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HETEROSIS STUDIES FOR EARLINESS, FRUIT YIELD AND YIELD ATTRIBUTING TRAITS IN CHILLI (*CAPSICUM ANNUM* L.)

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ABSTRACT
A study was conducted in chilli to estimate the magnitude of heterosis for earliness, fruit yield and its eleven yield attributing traits. Thirty F_1 hybrids were derived from crosses between ten female lines and three testers using line × tester analysis and these F_1s along with parents were evaluated during kharif 2010-11 using Randomized Block Design. A wide range of heterosis over better parent was observed in F_1 generation for yield per hectare and its attributing traits. Among 30 F_1s crosses, crosses SC-304 × ArkaLohit and SC-277 × Local had revealed the highest significant desirable heterobeltiosis for early maturity. The crosses SC-502 × ArkaLohit was recognized as the best heterotic cross for fruit yield per hectare as it exhibited highest positive over better parent.Hence, they could be further evaluated to exploit the heterosis or utilized in future breeding programmes to obtain desirable segregates for the development of superior genotypes

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important valuable commercial spice-cum-vegetable crops grown in India under various agro climatic conditions viz., tropical, sub- tropical and temperate climates (Hazra *et al.*, 2011). India is the major producer, consumer and exporter of chilli, covering an area of 0.77 million hectares with a production of 0.659 million tonnes averaging a productivity of 0.86 tonnes per hectare (Anon., 2013). Even though India ranks first in chilli area and production, the yield potential is low due to poor yielding varieties and high incidence of pests and diseases. There is need to develop high yielding, disease resistant hybrids having high quality parameters.

Heterosis breeding is an important crop improvement method adopted in many crops all over the world. It is a quick and convenient way of combining desirable characters which has assumed greater significance in the production of F_1 hybrids (Ramesh *et al.*, 2013). In chilli, heterosis was first reported by Despande (1933). Chilli has been classified under self-pollinated crop, but the extent of 2 to 96 % out-crossing was observed under open pollination (AVRDC,2000) and it has a substantial amount of non additive genetic variance, hybrid vigour for yield (Doshi and Shukla, 2000) which can be exploited profitably through heterosis breeding. It has been advantageous for increased chilli production and for effective transfer of desirable genes controlling both quantitative and qualitative traits in the resultant progenies. Therefore, to meet this objective in shorter time heterosis breeding has been undertaken to develop and identify the suitable best performing hybrids.

The studies of heterosis in Chilli have also been reported by Patel *et al.* (2002), Shankarnag *et al.* (2006), Satish and Lad (2007), Prasath and Ponnuswami (2008), Reddy *et al.* (2008), Patel *et al.* (2010), Chaudhary *et al.* (2014), Khalia and Hatem (2014), Kumar *et al.*(2014) and Patel *et al.* (2014).

Keeping in views of the above problems, the present study was undertaken to estimate the magnitude of heterosis for various yield and its component traits by crossing 10 lines and 3 testers using line × tester mating design . These studies would be helpful for selecting suitable parents for hybrid development which can be further evaluated for enhanced yield potential.

MATERIALS AND METHODS

The experimental material comprised of ten lines viz., SC-23, SC-277, SC-108, SC-105, SC-814, SC-502, SC-1154, SC-1001, SC-885, SC-304, which were crossed with three different testers viz., Arka Lohit, Local (Land races) and Kashmir Long-1 in Line × Tester fashion to generate 30 F_1s. The seeds of thirteen parents and their resultant 30 F_1s were grown in the field using a randomized block design with three replications during kharif 2011 at Vegetable Research Farm of SKUAST-Kashmir, Shalimar. Each replication consisted of 43 treatments consisting of 13 parents (10 lines,3 testers) and 30 crosses which were planted at 45cm × 45cm spacing. Recommended package and practices are applied to raise a healthy crop. Observations were recorded on five randomly selected plants for eleven characters viz. Plant height (cm), Plant spread (cm), Fruits plant[1], Average fruit weight(g), Days to first flower, Days to fruiting, Days to ripening, Fruit length, Fruit width, Yield hectare^{-1} and Seeds fruit^{-1}. The data recorded on the material generated as per Line × Tester model of Kempthorne (1957).

