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GENETIC ANALYSIS OF YIELD AND LEAF CURL VIRUS RESISTANCE IN CHILLI (*Capsicum annuum* L.)

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DECLARATION

I hereby declare that this thesis entitled **"Genetic analysis of yield and leaf curl virus resistance in chilli (*Capsicum annuum* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Genetic analysis of yield and leaf curl virus resistance in chilli (*Capsicum annuum* L.)"** is a record of research work done independently by Mr.A.Muthuswamy (2000-21-14) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

1. INTRODUCTION

Chillies are the green and dried ripe fruits of the crop *Capsicum annuum* L. It forms an indispensable condiment, spice and vegetable in every house in the world in the form of dry chilli or powder, green chilli, pickles and other culinary preparation. It is a member of nightshade family Solanaceae. This crop is mainly cultivated in tropical and subtropical countries *viz.*, India, Africa, Japan, Mexico, Turkey, USA etc.

Chilli originated in tropical America (Mexico, Guatemala) and Bulgaria and the seeds were brought to old world by Columbus. It was introduced into India by Portuguese in 16th century and by the end of 19th century, its cultivation was spread throughout the country.

Chillies forms an indispensable adjunct in every house of tropical world as it provides a spicy taste, pungency and adds appealing colour to the food preparation. Besides, it is the source of protein, carbohydrates, minerals, vitamin C and A and carotenes. The active principle of pungency is due to the presence of a crystalline volatile alkaloid called capsaicin. Capsaicin is not a single compound but a mixture of 20 capsainoids. Important capsainoids are dihydrocapsaicin, vanillyldamide and decyclic acid vanillylamide. Chilli is also a rich source of red pigments namely capsorubin, cryptoxanthin and related carotenoids, which are esters of capsanthin. Oleoresin, which is extensively used in the west in food preparations for uniform quality, longer shelf life, taste and flavour can also be obtained from chillies. It is used in cosmetics, beverages and in medicine for treatment of inflammation.

In India, chilli is grown in an area of 9.65 lakh hectares with an annual production of 10.75 lakh tonnes with productivity of 1.11 t ha^{-1} (Peter *et al.*, 2004) as against the world average of 2.0 tonnes per hectare. As there exists a tremendous demand for Indian chillies in the international market, there is a wide scope to improve the exports considerably. The expected demand indicated the necessity to increase both production and productivity level through high yielding varieties.

The low productivity could mainly be attributed to its cultivation under rainfed condition and the exposure of the crop to both abiotic and biotic stresses. One of the important biotic stresses in this crop is the leaf curl disease caused by the chilli leaf curl virus, which causes considerable loss in yield especially during summer. It is a DNA virus (gemini virus) spread by the vector, *Bemisia tabaci*. The only way to check viral disease is by controlling the vector population using insecticides. But only partial control of the disease can be achieved through the use of chemicals. Moreover, the use of insecticides makes chilli cultivation costly and hazardous to human being and environment. Due to this cultivation of chilli has become uneconomical particularly during summer season. Thus there is an urgent need to develop leaf curl virus resistant varieties for summer cultivation (Peter, 1998).

Studies on the inheritance patterns of leaf curl virus resistance in chilli carried out so far are very much limited.

To develop varieties with high yielding potential and resistance to leaf curl virus, a knowledge of gene action involved in the above two characters and their related traits is a pre requisite. Only based on the knowledge of gene action involved for the different characters, suitable breeding method can be adopted.

Keeping in view the above facts, the present study was undertaken with the following objectives:

1. To study the variability, heritability and genetic advance for fruit yield and leaf curl virus resistance in a collection of chilli genotypes.
2. To estimate the extent of association between fruit yield and its component characters.
3. To assess in the hybrids, general combining ability of parents and specific combining ability of hybrids, the magnitude of heterosis

for fruit yield, leaf curl virus resistance and other desirable economic characters.

4. To estimate the additive, dominance and epistatic gene actions involved in the inheritance of yield and its component characters and leaf curl virus resistance through generation mean analysis for formulating future breeding programme to develop high yielding leaf curl virus resistant varieties.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Sweet pepper (*Capsicum annuum* L.) is a high value crop grown commercially in almost all parts of India for its large green blocky fruits which are used as vegetable. Proper and systematic evaluation of genetic resources is essential to understand and estimate the genetic variability, heterosis and gene action. In this section an attempt has been made to review the up-to-date literature under the following headings.

2.1 Variability

2.2 Heritability and genetic advance

2.3 Character association

2.4 Combining ability

2.5 Heterosis

2.6 Gene action

2.7 Genetics of leaf curl resistance

2.1 VARIABILITY

Presence of variability among genotypes is a pre-requisite for any crop improvement programme.

