **	86.33 **
IVPBC-535 × ACS-01-1	60.38 **	59.33 **	24.82 **	7.05 *	-16.13 **	-46.67 **	-2.20 **	1.06 **	-9.04	16.1 *
IVPBC-535 × AVNPC-131	20.77	20.77	20.99* **	20.99 **	-19.49 **	-19.49 **	-1.02 **	0.69 **	20.86 **	20.86 **
IVPBC-535 × ACS-03-13	84.41 **	83.21 **	45.32 **	24.64 **	7.42 **	-14.62 **	-1.31 **	0.40	-15.75 *	7.58
IVPBC-535 × ACS-03-14	106.99 **	105.64 **	5.65	9.19 **	23.21 **	-7.44 **	0.22	1.96 **	55.42 **	23.25 **
IVPBC-535 × SG-5	81.43 **	109.91 **	-0.62	-1.46	-11.64 **	-33.85 **	-1.74 **	-0.05	-14.64 *	8.99
ACS-01-1 × AVNPC-131	-14.76	-14.76	-35.52 **	-35.52 **	-7.18 **	-7.18 **	-4.53	-1.35 **	11.15	11.15
ACS-01-1 × ACS-03-13	24.75	19.61	8.44	-25.79 **	5.48 **	-16.15 **	-6.15 **	-3.03 **	-2.97	24.51 **
ACS-01-1 × ACS-03-14	31.32 *	27.42	22.78 **	26.89 **	-3.07 *	-27.18 **	-2.83 **	0.41 *	54.43 **	22.47 **
ACS-01-1 × SG-5	25.27	44.93 **	-16.81 **	-17.52 **	20.21 **	-10.00 **	-2.73 **	0.51 *	-18.82 **	6.56
AVNPC-131 × ACS-03-13	26.70	26.70	35.10 **	35.10 **	-25.90 **	-25.90 **	-1.70 **	-0.90 **	18.38* *	18.38 *
AVNPC-131 × ACS-03-14	18.81	18.81	-10.36 **	-7.36 *	-30.26 **	-30.26 **	-4.96 **	-4.96 **	16.15	-7.89
AVNPC-131 × SG-5	39.02 **	60.85 **	18.13 **	18.13 **	-3.59 **	-3.59 **	-1.07 **	-1.07 **	3.85	3.85
ACS-03-13 × ACS-03-14	42.80 **	38.57 **	4.77	8.28 *	5.81 **	-15.90 **	-0.93 **	-0.11	16.10	-7.93
ACS-03-13 × SG-5	-13.13	0.51	-6.57	-7.36 *	-3.87 **	-23.59 **	0.61 **	1.43 **	13.62 *	45.80 **
ACS-03-14 × SG-5	14.07	31.98 *	10.89 **	14.60 **	6.48 **	-20.00 **	-3.10 **	-3.45 **	85.14 **	46.82 **
S.Ed. (±)	68.99	68.99	3.68	3.68	0.04	0.04	0.18	0.18	2.02	2.02
Range	-16.07 to 106.99	-14.76 to 109.91	-64.95 to 51.54	-45.87 to 66.49	-41.89 to 29.15	-46.67 to -3.59	-6.15 to 1.29	-4.96 to 1.96	-18.82 to 94.45	-8.48 to 86.33

*, ** Significant at P<0.05 and P<0.01, respectively

for days to flowering; two for plant height and primary branches plant^{-1}; five for secondary branches plant^{-1}; 14 for fruits plant^{-1} and green fruit yield plant^{-1}; one for fruit length and fruit girth; three for pedicel length, fruit shape index and weight loss in fruits; 10 for fruit weight and 100 seed weight; 11 for seeds fruit^{-1} and 24 for moisture content in fruits. Whereas, over standard parent (SP) AVNPC-131, the crosses with significant desirable heterosis were 17 for days to flowering; fruits plant^{-1} and moisture content in fruits; 10 for plant height; eight for secondary branches plant^{-1}; 13 for fruit length; two for fruit girth; nine for pedicel length and fruit weight; 21 for fruit shape index; 15 for green fruit yield plant^{-1} and 14 for seeds fruit^{-1}. Heterosis observed for most of the characters was high and in varying proportion due to dominance gene effects rather than additive genes and it was high especially in crosses involving diverse parents which suggested that diversity based on plant type can be effectively used for exploitation of heterosis. Further, there was close agreement between *per se* performance and heterosis as the crosses which showed high mean performance also possessed greater heterosis percentage both over better as well as standard parent. Such positive relationship would be very useful in heterosis breeding for isolating successful hybrids (Ahmed & Muzafar 2000).

The highest heterosis value was observed for the cross ACS-03-13 × ACS-03-14 (-33.32%) over better parent and the cross *Kumathi* × SG-5 and IVPBC-535 × SG-5 (-26.25%) over standard parent for days to flowering. The cross ACS-01-1 × ACS-03-13 had highest desirable heterosis both over better parent (29.91%) and standard parent (39.71%) for plant height and moisture content in fruits (-6.15%) over better parent. For 100 seed weight, the cross combination KTPL-19 × IVPBC-535 showed highest positive heterosis over better parent (29.15%) and also superior over standard parent for fruit length (58.84%) and seeds fruit^{-1} (66.49%). For secondary branches plant^{-1}, the cross ACS-03-14 × SG-5 (27.76%) exhibited highest value followed by AVNPC-131 × ACS-03-14 (21.71%) and AVNPC-13 × SG-5 (20.09%) were superior over better parent. The crosses ACS-03-13 × SG-5 (26.33%), KTPL-19 × SG-5 (24.71%) and ACS-03-13 × ACS-03-14 (23.09%) also had maximum heterosis over standard check for secondary branches plant^{-1}. The combination IVPBC-535 × ACS-03-13 was observed to be superior over better parent for primary branches plant^{-1} (41.73%) as well as showed highest heterosis over standard parent for fruits plant^{-1} (96.86%). Highest heterosis over better parent for pedicel length (24.24%) and over standard parent for moisture content in fruits heterosis (-4.96%) were observed in the cross combination AVNPC-131 × ACS-03-14. Similar results were reported by Joshi (1986), Lee *et al.* (1989), Ahmed & Muzafar (2000) and Sarujpisit *et al*. (2012).