Estimation of heterosis

The magnitude of heterosis was estimated in relation to better parent values. They were thus, calculated as percentage increase or decrease of F_{1S} better parent (B.P) using the methods of Turner (1953) and Panse and Sukhatme (1978)

$$\text{Percent heterosis over better parent (BPH)} = \frac{F_1 - BP}{\text{(Heterobeltiosis)}\ BP} \times 100$$

Where,

F_1 = Mean performance of F_1 hybrid

BP = Mean performance of better parent

RESULTS AND DISCUSSION

The analysis of variance revealed significance differences among treatments for all the characters studied (Table 2). Lines and testers (except for fruit width) differed significantly for all the traits. Lines when compared to testers differed significantly for all the traits except plant spread, number of fruits plant-$^{-1}$, average fruit weight, and fruit width. Performances of crosses was also significant when compared to parents for all the traits under study which suggested the existence of substantial heterosis. Similar results were also reported by (Reddy *et al.*,2008).The variance components due to lines, testers and line × tester interaction revealed that the variances due to lines showed significant differences for all the traits. Similarly variance due to line × tester interaction were highly significant for all the characters and more in magnitude than their corresponding variance components due to lines and testers for all the traits except for plant height, plant spread and days to fruiting (where variance due to lines was more).

Exploitation of hybrid vigour in any crop depends on the magnitude and direction of heterosis.The main constituent of heterosis is the pronounced dominance gene action. The parents and the crosses exhibiting earliness in respect of days to first flower, days to fruiting and days to ripening *i.e.* negative heterosis were considered better parents. However, for all the other attributes studied, high values i.e positive heterosis was considered desirable.Estimates ofheterosis were expressed as percent increase (+) or decrease (-) in the average performance of hybrids over better parent (heterobeltiosis) in order to judge the potential of the crosses to be exploited on commercial scale through heterotic breeding which are presented in Table 4.

A wide range of heterosis over better parents were observed for most of the studied traits.The magnitude ofheterosis for plant height ranged from -24.73 to 35.54 %. Out of 30 crosses, only eight crosses showing significant positive heterosis viz., SC-108 × Kashmir Long-1 (35.54%) followed by SC-23 × Local (29.32%) .However, 15 crosses recorded significant negative heterosis viz. SC-502 × Local (-24.73%) followed by SC-1154 × ArkaLohit (-22.34%) and SC-885 × Local (-19.30%).Similar observation were also recorded in chilli by (Chaudhary *et al.*,2013; Lyngdoh *et al.*, 2013 (okra) Patel *et al.*, 2014; Kumar *et al.*, 2014 and Dubey *et al.*, 2014 (Brinjal).

Significant positive heterosis for plant spread in eleven crosses ranged from -53.88 to 68.02 percent. The crosses SC-23 × Kashmir Long-1 recorded highest heterosis of 68.02% followed by SC-23 × Local (51.57%). Ten crosses exhibited significant negative heterosisviz SC- 1154 × ArkaLohit (-53.88%) followed by SC-108 × ArkaLohit (-43.04).The results are in conformity with patel *et al.*(2010) and Payakhapaab *et al.*(2012).The range of heterobeltiosis was -43.59 to 86.76 % for number of fruit per plant. Seven crosses exhibited desired significant positive heterosis, whereas thirteen crosses exhibited significant negative heterosis over better parent. The crosses SC-277 × Kashmir Long-1 exhibited maximum significant heterosis of 86.76% followed by SC-502 × ArkaLohit (68.00%), SC-23 × Local (59.55%). Among heterotic hybrids, the cross SC-502 × ArkaLohit and SC-23 × Local recorded highest fruit number of 98.00 and 94.67 respectively. SC-1154 × Local recorded highest negative heterosis with a value of -45.30% followed by SC-1154 × ArkaLohit (-43.59%) and SC-105 × Local (-37.75%).This findings are in agreement with Payakhapaab *et al.* (2012), Patel *et al.* (2014) and Kumar *et al.* (2014).

