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Heterosis Studies for Fruit Yield and Related Traits in Hot Pepper (*Capsicum annuum* L.) under Leaf Curl Virus Disease Severity Conditions

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A B S T R A C T

Chilli leaf curl disease is a serious threat to summer crop of chilli in South India causing economic yield losses. Therefore, development of chilli hybrids having leaf curl tolerance and high yield is the present need in chilli growing regions. Seven high yielding lines were crosses with four resistant testers in line × tester mating design to produce 28 F_1 hybrids. Highest heterosis over better parent was exhibited by the cross L6 × T4 for fruit length (74.71%), by L4 × T3 for fruit girth (37.58%), by L6 × T1 for fruits plant^{-1} (37.86%), by L1 × T2 for fruit weight (51.64%) and by L3 × T2 for yield plot^{-1} (56.04%). Highest standard heterosis was exhibited by the cross L4 × T2 for fruit length (83.53%), L5 × T3 for fruit girth (45.26%), L6 × T1 for fruits plant^{-1} (90.60%), L1 × T2 for fruit weight (95.28%) and L3 × T2 for yield plot^{-1} (151.34%). Among the hybrids, L3 × T2, L1 × T1, L7 × T1 and L6 × T1 were showed high heterosis over high parent, mid-parent and standard check for yield and yield attributes. These hybrids could be utilized for future chilli improvement programme.

Introduction

Hot pepper or chilli (*Capsicum annuum* L., 2n=2×=24), a member of family Solanaceae, is a major vegetable-cum-spice crop having immense commercial as well as therapeutic value, it is being grown throughout the world including tropical and sub-tropical regions. In India, green chillies were cultivated in an area of 2.92 lakh ha with a total production of 29.55 lakh MT, with productivity of 10 MT ha (NHB, 2016) and dry chillies were cultivated on 7.75 lakh hectare with a production of 14.92 lakh tonnes and productivity was around 1.9 t/ha (FAO, 2014). Extensive use of non-selfed seeds of improved varieties or local landraces, incidence of various biotic and abiotic stresses have resulted in drastic reduction in quality and productivity of chilli (Chattopadhayay *et al.*, 2011). Among farmers the hot and sweet pepper hybrids are gaining popularity due to the expressed heterosis in them (Berke, 2000). Peppers grown from hybrid seeds are usually high yielding and highly uniform. This has spurred interest in developing hybrids in peppers. The most important step in developing hybrid is identification of parental combinations that produce hybrids with superior yield. Heterosis is described as superiority of F_1 hybrid performance i.e. hybrid vigour in relation to size or rate of growth of offspring over parents (Duvick 1999). Heterosis is a genetic phenomenon resulting from heterozygosity (Kuroda *et al.,* 1998). Mid-parent heterosis described as the difference between the hybrid and the mean of the two parents and this is often expressed as a percentage of the mid-parent performance (Falconer and Mackay 1996). The difference between the hybrid and better parent is suggested by Lamkey and Edwards (1999) and this type of heterosis is known as better parent or high parent heterosis. It is preferred in self-pollinated crops when the goal is to find better hybrids than either of the parents. Standard heterosis can be termed as the difference between the hybrid and the standard variety. Standard heterosis is of practical significance from the plant breeding point of view (Young and Virmani 1990). Heterosis for yield and related traits have been reported in chilli (Ahmed *et al.,* 1999, Bhagyalakshmi *et al.,* 1991, Bhutia *et al.*, 2015, Singh *et al.,* 2014, Payakhapaab *et al.*, 2012, Prasath and Ponnuswami (2008), Chaudhary *et al.,* 2013, Geleta and Labuschagne 2004, Marame *et al.,* 2009). The aim of this work was to estimate the extent of mid-parent, better parent and standard heterosis in chilli hybrids obtained from crosses between high yielding lines and resistant testers, and to determine the promising crosses for yield and yield related traits.