Variability studies in 31 varieties of sweet pepper revealed that both phenotypic and genotypic coefficients of variation were high for fruit number and fruit yield, medium for fruit weight and low for all the other characters (Singh and Brar, 1979). Rajput *et al.* (1981) also observed similar results of genotypic coefficient of variation for number of fruits per plant (19.20) and yield (18.28) in seven cultivars of chilli.

Ramakumar *et al.* (1981) observed high variability among 12 varieties for plant height, plant spread, fruit girth, number of seeds per fruit, number of fruits per plant and yield.

Nair *et al.* (1984) observed wide range of variability for number of primary and secondary branches, life span and number of seeds in a study with 30 genotypes. Evaluating 38 chilli lines, Gopalakrishnan *et al.* (1987a) observed similar results.

In a study involving 12 parents and their 66 F_1 and F_2 progenies, Gupta and Yadav (1984) found that the genotypic coefficient of variation ranged from 11 per cent of plant height to 62.6 for fruit girth.

Gopalakrishnan *et al.* (1987a) obtained high GCV for fruit length (42.17), main stem length (44.61), fruit weight (29.70), fruit per plant (35.28) and fruit yield per plant (32.31) in 38 lines of chilli.

In a study on ten *Capsicum annuum* and fifteen *Capsicum frutescens* cultivars, high levels of variation for fruits / plants, individual fruit weight and fresh fruit yield / plant in both species was observed by Adamu and Ado (1988). *Capsicum frutescens* showed high variation in 100-seed weight and dry fruit yield / plant also.

Vijayalakshmi *et al.* (1989) observed greater difference between phenotypic coefficients of variation (PCV) and genotypic coefficient of variation (GCV) for plant height, plant spread, number of flowers, number of pods, total yield and total dry pod yield indicating greater influence of environment on these characters. Gopalakrishnan *et al.* (1985) also obtained similar results with regard to number of branches per plant.

Das *et al.* (1990) reported significant differences among 30 genotypes for six components of fruit yield.

Evaluating fourteen F_6 families of the cross Acc 1683 x K2, Pitchaimuthu and Pappiah (1992) observed very high variability per plant for number of fruits, dry and fresh weight of fruit and plant height.

Acharya *et al.* (1992) reported high variability in 19 cultivars of chilli for number of fruits per plant, yield per plant, fruit length and circumference and seeds per fruit. This was similar to earlier works reported by Choudhary *et al.* (1985) and Gopalakrishnan *et al.* (1985). In a study of yield related traits in 20 chilli genotypes, Singh *et al.* (1994) reported that variability was greatest for weight of fresh red ripe fruits per plant.

Pitchaimuthu and Pappiah (1992) observed a close association between estimates of phenotypic and genotypic coefficients of variation for several characters in F_6 families indicating low environmental influence. However, length and girth of fruit and earliness were highly sensitive to environmental factors.

In a study with 79 genotypes of chillies, Rani *et al.* (1996a) noticed that both PCV and GCV were high for fruits per plant, mean fruit weight, yield per plant, fruit length, weight of seeds per fruits 100-seed weight and dry matter production.

Rani (1996a,b) observed significant differences among 73 chilli genotypes for fruit length, fruit diameter, fruit weight, seed weight and number of seeds per fruit.

In a study on genetic variability of several morphological characters in pickling pepper (*C. annuum*) cv. Madalina, Lupascu and Tanasescu (1996) noticed low phenotypic variation for shape index, plant height and pericarp thickness and medium to high variation for fruits/plant and fruit weight.

Nayeema *et al.* (1998) reported high variability for all the characters studied especially for fruit yield in 71 genotypes of chilli. Several other workers also obtained similar results (Rani and Singh, 1996; Singh and Singh, 1998 ; Das and Choudhary, 1999b).

Ambarus (1998) found that plant height and fruit yield per plant had low variability estimates (< 10 %) whereas fruit length showed moderate variability.

Devi and Arumugam (1999b) reported very high levels of phenotypic and genotypic variation for yield of fresh fruit per plant whereas plant height, days to first flowering and dry fruit yield per plant had moderate variation.

The study involving 30 germplasm of chilli revealed the existence of considerable amount of genetic variability for all the characters studied except fruit girth (Munshi and Behera, 2000). They obtained GCV ranging from 5.32 per cent (days to first fruit harvest) to 54.94 per cent (number of fruits per plant) in a study with 30 chilli germplasm.

In a study involving intra specific cross between a bell type 'Maor' and small fruited pungent chilli line 'Perennial' Chaim and Paran (2000) noticed GCV values low for plant height, moderate for fruit length and high for fruit weight and fruit diameter.

The analysis of variance of eight yield components in 13 chilli cultivars expressed considerable variability among various components (Rathod *et al.*, 2002). High GCV estimate for number of fruits per plant, fresh red chilli yield per plant and plant height was observed.

Higher phenotypic and genotypic coefficients of variation were observed for fruits per plant, fruit weight, fruit length, fruit girth, yield and leaf area (Sreelathakumary and Rajamony, 2002).