Thirteen crosses were noticed to exhibit significant positive heterosis for average fruit weight while five crosses exhibited significant negative heterosis over the better parent. The range

Table 1: Brief description of the parental genotypes used in experiments

S.No	Parent	Source	Plant habit	Fruit habit	Fruit colour
Lines					
1	SC-23	SKUAST-K	Medium tall	Pendulous	Light red
2	SC-277	SKUAST-K	Tall erect	Pendulous	Red
3	SC-108	SKUAST-K	Medium tall erect	Pendulous	Bright red
4	SC-105	SKUAST-K	Tall spreading	Pendulous	Red
5	SC-814	SKUAST-K	Tall erect	Pendulous	Bright red
6	SC-502	SKUAST-K	Medium tall erect	Pendulous	Bright red
7	SC-1154	SKUAST-K	Medium tall spreading	Pendulous	Red
8	SC-1001	SKUAST-K	Tall spreading	Semi erect	Deep red
9	SC-885	SKUAST-K	Medium .tall	Pendulous	Red
10	SC-304	SKUAST-K	Tall spreading	Semi erect	Bright Red
Testers					
11	ArkaLohit	I.I.H.R. Banglore	Tall erect	Pendulous	Deep Red
12	Kashmir Long-1	SKUAST-K	Medium tall spreading	Pendulous	Bright Red
13	Local	SKUAST-K	Medium tall erect	Pendulous	Blood Red

Table 2: Analysis of variance (mean squares)' for line × tester analysis for different components in chilli (*capsicum annum* L.)

Source of variation	d.f	Plant height (cm)	Plant spread (cm)	Number of fruits per plant	Average fruit weight	Days to first flower	Days to fruiting	Days to ripening	Fruit length	Fruit width	Yield per hectare	Seeds fruit^{-1}
Replications	2	4.18	0.02	4.31	0.09	0.18	0.23	5.27	0.08	0.00	4.14	8.03
Treatments	42	423.35**	255.17**	716.32**	9.21**	57.21**	61.76**	96.06**	5.68**	0.22**	9890.54**	3364.04**
Parents	12	372.12**	169.52**	478.53**	2.37**	57.53**	64.90**	28.03**	2.39**	0.08**	2599.80**	2713.00**
Parents(Lines)	9	325.09**	208.61**	600.01**	1.12**	44.70**	50.83**	33.76**	0.92**	0.09**	2933.54**	3498.55**
Parents (Testers)	2	19.08*	75.25**	164.77**	8.96**	30.95**	22.56**	8.32**	6.16**	0.10	1873.17**	475.11**
Parents (L vs. T)	1	1501.44**	6.24	12.72	0.46	226.16**	276.23**	15.97**	8.05**	0.00	1049.39*	118.91*
Parents vs. Crosses	1	2936.28**	364.11**	250.63**	73.23**	671.51**	728.81**	1141.14**	95.59**	1.39**	56010.44**	40329.19**
Crosses	29	357.90**	286.86**	830.77**	9.84**	35.90**	37.45**	88.17**	3.94**	0.23**	11317.06**	2358.78**
Error	84	3.98	4.67	8.68	0.27	1.67	2.11	1.28	0.18	0.02	250.86	23.26
Total	128	141.59	86.79	240.80	3.20	19.87	21.65	32.44	1.98	0.08	3410.03	1119.21

*Significant at 0.05 probability level ,**Significant at 0.01 probability level

Table 3: Mean performance of parents and crosses of chilli (*capsicum annuum* L.) genotypes for different horticulture traits