Materials and Methods

The investigation was carried out at the Department of Vegetable Science, College of Agriculture, Vellayani, Kerala Agricultural University (KAU), Trivandrum (India), during February to May (2017). The experimental field is situated at 8^o 42' North latitude, 76^o 98' East longitude and at an altitude of 29 m above sea level. The material for the present study comprised of seven high yielding lines, four leaf curl virus resistant testers and their 28 F_1 hybrids. To study the standard heterosis the check hybrid, Arka Harita F_1 from IIHR, Bengaluru was grown as commercial or standard checks. Seven genotypes with high yield namely, L1 (CHIVAR-3), L2 (CHIVAR-7), L3 (CHIVAR-6), L4 (CA-32), L5 (Vellayani Athulya), L6 (Keerthi) and L7 (CHIVAR-10) were crossed with four testers *viz.*, T1 (Sel-3), T2 (Sel-4), T3 (Sel-6) and T4 (CHIVAR-1) to get 28 cross combinations. All the 28 F_1 hybrids, their parents and two standard checks were sown in portrays (98 cells).

Thirty days old seedlings having 8-10 cm height were transplanted into the main field in a Randomized Block Design (RBD) with three replications during summer 2017. Twenty-eight plants for each entry were accommodated in four rows and plant × plant spacing was maintained at 0.45 m × 0.45m. The crop management practices as recommended by KAU were followed (KAU, 2016). The observations were recorded from five randomly plants excluding the border plants from three replications and the results were expressed as mean values. The traits included fruit length (cm), fruit girth (cm), fruits plant^{-1}, fruit weight (g) and fruit yield plot^{-1}. The length of full matured fruits was measured in centimeters from the pedicel attachment of the fruit to its tip. The girth of fruit was recorded at the middle portion of the fruit with the help of twine and scale. The number of mature fruits from each harvest were counted and finally added to work out the average number of fruits plant^{-1}. The weight of 10 randomly taken fruits from third picking was measured on the electronic balance and average fruit weight (g) was worked out. The weight of fruits harvested from each plot was recorded and expressed in kilograms.

Estimation of heterosis

The magnitude of heterosis was estimated in relation to better parent, mid parent and standard check. They were thus, calculated as percentage increase or decrease of F_1 hybrids over better parent (BP), mid parent (MP) and standard check (SC) using the methods of Turner (1953) and Hayes *et al.,* (1952).

Heterosis was expressed as per cent deviation of F_1 hybrid performance from the better parent and standard check

$$\% \text{ Heterosis better parent } = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\overline{F_1}$ and $\overline{BP}$ are mean values of F_1 hybrids and better parent, respectively.

$$\% \text{ Heterosis mid parent } = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

Where, $\overline{F_1}$ and $\overline{MP}$ are mean values of F_1 hybrids and better parent, respectively.

% Heterosis over standard check =

$$\frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where, $\overline{F_1}$ and $\overline{SC}$ are mean values of F_1 hybrids and standard check, respectively.

Results and Discussion

Analysis of variance for combining ability

The results of analysis of variance for combining ability for different characters are presented in the Table 1. The analysis indicated that the mean squares (MS) due genotypes were significant at P≤ 0.01 for all the characters studied indicating potential genetic differences among genotypes i.e. parents, their F_1 hybrids and standard checks. The MS due to replication were non-significant for all the characters except for fruits plant^{-1}. The MS due to parents were significant for all the characters. Significant differences among genotypes for fruit length (cm), fruit girth (cm), fruits plant^{-1} and fruit weight (g) was reported by Geleta and Labuschagne (2006), Legesse (2000), Hasanuzzaman *et al.,* (2012), Medeiros *et al.,* (2014), Rodrigues *et al.,* (2012), Singh *et al.,* (2014). For fruit yield plot^{-1} do Nascimento *et al.,* (2014) reported the significant differences among genotypes.

Significant differences due to lines and testers were found for all the characters. The hybrids/crosses differed significantly for all the characters. Lines vs testers showed significant differences for all the characters (Table 1). The MS due to parent vs crosses were showed significant differences for all the characters. The GCA effects for lines and SCA effects for crosses were significant at P≤ 0.01 for all the traits studied. The GCA effects for testers were observed to be significant for all the traits. The ratio of σ^2GCA/σ^2SCA was less than unity for all the characters (Table 2) which indicated the predominance of non-additive gene effects for these traits. Exploitation of hybrid vigor in all these crosses could be important in maximizing these traits. Earlier, the role of non-additive gene effects was emphasized by Hasanuzzaman *et al.,* (2012) for fruit length, fruit width, fruit weight and fruits plant^{-1}; by Nsabiyera *et al.,* (2012) for fruit length and fruit width. Importance of additive gene effects in the expression of fruit length, fruit width and fruit weight was reported by do Rego *et al.,* (2009) and Prasath and Ponnuswami (2008). The contribution of lines was more as compared to testers for all the characters (Table 2).