Nandadevi and Hosamani (2003a) observed high degree of PCV and GCV for number of primary branches, fruit length, pericarp thickness, and number of fruits per plant and green fruit yield per plant.

2.2 HERITABILITY AND GENETIC ADVANCE

Singh and Singh (1977b) observed high values for heritability and genetic advance for number of fruits per plant, number of branches, plant height, days to maturity and yield per plant in chilli.

Bavaji and Murthy (1982) noticed high heritability coupled with high genetic advance for branches per plant, fruit length, 50 fruit weight and fruits per plant in a study involving 25 varieties of chilli.

Nair *et al.* (1984) reported high heritability along with low genetic advance for days to flower, plant height, plant spread, number of primary branches and lifespan.

In their study using 12 varieties of chilli, Shah *et al.* (1986) observed high heritability and expected genetic advance for plant height, number of primary branches, fruit length, fruit width and number of fruits per plant.

Ghai and Thakur (1987) reported that total yield and number of fruits recorded the lowest value of heritability in narrow sense in a population comprising of parents, F_1s, F_2s and backcrosses in chilli. The expected genetic advance showed a wide range from 8.82 per cent for number of fruits per plant to 73.81 for fruit weight. But Depestre *et al.* (1989) obtained maximum narrow sense heritability and marked genetic advance for fruit number per plant, and yield in a natural population of *C. annuum* cv espanol.

The highest estimates of heritability and genetic advance were found for yield per plant in a study involving 30 genotype of chilli (Das *et al.*, 1989). High heritability coupled with high genetic advance was recorded for leaf area index, fruits per plant, fruit weight, seeds per fruit, plant height and fruit length (Varalakshmi and Babu, 1991).

In a study nine cultivars of chilli, Nandi (1993) noticed that length and weight of pod and yield per plant had medium to high heritability and high genetic advance.

Singh *et al.* (1994) obtained high heritability for fruit length, weight of fresh ripe fruits, dry fruit weight, number of fruits per plant and fruit diameter.

Pitchaimuthu and Pappiah (1995) found high heritability coupled with high genetic advance for number of fruits per plant, fruit length and fruit girth while evaluating fourteen F_6 families from the cross Acc.1683 x K2.

In a study with 71 genotypes of hot pepper Nayeema *et al.* (1998) observed high heritability coupled with high genetic advance for the characters fruit yield per plant, seed number per fruit, pericarp thickness and average fruit weight.

Heritability and genetic advance were high for number of fruits per plant and fruit weight (Devi and Arumugam, 1999b).

In their study on ten quantitative traits in pepper, Chaim and Paran (2000) observed that days to first ripened fruit and total soluble solids had low values for narrow sense heritability whereas other traits showed moderate to high values.

Ibrahim *et al.* (2001) observed that highest heritability was exhibited for plant height (98.12 %) followed by fruit length (96.74 %) and number of fruits per plant (96.18 %) in chilli.

As per the reports of Rathod *et al.* (2002), heritability was high for day to 50 per cent flowering, plant height, number of primary branches and fruits per plant, length and diameter of fruit, 100-seed weight, seed percentage, harvest index and fresh red chilli yield per plant. High heritability coupled with high genetic advance was recorded for the number of fruits per plant, fresh red chilli yield per plant and plant height

Acharyya *et al.* (2002) observed high heritability coupled with high genetic advance for total fresh yield per plant under both leaf curl infected and non-infected environments in chilli.

High heritability and genetic advance were noted for number of fruits per plant, fruit weight, fruit length, fruit girth, yield and leaf area by Sreelathakumary and Rajamony (2002).

Chaim and Paran (2000) recorded high heritability (broad sense) values for fruit weight, fruit diameter, fruit length and pericarp thickness but low heritability for plant height.

In their study on 26 chilli genotypes Nandadevi and Hosamani (2003a) reported high heritability coupled with high genetic advance for fruit length and green fruit yield per plant.

2.3 CHARACTER ASSOCIATION

A knowledge of the correlation between yield and its component characters is essential for choosing the characters for selection.

Pandian and Sivasubramanian (1978) found that the total number of fruits harvested per plant had significant positive association with flowers produced during 66 – 86 days in chilli.

Yield was found to be negatively correlated with days to flowering (Rao *et al.*, 1981). But, Sundaram and Ranganathan (1978) and Veerappa (1982) reported significant positive correlation of yield with days to flowering.

Choudhary *et al.* (1985) observed positive correlation of yield per plant with fruit girth and weight of ten fruits, which in turn had a significant positive association with number of seeds per fruit. But Gopalakrishnan *et al.* (1985) observed negative correlation of fruit girth with fruit yield per plant while fruit length showed maximum positive correlation with yield.

Miranda *et al.* (1988b) observed positive genotypic correlation of total yield per plant with early yield, average weight per sampled fruit and fruit length.