S.No	Genotypes	Plant height (cm)	Plant spread (cm)	Fruits plant^{-1}	Average fruit weight	Days to first flower	Days to fruiting	Days to ripening	Fruit length	Fruit width	Yield hectare^{-1}	Seeds fruit^{-1}
Parents												
1	SC-23	63.13	28.63	59.33	6.07	109.17	124.20	166.83	8.87	1.00	170.95	76.00
2	SC-277	65.50	41.67	42.00	5.87	110.17	125.90	167.43	8.23	0.90	117.54	179.00
3	SC-108	65.47	32.67	53.33	6.43	103.17	116.27	167.37	7.53	1.23	164.19	70.67
4	SC-105	60.17	43.47	68.00	5.27	105.10	120.13	165.37	7.63	0.90	181.09	85.67
5	SC-814	74.83	38.17	37.67	7.07	106.17	123.47	168.60	8.07	1.37	126.86	80.67
6	SC-502	44.83	28.33	38.00	6.13	98.10	113.23	164.40	7.67	1.03	111.20	72.67
7	SC-1154	52.17	52.40	78.00	5.03	108.27	123.67	168.60	7.27	1.23	186.75	104.33
8	SC-1001	66.30	48.50	34.33	6.03	103.00	119.23	158.40	8.77	1.30	98.51	68.00
9	SC-885	43.17	43.50	49.67	5.63	110.10	124.13	170.33	8.03	1.13	132.79	98.33
10	SC-304	50.50	32.17	51.00	5.27	108.17	124.27	168.70	7.37	0.90	128.32	61.00
11	Arka Lohit	71.33	42.83	58.33	3.63	115.33	130.93	166.30	7.57	0.93	100.95	80.00
12	Kashmir Long-1	72.50	32.83	45.33	6.77	109.00	126.17	169.57	10.43	1.30	147.35	104.67
13	Local	76.17	38.33	45.67	6.47	111.23	126.20	168.50	9.07	1.10	140.23	96.67
F_1 Crosses												
14	SC-23 × Arka Lohit	80.17	47.17	60.67	7.97	103.43	117.63	152.53	12.13	1.10	231.67	152.67
15	SC-23 × Kashmir Long-1	85.50	55.17	68.33	9.43	98.23	113.00	150.97	10.10	1.30	307.01	143.33
16	SC-23 × Local	98.50	58.10	94.67	10.17	102.27	117.70	154.63	10.27	1.23	189.35	149.67
17	SC-277 × Arka Lohit	73.17	45.47	51.33	7.77	99.33	113.20	152.13	11.60	1.10	189.24	156.67
18	SC-277 × Kashmir Long-1	87.17	56.17	84.67	6.10	106.37	121.50	168.30	9.50	1.17	269.28	122.00
19	SC-277 x Local	68.67	46.47	60.67	6.57	95.60	113.27	160.20	11.10	1.23	190.66	146.00
20	SC-108 × Arka Lohit	82.10	24.40	55.67	10.03	103.63	120.33	160.23	9.73	1.43	266.43	172.33
21	SC-108 × Kashmir Long-1	98.27	42.67	75.67	7.13	98.50	113.83	163.00	9.13	1.57	258.20	105.33
22	SC-108 × Local	83.63	48.27	50.33	7.03	101.70	116.70	154.37	10.17	1.13	168.39	121.00
23	SC-105 × Arka Lohit	73.17	47.90	64.67	6.67	105.33	122.37	169.17	13.50	1.37	204.76	119.67
24	SC-105 × Kashmir Long-1	75.50	46.27	45.67	7.27	108.00	124.23	166.17	10.10	1.63	157.83	136.00
25	SC-105 × Local	83.07	53.00	42.33	9.33	99.50	114.10	154.37	8.77	1.50	188.26	151.00
26	SC-814 × Arka Lohit	63.93	33.50	40.33	8.57	101.97	116.30	158.37	11.47	1.13	164.37	125.67
27	SC-814 × Kashmir Long-1	63.77	38.10	43.67	7.23	103.10	118.37	161.33	9.43	1.73	150.55	157.33
28	SC-814 × Local	72.90	63.30	39.67	5.33	108.50	123.70	169.20	8.87	1.20	101.08	143.33
29	SC-502 × Arka Lohit	65.93	42.50	98.00	5.73	109.43	124.33	166.43	10.77	1.07	268.04	174.33
30	SC-502 × Kashmir Long-1	66.17	32.83	40.33	4.77	100.47	115.33	165.27	9.47	1.70	91.26	110.67
31	SC-502 × Local	57.33	45.33	43.67	10.13	106.17	121.50	160.40	9.73	1.17	211.64	129.33
32	SC-1154×Arka Lohit	55.40	24.17	44.00	9.90	103.20	118.23	163.40	9.57	1.53	207.94	106.33
33	SC-1154 × Kashmir Long-1	72.40	27.33	48.67	6.40	102.27	117.77	154.13	8.43	0.90	136.40	98.33
34	SC-1154 × Local	73.90	35.17	42.67	5.97	98.77	113.30	158.30	12.03	1.17	121.21	117.33
35	SC-1001 × Arka Lohit	72.40	38.00	66.33	7.30	100.70	115.50	166.23	9.97	1.90	230.63	140.00
36	SC-1001 × Kashmir Long-1	65.37	49.17	40.67	4.60	107.23	121.40	165.30	10.17	1.67	89.01	149.33
37	SC-1001 × Local	65.70	43.17	36.67	4.07	100.03	115.33	155.27	9.67	1.10	71.13	114.00
38	SC-885 × Arka Lohit	73.30	36.63	46.00	8.57	102.33	117.53	164.13	8.67	1.63	187.84	107.33
39	SC-885 × Kashmir Long-1	62.33	36.83	38.00	6.93	105.70	120.70	159.60	9.47	0.83	125.62	145.67
40	SC-885 × Local	61.47	43.17	49.67	5.47	104.30	119.97	162.40	9.93	1.10	129.12	66.00
41	SC-304 × Arka Lohit	63.03	40.00	39.33	10.23	98.37	113.73	164.33	9.57	1.30	192.34	148.67
42	SC-304 × Kashmir Long-1	65.23	27.43	43.00	7.60	100.17	115.47	156.70	8.97	1.87	156.82	49.00
43	SC-304 × Local	63.33	44.00	60.33	9.57	100.13	115.63	157.17	9.43	1.10	274.43	115.33
	SE+	1.62	1.76	2.40	0.42	1.05	1.18	0.92	0.34	0.11	12.93	3.93