Estimation of heterosis over better parent, mid parent and the standard check

The results pertaining to the per cent heterosis expressed over the better parent (BP), mid parent and standard commercial F_1 hybrid (Arka Harita) has been reported in Table 3a, 3b and 3c and are discussed character wise under the following heads;

Fruit length (cm)

Fruit length is an important trait in chilli that is destined for fresh consumption. The smaller fruits are more suitable for the production of dehydrated products (Klieber, 2001 and Lannes *et al.,* 2007). The range of heterosis over better parent varied from -24.11% in the cross L5 × T1 to 74.71% in the cross L6 × T4. Out of 28 hybrids evaluated, 19 and six hybrids exhibited significant positive and negative heterosis over the better parent, respectively. Extent of significant positive heterosis over better parent ranged from 7.49% in the cross L3 × T1 to 74.71% in the cross L6 × T4. Five cross combinations namely, L6 × T4 (74.71%), L1 × T2 (66.16%), L4 × T2 (63.78%), L1 × T4 (48.12%) and L4 × T4 (44.88%) exhibited significant high positive heterosis over the better parent. Twenty-six hybrids showed significant positive heterosis over mid parent. The range of heterosis over the check hybrid Arka Harita varied from -10.59 (L2 × T4) to 83.53% (L4 × T2). The extent of heterobeltiosis varied from -64.66 to 6.14% for fruit length (Bhutia *et al.,* 2015) while, Payakhapaab *et al.,* (2012) observed the range of heterobeltiosis from -12.43 to 40.36%. Singh *et al.,* (2014) reported the magnitude of heterobeltiosis from -5.13 to 39.64% and they observed 47 hybrids with significant and positive heterosis over their respective better parent. The range of standard heterosis was observed from -20.59 to 39.85% (Prasath and Ponnuswami, 2008). Butcher *et al.,* (2013) reported the heterobeltiosis in the crosses SP15 × SP128 (24.49%), SP79 × SP2 (23.74%), SP15 × SP5 (21.84%) and SP15 × SP57 (21.21%). Naresh *et al.,* (2016) recorded the range of heterobeltiosis from -88.92 to 15.84%. They observed the highest heterosis of 31.36 and 33.33% over better parent and standard check, respectively.

Fruit girth (cm)

Fruits with larger width have more potential to produce fruits with thicker pericarp and higher weight. The range of heterosis over better parent varied from -13.15% (L7 × T1) to 37.58% (L4 × T3). Out of 28 hybrids evaluated, thirteen hybrids exhibited significant positive heterosis over the better parent. Extent of significant positive heterosis over better parent ranged from 11.49% in the cross L4 × T2 to 37.58% in the cross L4 × T3. Hybrids L4 × T3 (37.58%), L2 × T3 (32.66%), L6 × T3 (27.94%), L3 × T1 (24.47%) and L4 × T1 (23.83%) exhibited significant high positive heterosis over the better parent. The range of significant heterosis over mid parent ranges from -15.63% (L5 × T2) to 45.39% (L2 × T3). The range of standard heterosis varied from 10.88% (L7 × T4) to 45.26 (L5 × T3) over Arka Harita.

