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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 $F_1$s 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 $F_1$s crosses, crosses SC-304 × Arka Lohit and SC-277 × Local had revealed the highest significant desirable heterobeltiosis for early maturity. The crosses SC-502 × Arka Lohit 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 $F_1$s. The seeds of thirteen parents and their resultant 30 $F_1$s 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.Themagnitude ofheterosis for plant height ranged from -24.73 to 35.54 %. Out of 30 crosses, only eight crosses showing significantpositiveheterosis 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 × Arka Lohit (-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 × Arka Lohit (-53.88%) followed by SC-108 × Arka Lohit (-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 × Arka Lohit (68.00%), SC-23 × Local (59.55%). Among heterotic hybrids, the cross SC-502 × Arka Lohit 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 × Arka Lohit (-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).

**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 |

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 of heterosis was -37.11 to 96.69 percent. The crosses SC-1154 × Kashmir Long-1 (96.69%) followed by SC-304 × Arka Lohit (94.30%), SC-23 × Local (57.22%), SC-108 × Arka Lohit (55.96%). SC-885 × Arka Lohit (52.07%), SC-1154 × Arka Lohit (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

**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

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 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 × Arka Lohit (-14.71%) recorded highest desirable negative heterosis followed by SC-277 × Local (-14.05%), SC-277 × ArkaLohit (-13.87%) and SC-814 × Arka Lohit (-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 × Arka Lohit recorded highest negative heterobeltiosis of -13.54% followed by SC-304 × Arka Lohit (-13.14%), SC-1001 × Arka Lohit (-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 ×Arka Lohit (-9.14%) and SC-1154 × Kashmir Long-1 (-9.10%). Hybrid SC-105 × Arka Lohit 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 × Arka Lohit (76.86%) recorded highest heterobeltiosis followed by SC- 814 × Arka Lohit (42.15%), SC-277 × Arka Lohit (40.89%) and SC-502 × Arka Lohit (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 × Arka Lohit (46.43%) recorded highest positive heterosis followed by SC-1001 × ArkaLohit (46.15%), SC-885 × Arka Lohit (44.12%) and SC-304 × Kashmir Long-1 (43.59%). Only two crosses showed significant negative heterosis viz. SC-502 × Arka Lohit (-24.32%) and SC-885 × Kashmir Long-1 (-35.90%). This results is conformity

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

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 negative heterosis over the better parent. Highest heterobeltiosis of 141.05% was exhibited by cross SC-502 × ArkaLohit, followed by SC-1001 × Arka Lohit (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 × Arka Lohit followed by SC-108 × Arka Lohit (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 × Arka Lohit was recognized as the best heterotic cross for fruit yield followed by SC-1001 × Arka Lohit 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.

## REFERENCES

**Anonymous 2013.** Special Report on Chilli. *IIVR Annual Report, Varanasi.*, p. 77.

**AVRDC (Asian Vegetable Research and Development Centre). 2000.** Multiplying seed of pepper lines. International cooperators' guide. *Asian Vegetable Research and Development Center,* Taiwan. p. 1.

**Chaudhary, A., Kumar, R. and Solankey, S. S. 2014.** Estimation of heterosis for yield and quality components in chilli (*Capsicum annuum* L.). *African J. Biotechnology*. **12(47):** 6605-6610.

**Deshpande, R. B. 1933.** Studies in India Chillies. III. The inheritance of some characters in *Capsicum annuum* L. *Indian J. Agricultural Sciences*. **3:** 219-300.

**Doshi, K. M. and Shukla, P. T. 2000**. Expression of heterosis in chilli (*Capsicum annuum* L.). *Capsicum Egg Plant Newsl*. **19:** 66-69.

**Dubey, R., Das, A., Ojha, M. D., Saha, B., Ranjan, A. and Singh,P. K.**

**2014.** Heterosis and Combining ability studies for yield and yield attributing traits in brinjal (*Solanum melongena* L.).*The Bioscan*. **9(2):** 889-894.

**Hasanuzzaman, M., Hakim, M. A., Hanafi, M. M., Juraimi, A. S., Islam, M. M. and Shamsuddin, A. K. M. 2013.** Study of heterosis in Bangladeshi chilli (*Capsicum annuum*L.) landraces. *Agrociencia*. **47:** 683-690.

**Hazra, P., Chattopadhyay, A., Karmakar, K. and Dutta, S. 2011**. *Modern Technology in Vegetable Production,* New India Publishing Agency, New Delhi, India. p. 478.