Yield per plant was found to be significantly and positively correlated with number of primary and secondary branches per plant and number of seeds per fruit in a variability study involving 30 chilli lines (Das *et al.*, 1989). Significant negative correlation of yield with days to 50 per cent flowering and days taken for fruit set with maturity was reported by Bhagyalakshmi *et al.* (1990).

Ali (1994) reported positive association of fruit yield with number of seeds per fruit and number of fruits per plant. Plant height, plant spread, number of primary branches per plant and number of secondary branches per plant showed significant positive correlation with yield (Rani, 1995).

Rani (1996b) reported positive correlation between seed weight per fruit and number of seeds per fruit. She further concluded that genetic improvement of seeds per fruits, seed weight per fruit diameter and fruit weight are important for obtaining higher fruit yield.

Vallejo *et al.* (1997) reported that fruit yield in chilli had positive genotypic correlation with number of fruits per plant whereas negative with mean fruit weight and mean locule weight. Besides a highly negative and very significant genetic correlation was observed between fruits per plant and mean fruit and mean locule weight.

Number of fruits per plant average fruit weight, plant height, plant spread and fruit length showed positive correlation with fruit yield (Ahmed *et al.*, 1997). Dahiya *et al.* (1991) and Khurana *et al.* (1993) also observed similar association of components with yield.

Subashri and Natarajan (1999) obtained positive association of yield with branches per plant, fruit per plant, fruit weight and fruit length in F_2 population in chilli. Correlation study in 25 genotypes of chilli showed that yield exhibited positive correlations with fruit weigh, fruit per plant and primary branches per plant (Das and Choudhary, 1999a). The high magnitude of positive direct effect of branches per plant, fruits per plant and fruit size on yield was reported by Deka and Shadeque (1997).

The relationship between 5 fruit characteristics in six pepper cultivars studied by Dimova and Panayotov (1999) revealed that pericarp weight had highest direct effect on fruit weight (0.762 – 0.941) while the other fruit characteristics affected fruit weight mainly via pericarp. Positively significant correlation was observed between dry fruit yield and number of fruits per plant, capsaicin content and plant height (Devi and Arumugam, 1999a).

Chaim and Paran (2000) reported that the high genetic correlation coefficient of fruit weight with fruit diameter, pericarp thickness and pedicel diameter in chilli. In contrast, fruit weight had a low correlation coefficient with fruit length.

Yield per plant was significantly and positively correlated with number of fruits per plant and fruit weight (Munshi *et al.*, 2000). Kohli and Chatterjee (2000) reported significant negative correlation between capsaicin content and yield.

Studying seventeen genotypes of chilli, Ibrahim *et al.* (2001) reported that dry fruit yield exhibited significant positive correlation with number of fruits per plant, number of branches, fruit length, fruit width and plant height. Besides, number of fruits per plant showed highly significant positive correlation with number of branches and plant height but negative correlation with fruit length.

In their study on thirteen genotypes of chilli, Rathod *et al.* (2002) observed the significant positive association of wet red chilli yield with number of fruits per plant, 100-seed weight, seed percentage and harvest index. The association among the yield components revealed the positive significant relationship between 100 seed weight, seed percentage and harvest index. Nandadevi and Hosamani (2003a) revealed the positive association of yield per plant with number of fruits per plant and pedicle length.

2.4 COMBINING ABILITY

The information derived from combining ability analysis form the basis for the plant breeder to make crucial decisions to identify the genotypes and adopt suitable technique and methods for future breeding programme. To study the combining ability line x tester and diallel cross technique are used. List of literature and their summary pertaining to combining ability in chilli are presented in Table1.

2.5 HETEROSIS

The deviation of a character in an F_1 hybrid from the mean (arithmetic or geometric) of the two parents is referred as "heterosis". Shull (1908) referred to this phenomena as 'special stimulus of heterozygous' and in his words, it is increased vigour size, fruit fullness, speed of development, resistance to disease and insect pests manifested by outbreeding organism as compared with corresponding inbreds.

Heterosis breeding has resulted in the improvement of crop plants with respect to maximum performance under optimal growing conditions. Hybrid vigour has resulted in spectacular yield increase in maize, sorghum, bajra and sunflower hybrids. Heterosis has been commercially

Table 1. Combining ability for quantitative and qualitative characters in chilli (*Capsicum annuum* L.)