Bhutia *et al.,* (2015) observed the extent of heterobeltiosis and mid-parent heterosis from -37.88 to 4.49% and -23.77 to 10.20%, respectively for fruit girth. The range of heterosis over better parent varied from -20.60 to 10.41% for fruit width. Chaudhary *et al.,* (2013) identified three best hybrids namely Japanese Longi × DC-16, Japanese Long l × Punjab Lal and Kashi Sindhuri × R Line based on heterobeltiosis and mid-parent heterosis. Naresh *et al.,* (2016) observed the range of heterobeltiosis from -32.76 to 21.53% for fruit width and the highest standard heterosis of 165.00% was exhibited by the hybrid IHR 4507 × IHR 3476. Recently, Ganefianti and Fahrurrozi (2018) reported the highest heterosis and better parent heterosis in the hybrids B (KG 2) × E (KG 5) and D (KG 4) × G (KG 7) for fruit length and fruit diameter. Positive as well as negative heterosis for fruit girth and fruit width has been reported by Payakhapaab *et al.*, 2012; Singh *et al.*, 2014; Prasath and Ponnuswami (2008); Butcher *et al.*, 2013; Geleta and Labuschagne (2004) and Shrestha *et al.*, (2011).

Fruits plant^{-1}

In chilli, number of fruits is the most important primary component of yield plant^{-1}. Heterosis for fruit yield has been attributed to heterosis for fruit plant^{-1}. The observed range of significant heterobeltosis among hybrids was -48.49% (L1 × T2) to 64.77% (L7 × T3).

Significant positive heterosis was observed in 12 hybrids over better parent. Hybrid L7 × T3 exhibited highest positive significant heterosis (64.77%) over its better parent. The range of heterosis over mid parent varied from -31.87 (L4 × T3) to 79.52% (L7 × T3). The range of significant heterosis over the check hybrid varied from -31.21% (L5 × T1) to 90.60% (L6 × T1) over Arka Harita.

Earlier, the range of heterobeltiosis was reported from 44.77 to 0.29% (Bhutia *et al.*, 2015); from -79.30 to 205.95% (Singh *et al.*, 2014); from -46.06 to 47.06% (Payakhapaab *et al.*, 2012); from -42.40 to 85.40% (Shrestha *et al.*, 2011); from -44.00 to 11.00% (Perez-Grajales *et al.*, 2009); from -42.86 to 79.61% (Marame *et al.*, 2009). In the current study, the range of mid parent heterosis varied from -31.87 (L4 × T3) to 79.52% (L7 × T3) and the hybrids L7 × T3 showed highest mid-parent heterosis of 79.52%. In chilli, mid-parent heterosis for fruits plant^{-1} has been observed from -23.70 to 37.72% by Bhutia *et al.*, (2015). The range standard heterosis varied from -35.13% (L5 × T1) to 79.75% (L6 × T1) and -31.21% (L5 × T1) to 90.60% (L6 × T1) over CH-27 and Arka Harita, respectively. The range of standard heterosis from -22.94 to 137.61 and -37.50 to 136.36% was observed by Prasath and Ponnuswami (2008) and Marame *et al.*, (2009), respectively.

Fruit weight (g)

Fruit weight directly contributes towards total yield and it plays a key role in acceptance of chillies by the consumer. The range of significant heterosis over better parent varied from -31.54% (L5 × T1, L5 × T3) to 51.65% (L1 × T2). Out of 28 hybrids evaluated, ten hybrids exhibited significant positive heterosis over the better parent.

Extent of significant positive heterosis over better parent ranged from 6.55% in the cross L4 × T2 to 51.65% in the cross L1 × T2. Four cross combinations namely, L1 × T2 (51.64%), L1 × T4 (39.47%), L1 × T1 (36.84%) and L6 × T3 (23.17) exhibited significant high positive heterosis over the better parent. Heterobeltiosis from -28.65 to 57.52% has been reported by Singh *et al.*, (2014), from -58.60 to 45.08% by Prasath and Ponnuswami (2008), from -38.63 to 64.96% by Butcher *et al.*, (2013) and from -38.19 to 50.29% by Marame *et al.*, (2009) for fruit weight. Heterobeltiosis up to 123.33% and up to 87.20% has been reported by Chaudhary *et al.*, (2013) and Shrestha *et al.*, (2011), respectively.

Twenty-three hybrids showed significant positive heterosis over mid-parent and the highest mid-parent heterosis was exhibited by the hybrid L2 × T2 (65.27%). Heterosis over mid-parent up to 123.33% has been reported by Chaudhary *et al.*, (2013), from -37.42 to 79.46% by Butcher *et al.*, (2013) and from -32.94 to 74.29% by Marame *et al.*, (2009) for fruit weight.