**Khalil, M. R. and Hatem, M. K. 2014.** Study on combining ability and heterosis of yield and Its components in pepper (*Capsicum annum*, L.). *Alex. J. Agric. Res.* **59(1):** 61 71.

**Kempthorne, O. 1957**. An Introduction to Genetics Statistics. *J. Wiley and Sons,* New York, pp. 41-43.

**Kumar, R. L., Sridevi, O., Kage, U. K., Salimath, P. M., Madalageri, D. and Natikar, P. 2014.** Heterosis Studies in Chilli (*Capsicum annuum*L.). *International J. Horticulture*. **4(8):** 40-43.

**Lyngdoh,Y. A., Mulge, R. and Shadap, A. 2013.** Heterosis and Combining ability studies in near homozygous lines of okra [*Abelmoschus esculentus* (l.) moench] for growth parameters. *The Bioscan*. **8(4):** 1275-1279.

**Makani, A. Y., Patel, A. Y., Bhatt, M. M. and Patel, P. C. 2013**. Heterosis for yield and its contributing attributes in brinjal (*Solanum melongena* L.). *The Bioscan*. **8(4):** 1369-1371.

**Panse, V. G. and Sukhatme, P. V. 1978.** Statistical Methods for Agricultural Workers. *ICAR Publication (2nd Ed.), New Delhi.*

**Patel, J. A., Patel, M. J., Patel, S. B., Patel, M. N., Acharya, R. R. and Bhalala, M. K. 2002.** Heterosis for greenfruit yield and its components in chilli(*Capsicum annuum* L.). In: Abstr. *International Conference on Vegetables*, November 11-14, Bengaluru,Karnataka. pp.102-103.

**Patel, M. P., Patel, A. R., Patel, J. B. and Patel, J. A. 2010.** Heterosis for green fruit yield and its components in chilli (*Capsicum annuum var. longicum* (D.G) Sendt) over environments. *Electronic J. Plant Breeding*. **1(6):** 1443-1453.

**Patel, A. L., Kathiria, K. B. and Patel, B. R. 2014.** Heterosis in mild pungent chilli (*Capsicum annuum* L.) *J. Spices and Aromatic Crops*. **23(2):** 178-185.

**Payakhapaab, S., Boonyakiat, D. and Nikornpun, M. 2012.** Evaluation of Heterosis and Combining ability of Yield Components in Chillies. *J. Agricultural Science*. **4(11):** 154-161.

**Prasath, D. and Ponnuswami, V. 2008.** Heterosis and Combining ability for morphological yield and quality characters in paprika type chilli hybrids. *Indian J. Horticulture*. **65(4):** 441-445.

**Ramesh, M., Lavanya, C., Sujatha, M., Sivasankar, A., Aruna Kumari, J. and Meena, H. P. 2013.** Heterosis and combining ability for yield and yield component characters of newly developed castor (*Ricinus communis* L.) hybrid. *The Bioscan*. **8(4):** 1421-1424.

**Reddy, M. G., Kumar, H. D. M. and Salimath, P. M. 2008**. Heterosis Studies in Chilli (*Capsicum annuum*L.). *Karnataka J. Agriculture Science*. **21(4):** 570-571.

**Reddy, E. E. P. and Patel, A. I. 2014.** Heterosis Studies for Yield and Yield Attributing Characters in Brinjal (*SolanumMelongena* L.). *J. Recent Advance in Agriculture*. **2(2):** 175-180.

**Satish, R. G. and Lad, D. B. 2007.** Heterosis Studies in chilli (*Capsicum annum* L.). *J. Maharashtra Agriculture University*. **32:** 68-71.

**Shankar, A., Reddy, R. V. S. K., Sujatha, M. and Pratap, M. 2014.** Development of superior $F_1$ hybrids for commercial exploitation in tomato, *Solanum lycopersicum*L. *International J. Farm Sciences*. **4(2):** 58-69.

**Shankarnag, B., Madalageri, M. B. and Mulge, R. 2006.** Manifestation of heterosis for growth,earliness and early green fruit yield in chilli. *Indian J. Horticulture*. **63:** 410-414.

**Sharma, V. K., Punetha, S. and Sharma, B. B. 2013.** Heterosis studies for earliness, fruit yield and yield attributing traits in bell pepper. *African J. Agricultural Research*. **8(29):** 4088-4098.

**Turner, J. M. 1953.** A Study of heterosis in upland cotton II. Combining ability and inbreeding effects. *Agronomy J.* **45:** 484-490.