of heterosis was -37.11 to 96.69 percent. The crosses SC-1154 × Kashmir Long-1 (96.69%) followed by SC-304 × ArkaLohit (94.30%), SC-23 × Local (57.22%), SC-108 × ArkaLohit (55.96%). SC-885 × ArkaLohit (52.07%), SC-1154 × ArkaLohit (56.70%), SC-304 × Local (47.94%), SC-105 × Local (44.33%) and SC-23 × Kashmir Long-1 (39.41%) were the best hybrids with regard to average fruit weight exhibiting highest significant positive heterosis. SC-1001 × Local (-37.11%) followed by SC-1001 × Kashmir Long-1 (-32.02%) and SC-502 × Kashmir Long-1 (-29.56%) recorded significant

Table 4: Estimates of heterobeltiosis for different characters in chilli (*capsicum annum* L.)

S. No.	Crosses	Plant height	Plant spread	Number of fruits per plant	Average fruit weight	Days to first flower	Days to fruiting	Days to ripening	Fruit length	Fruit width	Yield per hectare	Number of seeds per fruit
1	SC-23 × Arka Lohit	12.38**	10.12*	2.25	31.32**	-10.32**	-10.16**	-8.57**	36.84**	10	35.52**	90.83**
2	SC-23 × Kashmir Long-1	17.93**	68.02**	15.17**	39.41**	-10.02**	-10.44**	-10.97**	-3.19	0	79.59**	36.94**
3	SC-23 × Local	29.32**	51.57**	59.55**	57.22**	-8.06**	-6.74**	-8.23**	13.24**	12.12	10.77	54.83**
4	SC-277 × Arka Lohit	2.57	6.15	-12.00*	32.39**	-13.87**	-13.54**	-9.14**	40.89**	17.86	61.01**	-12.85**
5	SC-277 × Kashmir Long-1	20.23**	34.80**	86.76**	-9.85	-3.45**	-3.70**	-0.75	-8.95*	-10.26	82.75**	-31.84**
6	SC-277 × Local	-9.85**	11.52**	32.85**	1.55	-14.05**	-10.25**	-4.93**	22.43**	12.12	35.96**	- 18.44**
7	SC-108 × Arka Lohit	15.09**	-43.04**	-4.57	55.96**	-10.14**	-8.10**	-4.26**	28.63**	16.22	62.27**	115.42**
8	SC-108 × Kashmir Long-1	35.54**	29.95**	41.88**	5.42	-9.63**	-9.78**	-3.87**	-12.46**	20.51*	57.25**	0.64
9	SC-108 × Local	9.80**	25.91**	-5.63	8.76	-8.57**	-7.53**	-8.39**	12.13**	-8.11	2.56	25.17**
10	SC-105 × Arka Lohit	2.57	10.20**	-4.9	26.58**	-8.67**	-6.54**	1.72*	76.86**	46.43**	13.07	39.69**
11	SC-105 × Kashmir Long-1	4.14	6.44	-32.84**	7.39	-0.92	-1.53	-1.67*	-3.19	25.64*	-12.84	29.94**
12	SC-105 × Local	9.06**	21.93**	-37.75**	44.33**	-10.55**	-9.59**	-8.55**	-3.31	36.36**	3.96	56.21**
13	SC-814 × Arka Lohit	-15.90**	-21.79**	-30.86**	21.23**	-11.59**	-11.18**	-6.07**	42.15**	-17.07	29.56*	55.79**
14	SC-814 × Kashmir Long-1	-12.05**	-0.17	-3.68	2.36	-5.41**	-6.18**	-4.86**	-6.71	26.83**	2.17	50.32**
15	SC-814 × Local	-4.29	65.13**	-13.14*	-24.53**	-2.46*	-1.98	0.36	-2.21	-12.2	-27.92*	48.28**
16	SC-502 × Arka Lohit	-7.57**	-0.78	68.00**	-6.62	-5.12**	-5.04**	0.08	40.43**	-24.32**	141.05**	117.50**