The range of standard heterosis varied from 12.26 to 95.28% over check Arka Harita. Marame *et al.*, (2009) reported the range of economic superiority over standard check from -50.22 to 1.31%.

Fruit yield plot^{-1} (kg)

The range of significant heterosis over better parent varied from -53.39% in the cross L4 × T3 to 56.04% in the cross L3 × T2. Out of 28 hybrids evaluated, thirteen hybrids exhibited significant positive heterosis over the better parent. Extent of significant positive heterosis over better parent ranged from 6.19% in the cross L1 × T4 to 56.04% in the cross L3 × T2. Four cross combinations namely, L3 × T2 (56.04%), L7 × T1 (51.17%), L1 × T1 (42.31%) and L6 × T1 (37.52%) exhibited significant positive heterosis over the better parent. The hybrids which showed high significant positive heterosis over mid parent were L3 × T2 (100.17%), L7 × T1 (91.59%) and L1 × T1 (88.21%).

Table.1 Analysis of variance for combining ability including parents in line × tester design

Source of variation	df	Fruit length (cm)	Fruit girth (cm)	Fruits plant^{-1}	Fruit weight (g)	Yield per plot (kg)
Replication	2	0.83	0.03	680.67**	0.10	0.12
Parents	10	5.86**	0.59**	2981.09**	3.69**	35.25**
Lines (L)	6	6.58**	0.72**	2806.85**	4.87**	5.10**
Testers (T)	3	4.22**	0.51**	218.97**	0.86**	2.90**
Crosses	27	5.51**	0.51**	2897.95**	1.64**	52.06**
Lines vs Testers	1	6.40**	0.08*	12312.91**	5.10**	313.23**
Parent vs Crosses	1	66.42**	5.65**	3490.29**	1.59**	157.88**
GCA lines	6	15.08**	0.99**	5319.07**	3.05**	99.53**
GCA testers	3	4.44**	0.76**	5173.94**	2.59**	100.12**
SCA crosses	18	2.50**	0.30**	1711.57**	1.01**	28.23**
Error	76	0.05	0.04	9.67	0.03	0.13

*significant at $P \leq 0.05$; **significant at $P \leq 0.01$

Table.2 Components of genetic variance and Proportional contributions (%) of Line, Tester and their interactions to total variance for various characters

	Fruit length (cm)	Fruit girth (cm)	Fruits plant^{-1}	Fruit weight (g)	Yield per plot (kg)
Components of genetic variance					
$\sigma^2 gca$	0.06	0.04	26.36	0.01	0.52
$\sigma^2 sca$	0.81	0.08	566.92	0.32	9.36
$\sigma^2 gca / \sigma^2 sca$	0.07	0.5	0.04	0.03	0.05
Proportional contributions (%) of Line, Tester and their interactions to total variance					
Lines	60.80	43.28	40.79	41.35	42.48
Testers	8.95	16.66	19.84	17.54	21.39
Lines × Testers	30.25	40.06	39.37	41.11	36.15

Table.3a Per cent heterosis of F1 hybrids over better parent (BP), mid parent (MP) and standard checks for fruit length (cm) and fruit girth (cm)