Characters	Materials and methods	Combining ability variance		References
		gca	*sca*	
Days to flower initiation	8 x 8 full diallel	Significant	NS	Singh and Singh (1977a)
	12 x 3 L x T	Significant	NS	Pandey *et al*. (1981a)
	4 x 4 full diallel	Significant	NS	Gopalakrishnan *et al*. (1987b)
	9 x 9 full diallel	Significant	Significant	Cao and Su (1988)
	18 x 4 L x T	Significant	NS	Gaddagimath (1992)
	20 x 3 L x T	NS	Significant	Jagadeesh (1995)
	5 x 5 diallel	Significant	Significant	Lazic (1997)
	10 x 10 diallel	Significant		Echeverri *et al*. (1998)
	10 x 10 diallel	Significant	Significant	Lohithaswa *et al*. (2000)
Days to 50 per cent flowering	6 x 6 diallel	Significant	Significant	Nandadevi and Hosamani (2003b)
Days to 75 per cent flowering	9 x 9 diallel	NS	Significant	Joshi (1988)
Number of branches	4 x 4 diallel	Significant	Significant	Milkova (1984)
	9 x 9 diallel	Significant	Significant	Cao and Su (1988)
	8 x 8 diallel	Significant	NS	Patil (1990)
	18 x 4 L x T	NS	Significant	Gaddagimath (1992)
	18 x 3 L x T	NS	Significant	Mulge (1992)
	15 x 3 L x T	NS	Significant	Pandian and Shanmugavelu (1992)
	20 x 3 L x T	Significant	NS	Jagadeesh (1995)
	-	NS	Significant	Patil (1997)
	3 x 8 L x T	NS	Significant	Shukla *et al*. (1999)
Number of fruits per plant	12 x 3 L x T	Significant	NS	Pandey *et al* (1981a,b)
	7 x7 diallel	NS	Significant	Gaddagimath *et al*. (1988)
	12 x 2 L x T	Significant	NS	Kaul and Sharma (1988b)
	6 x 6 diallel	Significant	NS	Miranda *et al*. (1988a)
	6 x 6 diallel	Significant	Significant	Bhagyalakshmi *et al*. (1991)
	18 x 4 L x T	Significant	NS	Gaddagimath (1992)

Table 1. continued...

Number of fruits per plant	15 x 3 L x T	NS	Significant	Pandian and Shanmugavelu (1992)
	4 x 4 diallel	Significant		Nowaczyk *et al.* (1993)
	20 x 3 L x T	NS	Significant	Jagadeesh (1995)
	10 x 10 diallel	Significant	Significant	Lohithaswa (1997)
	20 x 3 L x T	Significant	Significant	Patil (1997)
	10 x10 diallel	Significant	NS	Echeverri *et al.* (1998)
	6 x 2 L x T	Significant	Significant	Jadhav *et al.* (2001)
	6 x 6 diallel	Significant	Significant	Ahmed *et al.* (1999)
	3 x 8 L x T	NS	Significant	Shukla *et al.* (1999)
	6 x 6 diallel	Significant	Significant	Nandadevi and Hosamani ((2003b)
Average fruit weight	6 curves	NS	Significant	Khalf – Allah *et al.* (1975)
	Top cross of 19 var.	Significant	NS	Dolgikh and Sviridova (1983)
	4x 4 diallel	Significant	NS	Gopalakrishnan *et al.* (1987b)
	9 x 9 diallel	Significant	Significant	Joshi (1988)
	6 x 6 diallel	Significant	NS	Miranda and Costa (1988)
	4 x 4 diallel	Significant	NS	Nowaczyk *et al.* (1993)
	10 x 10 diallel	Significant	Significant	Lohithaswa *et al.* (1999)
	20 x 3 L x T	Significant	Significant	Patil (1997)
	6 x 6 diallel	Significant	Significant	Ahmed *et al.* (1999)
	3 x 8 L x T	NS	Significant	Shukla *et al.* (1999)
	6 x 2 L x T	Significant	Significant	Jadhav *et al.* (2001)
	6 x 6 diallel	Significant	Significant	Nandadevi and Hosamani (2003b)
Fruit yield per plant	8 x 8 diallel	Significant	NS	Betlack (1973)
	6 curves	NS	Significant	Khalf-Allah *et al* (1975)
	8 x 8 diallel	NS	Significant	Singh and Singh (1978 a,b)
	12 x 3 L x T	Significant	NS	Pandey *et al.* (1981b)
	7 x 7 diallel	NS	Significant	Gaddagimath *et al.* (1988)
	6 x 6 diallel	NS	Significant	Miranda *et al.* (1988 a)
	12 x 12 L x T	Significant	NS	Kaul and Sharma (1988 b)
	8 x 8 diallel	Significant	NS	Patil (1990)

Table 1. continued...