17	SC-502 × Kashmir Long-1	-8.74**	0	-11.03	-29.56**	-7.83**	-8.59**	-2.54**	-9.27*	30.77**	-38.07**	5.73
18	SC-502 × Local	-24.73**	18.26**	-4.38	56.70**	-4.55**	-3.72**	-4.81**	7.35	6.06	50.93**	33.79**
19	SC-1154× Arka Lohit	-22.34**	-53.88**	-43.59**	96.69**	-10.52**	-9.70**	-3.08**	26.43**	24.32*	11.34	1.92
20	SC-1154 × Kashmir Long-1	-0.14	-47.89**	-37.61**	-5.42	-6.18**	-6.66**	-9.10**	-19.17**	-30.77	-26.96**	-6.05
21	SC-1154 × Local	-2.98	-32.89**	-45.30**	-7.73	-11.21**	-10.22**	-6.11**	32.72**	-5.41	-35.10**	12.46**
22	SC-1001 × Arka Lohit	1.5	-21.65**	13.71**	20.99	-12.69**	-11.79**	-0.04	13.69**	46.15**	128.46**	75.00**
23	SC-1001 × Kashmir Long-1	-9.84**	1.37	-10.29	-32.02**	-1.62	-3.78**	-2.52**	-2.56	28.21**	-39.59**	42.68**
24	SC-1001 × Local	-13.74**	-11.00*	-19.71**	-37.11**	-10.07**	-8.61**	-7.85**	6.62	-15.38	-49.27**	17.93**
25	SC-885 × Arka Lohit	2.76	-15.79**	-21.14**	52.07**	-11.27**	-10.23*	-3.64**	7.88	44.12**	41.46**	9.15*
26	SC-885 × Kashmir Long-1	-14.02**	-15.33**	-23.49**	2.46	-4.00**	-4.33**	-6.30**	-9.27*	-35.90**	-14.74	39.17**
27	SC-885 × Local	-19.30**	-0.77	0	-15.46*	-6.23**	-4.94**	-4.66**	9.56*	-2.94	-7.92	32.88**
28	SC-304 × Arka Lohit	-11.64**	-6.61	-32.57**	94.30**	-14.71**	-13.14**	-2.59**	26.43**	39.29**	49.89**	85.83**
29	SC-304 × Kashmir Long-1	-10.02**	-16.45*	-15.69**	12.32	-8.10**	-8.48**	-7.59**	-14.06**	43.59**	6.43	-53.18**
30	SC-304 × Local	-16.85**	14.78*	18.30**	47.94**	-9.98**	-8.37**	-6.84**	4.04	0	95.71**	19.31**

*Significant at 0.05 probability level, **Significant at 0.01 probability level

negative heterosis. The results for average fruit weight are in agreement with were also Reddy *et al.* (2008), Chaudhary *et al.*(2013) and Kumar *et al.*(2014)

All the 30 crosses exhibited desirable significant negative heterosis for days to first flower except two crosses viz., SC-105 × Kashmir Long-1 and SC-1001 × Kashmir Long-1 which were no significant. SC-304 × ArkaLohit (-14.71%) recorded highest desirable negative heterosis followed by SC-277 × Local (-14.05%), SC-277 × ArkaLohit (-13.87%) and SC-814 × ArkaLohit (-11.59%). The crosses SC-814 × Local and SC-277 × Kashmir Long-1 showed minimum heterosis with a value of -2.46% and -3.45%. The importance of negative heterosis for days to flowering has been observed in chilli by (Patel *et al.*, 2010; Sharma *et al.*, 2013 (bell pepper); Makani *et al.*, 2013 (brinjal); Patel *et al.*, 2014; Reddy and Patel 2014 (brinjal) and Shankar *et al.*, 2014 (tomato).