Hybrid	Fruit length (cm)			Fruit girth (cm)		
	Per cent heterosis over			Per cent heterosis over		
	BP	Arka Harita F_1	MP	BP	Arka Harita F_1	MP
1 × 1	40.22**	13.82**	44.94**	20.57**	19.30**	27.34**
1 × 2	66.16**	61.76**	81.22**	-1.15	20.70**	9.21*
1 × 3	1.37	9.12*	15.58**	13.13*	17.89**	16.06**
1 × 4	48.12**	20.24**	68.93**	15.68**	16.49**	16.70**
2 × 1	11.61**	17.65**	29.79**	19.84**	5.96	21.53**
2 × 2	27.23**	34.12**	32.29**	-5.17	15.79**	11.30*
2 × 3	-8.20**	-1.18	-7.23**	32.66**	38.25**	45.39**
2 × 4	-15.18**	-10.59**	7.34*	-9.06	-8.42	-1.88
3 × 1	7.49*	10.59**	23.72**	24.47**	23.16**	31.46**
3 × 2	12.06**	15.29**	15.16**	-10.63*	9.12	-1.27
3 × 3	23.50**	32.94**	26.29**	5.72	10.18	8.46
3 × 4	13.49**	16.76**	42.34**	4.53	5.26	5.45
4 × 1	47.51**	65.29**	75.90**	23.83**	29.47**	34.18**
4 × 2	63.78**	83.53**	75.28**	11.49*	36.14**	20.12**
4 × 3	35.96**	52.35**	38.69**	37.58**	43.86**	37.82**
4 × 4	44.88**	62.35**	87.44**	20.47**	25.96**	22.74**
5 × 1	-24.11**	12.94**	0.52	-7.61	27.72**	12.69**
5 × 2	-1.19	47.06**	19.47**	-20.56**	9.82	-15.63**
5 × 3	-9.09**	35.29**	5.50*	5.08	45.26**	19.83**
5 × 4	-10.67**	32.94**	26.61**	0.25	38.60**	16.01**
6 × 1	33.33**	1.18	43.04**	18.41**	30.88**	31.57**
6 × 2	-6.95*	-9.41**	11.19**	8.62	32.63**	14.03**
6 × 3	16.39**	25.29**	44.65**	27.94**	41.40**	31.70**
6 × 4	74.71**	14.59**	80.79**	15.56**	27.72**	20.93**
7 × 1	38.12**	32.35**	54.16**	-13.15**	-0.35	-1.90
7 × 2	29.00**	25.59**	30.02**	7.76	31.58**	11.11**
7 × 3	9.56**	17.94**	15.93**	7.65	23.51**	12.82**
7 × 4	-6.08	-10.00**	14.65**	-3.36	10.88*	2.93
SE	0.18		0.16	0.16		0.14
CD at $P \leq 0.05$	0.35		0.31	0.31		0.27
CD at $P \leq 0.01$	0.46		0.41	0.41		0.35

*,**: Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Table.3b Per cent heterosis of F1 hybrids over better parent (BP), mid parent (MP) and standard checks for fruit weight (g) and fruits plant^{-1}

Hybrid	Fruit weight (g)			Fruits plant^{-1}		
	Per cent heterosis over			Per cent heterosis over		
	BP	Arka Harita F_1	MP	BP	Arka Harita F_1	MP
1 × 1	36.84**	47.17**	42.79**	4.09*	62.08**	31.79**
1 × 2	51.65**	95.28**	65.27**	-48.49**	-19.80**	-28.87**
1 × 3	4.63	27.83**	11.29**	-17.03**	29.19**	7.99**
1 × 4	39.47**	50.00**	44.22**	-23.71**	18.79**	1.29
2 × 1	7.30	17.92**	13.12**	11.98**	53.69**	35.10**
2 × 2	-4.03	23.58**	3.56	-31.30**	-5.70*	-8.91**
2 × 3	-14.29**	4.72	-9.76**	-17.36**	13.42**	2.74
2 × 4	3.00	13.21**	7.62*	-11.25**	21.81**	12.73**
3 × 1	6.67*	35.85**	20.25**	16.08**	42.95**	33.96**
3 × 2	14.29**	47.17**	14.92**	37.33**	69.13**	75.30**
3 × 3	8.89**	38.68**	11.15**	9.81**	35.23**	30.84**
3 × 4	-2.96	23.58**	8.49**	-0.82	22.15**	20.93**
4 × 1	-1.82	27.36**	11.57**	2.84	33.89**	21.46**
4 × 2	6.55*	38.21**	6.93*	-27.58**	-5.70*	-5.70*
4 × 3	-13.45**	12.26**	-10.86**	-44.07**	-27.18**	-31.87**
4 × 4	-8.36*	18.87**	3.28	-44.85**	-28.19**	-31.30**
5 × 1	-31.54**	44.34**	-6.71**	-23.79**	-31.21**	-10.09**
5 × 2	-22.42**	63.58**	-3.67	23.08**	-14.09**	29.62**
5 × 3	-31.54**	44.34**	-13.31**	19.28**	-0.34	36.24**
5 × 4	-29.71**	48.21**	-4.79*	14.04**	-10.07**	27.01**
6 × 1	-1.23	13.68**	6.40	37.86**	90.60**	66.81**
6 × 2	-7.69*	18.87**	-2.51	-19.66**	11.07**	6.77**
6 × 3	23.17**	50.47**	26.84**	-14.56**	18.12**	6.51**
6 × 4	7.38*	23.58**	14.66**	-10.68**	23.49**	13.76**
7 × 1	13.92**	69.81**	37.14**	33.22**	33.22**	40.04**
7 × 2	-0.63	48.11**	6.62*	13.42**	13.42**	33.60**
7 × 3	-27.85**	7.55	-20.70**	64.77**	64.77**	79.52**
7 × 4	-23.67**	13.77**	-8.81**	5.03	5.03	17.45**
SE	0.14		0.12	2.53		2.19
CD at $P \leq 0.05$	0.28		0.25	4.95		4.29
CD at $P \leq 0.01$	0.37		0.32	6.50		5.62