Fruit yield per plant	6 x 6 diallel	Significant	Significant	Bhagyalakshmi *et al.* (1991)
	18 x 4 L x T	NS	Significant	Gaddagimath (1992)
	15 x3 L x T	NS	Significant	Pandian and Shanmugavelu (1992)
	4 x4 diallel	Significant	NS	Nowaczyk *et al.* (1993)
	20x3 L x T	NS	Significant	Jagadeesh (1995)
	10x10 diallel	NS	Significant	Lohithaswa (1997)
	20x3 L x T	NS	Significant	Patil (1997)
	10x10 diallel	Significant	NS	Echeverri *et al.* (1998)
	6 x6 diallel	Significant	Significant	Ahmed *et al.* (1999)
	3x8 LxT	NS	Significant	Shukla *et al.* (1999)
	6x6diallel	NS	Significant	Gandhi and Navale (2000)
	10x10 diallel	NS	Significant	Lohithaswa *et al.* (2000)
	7x7 diallel	Significant	Significant	Legesse (2000)
	6x2 LxT	Significant	Significant	Jadhav *et al.* (2001)
	6x6 diallel	Significant	Significant	Nandadevi and Hosamani (2003b)
Fruit length	4x4 diallel	Significant	NS	Lippert (1975)
	8x8 diallel	NS	Significant	Singh and Singh (1977a)
	9x9 diallel	Significant	NS	Sontakke (1981)
	4x4 diallel	Significant	Significant	Gopalakrishnan *et al.* (1987b)
	9x9 diallel	Significant	Significant	Joshi (1988)
	12x2 LxT	Significant	NS	Kaul and Sharma (1988b)
	8x8 diallel	Significant	Significant	Patil (1990)
	6x6 diallel	Significant	Significant	Bhagyalakshmi *et al.* (1991)
	18 x4 diallel	Significant	NS	Gaddagimath (1992)
	20x3 LxT	NS	Significant	Jagadeesh (1995)
	Diallel	Significant	Significant	Lohithaswa (1997)
	20x3 LxT	NS	Significant	Patil (1997)
	10x10 diallel	Significant	NS	Echeverri *et al.* (1998)
	6x6 diallel	Significant	Significant	Ahmed *et al.* (1999)
	6x6 diallel	Significant	NS	Nandadevi and Hosamani (2003b)

Table 1. continued...

Fruit girth	9x9 diallel	Significant	Significant	Joshi (1988)
Fruit width	4x4 diallel	NS	Significant	Lipert (1975)
	4x4 diallel	Significant	NS	Milkova (1979)
	12x2 L x T	Significant	Significant	Kaul and Sharma (1988 b)
	8x8 diallel	NS	Significant	Patil (1990)
	18 x 4 L x T	Significant	NS	Gaddagimath (1992)
	20x3 L x T	NS	Significant	Jagadeesh (1995)
	Diallel	Significant	Significant	Lohithaswa (1997)
	20x3 L x T	Significant	Significant	Patil (1997)
	10x10 diallel	Significant	NS	Echeverri *et al*. (1998)
	10x10 diallel	Significant	Significant	Lohithaswa *et al*. (2000)
Plant height	10x10 diallel	Significant	Significant	Milkova (1977)
	12x3 L x T	Significant	NS	Pandey *et al*. (1981b)
	7x7 diallel	Significant	NS	Gaddagimath *et al*. (1988)
	9x9 diallel	Significant	Significant	Joshi (1988)
	6x6 diallel	NS	Significant	Miranda *et al*. (1988 a,b)
	8x8 diallel	Significant	NS	Patil (1990)
	6x6 diallel	Significant..	Significant	Bhagyalakshmi *et al*. (1991)
	15x3 L x T	NS	Significant	Pandian and Shanmugavelu (1992)
	20x3 L x T	Significant	NS	Jagadeesh (1995)
	10x10 diallel	Significant	NS	Echeverri *et al*. (1998)
	6x6 diallel	Significant	Significant	Ahmed *et al*. (1999)
	3x8 L x T	NS	Significant	Shukla *et al*. (1999)
	6x6 diallel	NS	Significant	Gandhi and Navale (2000)
	10x10 diallel	Significant	Significant	Lohithaswa *et al*. (2000)
	6x2 L x T	Significant	Significant	Jadhav *et al*. (2001)
Number of seeds per fruit	4x4 diallel	Significant	NS	Martin and Lippert (1975)
	8x8 diallel	Significant	Significant	Singh and Singh (1978 b)
	4x4 diallel	Significant	Significant	Milkova (1984)

Table 1. continued...

Number of seeds per fruit	7x7 diallel	NS	Significant	Gaddagimath *et al.* (1988)
	6x6 diallel	Significant	Significant	Bhagyalakshmi *et al.* (1991)
	8x8 diallel	Significant	Significant	Patil (1990)
	18x4 L x T	Significant	NS	Gaddagimath (1992)
	15 x 3 L x T	NS	Significant	Pandian and Shanmugavelu (1992)
	10x10 diallel	Significant	Significant	Lohithaswa (1997)
	20 x 3 L x T	Significant	Significant	Patil (1997)
	6x6 diallel	Significant	Significant	Nandadevi and Hosamani (2003b)
Seed weight per fruit	4x4 diallel	Significant	Significant	Singh & Singh (1976)
	-	Significant	Significant	Gaddagimath (1985)
	8x6 L x T	Significant	Significant	Bhagyalakshmi *et al.* (1991)
	18 x4 L x T	Significant	Significant	Gaddagimath (1992)
	15 x3 L x T	Significant	Significant	Pandian and Shanmugavelu (1992)
Capsaicin content	6x6 diallel	Significant	NS	Park and Takahashi (1980)
	10x10 diallel	Significant	Significant	Lohithaswa (1997)
	20x3 L x T	NS	Significant	Patil (1997)
	6 generation mean analysis	Significant	NS	Ahmed *et al.* (1998)
	10x 10 diallel	Significant	Significant	Lohithaswa *et al.*.(1999)