The magnitudes of heterosis for days to fruiting in crosses ranged from -1.53 to -13.54 % over better parent. Twenty eight crosses exhibited significant negative heterosis over better parent. The cross SC-277 × ArkaLohit recorded highest negative heterobeltiosis of -13.54% followed by SC-304 × ArkaLohit (-13.14%), SC-1001 × ArkaLohit (-11.79%) and SC-814 × ArkaLohit (-11.18%). None of the crosses exhibited significant positive heterosis. SC-277 × Kashmir Long-1 (-3.70%) and SC- 502 × Local (-3.72%) recorded minimum heterosis.The magnitude of heterosis for days to ripening over better parent varied from -10.97 to 1.72 percent. Twenty five crosses exhibited significant negative heterosis. The cross SC-23 × Kashmir Long-1 recorded highest negative heterobeltiosis of -10.97% followed by SC-277 ×ArkaLohit (-9.14%) and SC-1154 × Kashmir Long-1 (-9.10%). Hybrid SC-105 × ArkaLohit exhibited significant positive heterosis of 1.72%. Rest of the crosses were no significant.

The magnitude of heterosis for fruit length were ranged from -9.27 to 76.86 % over the better parent, with fourteen crosses exhibiting significant positive heterosis. Among different crosses, the crosses SC-105 × ArkaLohit (76.86%) recorded highest heterobeltiosis followed by SC- 814 × ArkaLohit (42.15%), SC-277 × ArkaLohit (40.89%) and SC-502 × ArkaLohit (40.43%). The crosses SC-1154 × Kashmir Long-1, SC-304 × Kashmir Long-1 and SC-108 × Kashmir Long-1 were the poor hybrids with significant negative heterosis of -19.17%, -14.06% and -12.46% respectively. SC-502 × Kashmir Long-1 and SC-885 × Kashmir Long-1 exhibited equal negative significant heterosis of -9.27 percent. Report on significant positive heterosis for fruit length have presented by Payakhapaab *et al.* (2012) , Chaudhary *et al.*(2013) ,Patel *et al.* (2014) and Kumar *et al.* (2014). The magnitude of heterosis for fruit width were ranged from -35.90 to 46.43 % over the better parent. Twelve crosses exhibited significant positive heterosis. SC-105 × ArkaLohit (46.43%) recorded highest positive heterosis followed by SC-1001 × ArkaLohit (46.15%), SC-885 × ArkaLohit (44.12%) and SC-304 × Kashmir Long-1 (43.59%). Only two crosses showed significant negative heterosis viz. SC-502 × ArkaLohit (-24.32%) and SC-885 × Kashmir Long-1 (-35.90%). This results is conformity with Patel *et al.* (2010) and Chaudhary *et al.* (2013).Out of 30 crosses, fourteen crosses exhibited desired significant positive heterosis for yield per hectare and six crosses recorded significant

Table 5: Best three parents and cross combinations on the basis of their *per se* performance and heterotic values