*,**: Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Table.3c Per cent heterosis of F1 hybrids over better parent (BP), mid parent (MP) and standard checks for yield plot^{-1}

Hybrid	Yield plot^{-1}		
	Per cent heterosis over		
	BP	Arka Harita F_1	MP
1 × 1	42.31**	144.22**	88.21**
1 × 2	-8.55**	56.95**	19.95**
1 × 3	-3.13	66.25**	21.70**
1 × 4	6.19**	82.25**	47.25**
2 × 1	22.04**	84.06**	54.20**
2 × 2	-21.67**	18.14**	-1.91
2 × 3	-21.96**	17.69**	-6.75**
2 × 4	-5.92**	41.89**	25.16**
3 × 1	22.84**	97.86**	58.94**
3 × 2	56.04**	151.34**	100.17**
3 × 3	19.54**	92.55**	46.60**
3 × 4	-6.14**	51.19**	27.59**
4 × 1	0.89	74.33**	33.74**
4 × 2	-23.55**	32.10**	0.51
4 × 3	-53.39**	-19.46**	-41.29**
4 × 4	-51.46**	-16.13**	-32.56**
5 × 1	-27.68**	-4.30	-13.09**
5 × 2	8.64**	43.75**	29.28**
5 × 3	11.49**	47.52**	26.13**
5 × 4	-1.02	30.97**	25.78**
6 × 1	37.52**	121.31**	77.88**
6 × 2	-16.72**	34.01**	6.79**
6 × 3	11.91**	80.09**	37.20**
6 × 4	-5.97**	51.31**	27.77**
7 × 1	51.17**	129.87**	91.59**
7 × 2	12.65**	71.30**	41.50**
7 × 3	19.76**	82.10**	43.58**
7 × 4	-21.85**	18.83**	4.24
SE	0.30		0.26
CD at $P \leq 0.05$	0.58		0.50
CD at $P \leq 0.01$	0.77		0.66

*,**: Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

The range of heterosis varied from -19.46% (L4 × T3) to 151.34% (L3 × T2) over commercial hybrid Arka Harita. Payakhapaab *et al.,* (2012) found heterosis and heterobeltiosis from -44.41 (CA 1449 × CA 1448) to 77.94% (CA 1445 × CA 683) and from -48.35 (CA 1449 × CA 1448) to 72.96% (CA 1445 × CA 683), respectively for yield (t/1600 m^2). The range of standard heterosis was observed from -40.35 to 126.32% by Prasath and Ponnuswami (2008) for yield ha^{-1} and crosses which showed significant standard heterosis were Arka Abir × Byadagi Kaddi, Byadagi Kaddi × Co-4, MDU Y × Co-4 and Co-4 × MDU Y.

The superior crosses based on heterobeltosis, mid-parent heterosis and standard heterosis were L1 × T1, L1 × T3, L1 × T4, L3 × T1, L3 × T2, L3 × T3, L4 × T1, L6 × T1, L6 × T3, L7 × T1, L7 × T3 for fruit yield and yield attributes. These hybrids could be used further in chilli breeding programme.

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