NS-non significant
gca-general combining ability
sca-specific combining ability

exploited in several vegetable crops such as onion, tomato, cabbage, *carrot, brinjal, cucumber, watermelon and pumpkin* (Seshadri and Chatterjee, 1983).

Heterosis can be exploited in chilli also. Hybrid seed production can be economical since the fruits contain large number of seeds and the natural cross-pollination is to the extent of 7 to 68 per cent (Sekar and Arumugam, 1985). Heterosis for yield components in chillies was reported as early as by Deshpande (1933) and Pal (1945). The literature on heterosis for yield and other qualitative characters has been summarized in Table 2.

2.6 GENE ACTION

The choice of an appropriate breeding method for improvement of quantitative characters also depends largely on gene action. But the effects of individual genes cannot be measured. Environment also influence the phenotype expression of characters. Therefore the effect of individual genes must be considered using suitable statistical procedures to obtain genetic information.

The summary of literature pertaining to gene action on various quantitative and qualitative characters in chilli is presented in Table 3.

2.7 GENETICS AND BREEDING FOR LEAF CURL RESISTANCE

Leaf curl is a major destructive disease of chilli. A yield loss of 80 to 100 per cent has been reported in case of early infection by leaf curl virus (Singh *et al.*, 1979). Munshi and Sharma (1996) reported that the incidence of chilli leaf curl ranged from 11.5 to 96.0 per cent.

Fugro (2000) reported that leaf curl incited by virus is an important disease of chilli. Inspite of its severity, little work has been done in identifying resistant sources for developing resistant/ tolerant varieties. An attempt has been made to review the available literature on leaf curl.

Table 2. Extent of mid parent heterosis, heterobeltiosis and standard heterosis for quantitative and qualitative traits in chilli (*Capsicum annuum* L.)

Characters	Number of hybrids	Mid parent heterosis (%)	Heterobeltiosis (%)	Standard heterosis (%)	Reference
Days to flowering	72	-28.13 to 10.77	-7.66 to 42.33	-2.91 to 65.04	Gaddagimath (1992)
	60	-	-6.60 to 11.10	-13.80 to 6.20	Jagadeesh (1995)
	45	-	-	Upto 138.69	Echeverri *et al.* (1998)
	36	-14.81 to 15.85	-3.30 to 22.85	-9.84 to 14.82	Prasad (1999)
	-	-	-	-12.64 to 11.22	Shukla *et al.* (1999)
	45	-37.74 to 18.75	-47.76 to 10.00	-40.32 to 14.89	Lohithaswa *et al.* (2000)
Days to 50 per cent flowering	6	6.22 to 2.05	18.13 to 16.08	-	Gopalakrishnan *et al.* (1987b)
	45	-	Upto –45.23	-	Mishra *et al.* (1988)
	-	35.6 to 15.6	35.6 to 17.6	35.6 to 0.090	Patel *et al.* (1997)
Number of branches	28	-	1.86 to 33.49	-	Mishra *et al.* (1977)
	36	Upto 100.00	Upto 97.30	-	Nair *et al.* (1986)
	6	13.50 to 25.36	12.20 to 20.00	-	Gopalakrishnan *et al.* (1987b)
	45	-	Upto 75.00	-	Mishra *et al.* (1988)
	28	-11.60 to 21.00	-12.00 to 16.30	-	Patil (1990)
	72	-37.50 to 72.60	-50.00 to 70.27	-24.51 to 11.41	Gaddagimath (1992)
	60	-	-42.90 to 45.90	-38.10 to 5.30	Jagadeesh (1995)
	45	-52.76 to 25.30	-62.70 to 34.88	-38.16 to 114.47	Lohithaswa (1997)
	60	-24.22 to 112.25	-50.06 to 90.95	-45.33 to 33.30	Patil (1997)
	24	-	Upto 29.69	Upto 23.98	Ahmed and Hurra (2000)
Number of fruits per plant	28	-	-13.93 to 68.83	-	Mishra *et al.* (1977)
	72	-	0.00 to 67.86	-	Sontakke (1981)
	6	-111.00 to 128.00	-	-	Depestre and Espinosa (1986)
	12	-15.10 to 89.23	-32.58 to 71.47	-	Krishnakumari and Peter (1986)
	36	Upto 72.30	Upto 58.40	-	Nair *et al.* (1986)
	45	-	Upto 66.66	-	Mishra *et al.* (1988)

Table 2. continued...