Traits	*Per se* performance Parents	Crosses	Heterosis BP
Plant height	Local ,SC-814, Kashmir Long-1	SC-23× Local(98.50) SC-108 × Kashmir Long-1(98.27) SC-277 ×Kashmir Long-1(87.17)	SC-108 × Kashmir Long-1 (35.54%) SC-23 × Local (29.32%) SC-277 × Kashmir Long-1 (20.23)
Plant spread	SC-1154, SC-1001, SC-885	SC-814 × Local(63.30) SC-23×Local(58.10) SC-23 × Kashmir Long-1(55.17)	SC-23 × Kashmir Long-1 (68.02) SC-23 × Local (51.57). SC-277 × Kashmir Long -1(34.80)
Fruits plant $^{-1}$	SC-1154, SC-105, SC-23	SC-502 ×ArkaLohit(98) SC-23× Local (94.67) SC-277× Kashmir Long-1(84.67)	SC-277 × Kasmir Long-1 (86.76) SC-502 × ArkaLohit (68.00) SC-23 × Local (59.55)
Average fruit weight	SC-814,Kashmir Long-1, Local	SC-304 ×ArkaLohit (10.23) SC-23× Local (10.17) SC-502 × Local(10.13)	SC-1154 × Kashmir Long-1 (96.69) SC-304 × ArkaLohit (94.30) SC-23 × Local (57.22)
Days to first flower	SC-502, SC-1001, SC-108	SC-277 × Local(95.60) SC-23 × Kashmir Long-1(98.23) SC-304 × ArkaLohit(98.37)	SC-304 × ArkaLohit (-14.71) SC-277 × Local (-14.05) SC-277 × ArkaLohit (-13.87)
Days to fruiting	SC-502, SC-108, SC-1001	SC-23 × Kashmir Long-1(113) SC-277× ArkaLohit (113.20) SC-277 × Local(112.27)	SC-277 × ArkaLohit (-13.54) SC-304 × ArkaLohit (-13.14) SC-1001 × ArkaLohit (-11.79)
Days to ripening	SC-1001, SC-502, SC-105	SC-23 ×Kashmir Long-1(150.97) SC-277 × ArkaLohit(152.13) SC-23 × Local(152.53)	SC-23 × Kashmir Long-1 (10.97) SC-277 × ArkaLohit (-9.14) SC-1154 × Kashmir Long-1 (-9.10).
Fruit length	Kashmir Long-1 ,Local , SC-23	SC-105 × ArkaLohit (13.50) SC-23 ×ArkaLohit(12.13) SC-1154 × Local(12.03)	SC-105 × ArkaLohit (76.86) SC- 814 × ArkaLohit (42.15) SC-277 × ArkaLohit (40.89)
Fruit width	SC-814,Kashmir Long-1, SC-1154	SC-1001 × ArkaLohit (1.90) SC-304 × Kashmir Long-1(1.87) SC-105 × Kashmir Long-1(1.73)	SC-105 × ArkaLohit (46.43) SC-1001 × ArkaLohit (46.15) SC-885 × ArkaLohit (44.12)
Yield per hectare	SC-1154, SC-105, SC-23	SC-23 × Kashmir Long-1 (307.01) SC-304 × Local (274.43) SC-277× Kashmir Long-1(269.28)	SC-502 × ArkaLohit (141.05) SC-1001 × ArkaLohit (128.46), SC-277 × Kashmir Long-1 (82.75)
Number of seeds fruit $^{-1}$	SC-277, Kashmir Long-1, SC-1154	SC-502×Arka Lohit(174.33) SC-108×Arka Lohit(172.33) SC-277×Arka Lohit(156.67)	SC-502 × ArkaLohit (117.50) SC-108 × ArkaLohit (115.42) SC-23 × ArkaLohit (90.83).

negative heterosis over the better parent. Highest heterobeltiosis of 141.05% was exhibited by cross SC-502 × ArkaLohit, followed by SC-1001 × ArkaLohit (128.46%). The Crosses SC-1001 × Local was the poor combination exhibiting significant negative heterotic value of -49.27%, followed by SC-1001×Kashmir Long-1 (-39.59%) and SC-502 × Kashmir Long-1 (-38.07%).Similar results have been observed by Payakhapaab *et al.* (2012)

The magnitude of heterosis for number of seeds per fruit ranged from -12.85 to 117.50 % over better parent. Twenty two crosses showed significant positive heterosis, while four crosses exhibited significant negative heterosis. Highest heterosis of 117.50% over better parent was exhibited by the cross SC-502 × ArkaLohit followed by SC-108 × ArkaLohit (115.42%). The crosses SC-304 × Kashmir Long-1 exhibited significant negative heterosis of -53.18% followed by SC -277 × Kashmir Long-1 (-31.84%).The result reporting positive heterosis for number of seed per fruit are in complete agreement with Reddy *et al.*(2008) and Hasanuzzaman *et al.* (2013).

The present study reveals superior performance of the crosses was probably due to complementary interaction of additive, dominance or recessive genes at different loci i.e. epistasis.The crosses SC-502 × ArkaLohit was recognized as the best heterotic cross for fruit yield followed by SC-1001× ArkaLohit and SC-277 × Kashmir Long-1 as it exhibited highly significant positive heterosis over better parent. Therefore these crosses can be further evaluated and used in hybrid breeding programme to boost up the fruit yield under temperate climatic conditions.

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