The top ranking hybrids for green fruit yield were IVPBC-535 × SG-5, IVPBC-535 × ACS-03-14 and IVPBC-535 × ACS-03-13 with the heterosis over standard parent of 109.91%, 105.64% and 83.21%, respectively. Hybrid vigour for fruit yield in sweet pepper has been reported earlier by several workers (Joshi *et al.* 1995; Ahmed *et al*. 1996; Mamedov & Pyshnaja 2001; Pandey *et al*. 2002; Singh *et al.* 2012; Tembhurne & Rao 2012).

The cross AVNPC-131 × ACS-03-13 recorded highest heterosis over better parent for fruit length (33.69%) and fruit shape index (44.30%) and the cross IVPBC-535 × ACS-03-14 for fruit weight (52.91%) and green fruit yield plant^{-1} (106.99%). Similarly, the cross KTPL-19 × ACS-03-14 showed highest heterosis over standard parent for fruit girth (12.95%) and fruit weight (79.43%) and the cross IVPBC-535 × SG-5 for fruit shape index (92.41%) and green fruit yield plant^{-1} (109.91%). With regard to fruit girth the cross IVPBC-535 × ACS-01-1 (11.91%) only exhibited significant and positive heterobeltiosis. Out of 28 crosses, 14 crosses exhibited significant and positive heterobeltiosis, of which *Kumathi* × KTPL-19 (100.04%) was the best followed by *Kumathi* × ACS-01-1 (72.10%) and AVNPC-131 × ACS-03-13 (59.6%). Similar pattern of heterosis was established by Singh *et al.* (1992) and Shrestha *et al.* (2011). The higher value of heterobeltiosis was observed for seeds fruit^{-1} and weight loss in fruits in the crosses *Kumathi* × ACS-01-1 (51.54%) and ACS-01-1 × SG-5 (-18.82%), respectively.

In the present investigation, the results of heterobeltiosis indicated that 14 crosses exhibited significantly higher green fruit yield than respective better parent. A comparative study of three most heterotic crosses *viz*., IVPBC-535 × ACS-03-14, *Kumathi* × ACS-01-1 and IVPBC-535 × ACS-03-13 for green fruit yield corresponding to other attributes are presented in Table 3. In most of the cases, these crosses also exhibited significant and desirable heterosis for days to flowering, fruits plant^{-1}, fruit weight, seeds fruit^{-1}, 100 seed weight and moisture content in fruits. Probably, better parent heterosis in different yield components might have resulted in the expression of better parent heterosis for green fruit yield.

In case of standard heterosis, green fruit yield plant^{-1} was observed to be significant in 15 hybrids. A comparative study of three most heterotic crosses *viz*., IVPBC-535 × SG-5, IVPBC-535 × ACS-03-14 and IVPBC-535 × ACS-03-13 for green fruit yield corresponding to other attributes are presented in Table 3. In majority of the cases, these crosses also exhibited significant and desirable heterosis for days to flowering, fruits plant^{-1}, fruit length, fruit shape index, fruit weight and seed fruit^{-1}.

For green fruit yield plant^{-1}, out of 14 crosses (BP & SC), IVPBC 535 parent was involved in 12 crosses for significant and positive heterotic effect. This indicated that this parent is a good general combiner for green fruit yield plant^{-1}.

Table 3. Manifestation of better parent and standard parent heterosis for other characters in three crosses heterotic for green fruit yield plant^{-1}

Characters	Better Parent Heterosis			Standard Heterosis		
	IVPBC-535 × ACS-03-14	Kumathi × ACS-01-1	IVPBC-535 × ACS-03-13	IVPBC-535 × SG-5	IVPBC-535 × ACS-03-14	IVPBC-535 × ACS-03-13
Green fruit yield plant^{-1}	106.99**	94.49**	84.41**	109.91**	105.64**	83.21**
Days to flowering	-25.87**	1.24	-21.18**	-26.25**	-21.26**	-16.27**
Plant height	-31.69**	-24.63**	-7.49**	-15.29**	-18.63**	-1.87
Primary branches plant^{-1}	-19.08**	-8.13	41.73**	-7.22	-22.22*	0.00
Secondary branches plant^{-1}	15.00	-2.53	-16.76**	9.24	6.24	-1.39
Fruits plant^{-1}	21.20	72.10**	57.58**	58.72**	51.42**	96.86**
Fruit length	-5.94	1.31	5.70	53.38**	37.01**	53.97**
Fruit girth	-21.47**	3.92	-3.28	-20.26**	-8.07**	-9.67**
Pedicel length	12.95*	-1.73	-2.41	25.97**	9.52	5.19
Fruit shape index	-26.56**	-10.50	-15.63**	92.41**	48.73**	70.89**
Fruit weight	52.91**	-1.25	12.97**	32.34**	36.09**	-6.47
Seeds fruit^{-1}	5.65	51.54**	45.32**	-1.46	9.19**	24.64**
100 seed weight	23.21**	-9.46**	7.42**	-33.85**	-7.44**	-14.62**
Moisture content in fruits	0.22	-3.74**	-1.31**	-0.05	1.96**	0.40
Weight loss in fruits	55.42**	9.47	-15.75*	8.99	23.25**	7.58

*,** Significant at P<0.05 and P<0.01, respectively

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