Number of fruits per plant	28	-31.50 to 101.50	-41.80 to 68.40	-	Patil (1990)
	72	-46.23 to 183.51	-55.68 to 127.15	-6.47 to 197.06	Gaddagimath (1992)
	54	9.10 to 116.60	-7.40 to 10.53	-	Mulge (1992)
	60	-	-57.20 to 58.00	-24.80 to 189.10	Jagadeesh (1995)
	45	-	-	Upto 138.69	Echeverri *et al.* (1998)
	36	-60.49 to 239.55	-83.03 to 83.04	-85.82 to 56.36	Prasad (1999)
	24	-	Upto 71.73	Upto 71.73	Ahmed and Hurra (2000)
	45	-24.00 to 15.38	-42.5 to 67.0	-67.19 to 376.60	Lohithaswa *et al.* (2000)
	28	-45.80 to 75.48	-61.45 to 64.80	-16.92 to 132.7	Kumar and Lal (2001)
	15	-	Upto 183.60	-	Mamedov and Pyshnaja (2001)
	42	-	Upto 66.55	-	Singh and Hundal (2001b)
Average fruit weight	6	10.3 to 11.20	-	-	Depestre and Espinosa (1986)
	36	Upto 11.20	-	-	Nair *et al.* (1986)
	72	-22.42 to 155.30	-29.67 to 127.53	-44.24 to 92.13	Gaddagimath (1992)
	72	-20.80 to 26.50	-24.70 to 9.50	-	Mulge (1992)
	60	-	-28.11 to 14.80	-38.50 to 18.70	Jagadeesh (1995)
	45	-21.23 to 66.48	-43.42 to 46.50	-25.59 to 87.29	Lohithaswa (1997)
	60	-53.63 to 31.67	-54.73 to 31.21	-36.19 to 61.90	Patil (1997)
	15	--High	-	-	Zecevic (1997)
	15	High	-	-	Zecevic and Stevanovic (1997)
	24	-	Upto 71.73	10.95	Ahmed and Hurra (2000)
	15	-	Upto 129.70	-	Mamedov and Pyshnaja (2001)
	42	-	Upto 111.27	-	Singh and Hundal (2001b)
Fruit yield per plant	28	-	-18.80 to 71.40	-	Mishra *et al.* (1977)
	72	-	0.00 to 61.40	-	Sontakke (1981)
	30	-	>20.00	-	Chen (1985)
	12	-3.44 to 169.83	-22.22 to 157.56	-	Meshram and Mukeswar (1986)
	45	-	Upto 110.88	-	Mishra *et al.* (1988)
	28	-25.50 to 159.20	-45.50 to 88.50	-	Patil (1990)
	72	-26.29 to 223.96	-50.09 to 175.16	-55.37 to 252.89	Gaddagimath (1992)
	54	6.80 to 112.20	-4.40 to 110.00	-	Mulge (1992)

Table 2. continued...

Fruit yield per plant	60	-	-73.10 to 89.10	-44.00 to 72.80	Jagadeesh (1995)
	45	-41.06 to 195.19	-54.81 to 129.69	-31.64 to 316.44	Lohithaswa (1997)
	60	-64.64 to 123.77	-69.59 to 120.49	-72.06 to 77.43	Patil (1997)
	15	-	High	-	Zecevic and Stevanovic (1997)
	15	67.55	-	-	Zecevic (1997)
	45	-	-	Upto 138.69	Echeverri *et al.* (1998)
	24	-	Upto 174.52	Upto 83.53	Ahmed and Hurra (2000)
	21	-	High	-	Legesse (2000)
	28	-31.87 to 158.80	-48 to 105.87	-50.50 to 76.49	Kumar and Lal (2001)
	24	Upto 92.04	Upto 85.38	Upto 15.30	Patel *et al.* (2001)
	42	-	Upto 108.17	-	Singh and Hundal (2001b)
	30	-	Upto 219	-	Anandanayaki and Natarajan (2002)
	15	-	Upto 246.73	-	Nandadevi and Hosamani (2003b)
Fruit length	72	-4.28 to 17.87	-	-	Sontakke (1981)
	6	Up to 23.24	Up to 20.78	-	Gopalakrishnan *et al.* (1987b)
	45	-	Upto 63.85	-	Mishra *et al.* (1988)
	28	-11.10 to 61.0	-34.7 to 38.4	-	Patil (1990)
	72	-28.52 to 64.56	-46.71 to 31.93	-70.32 to 13.22	Gaddagimath (1992)
	60	-	-32.0 to 25.3	-26.7 to 25.9	Jagadeesh (1995)
	60	-9.32 to 45.85	-29.98 to 31.79	-9.44 to 58.24	Patil (1997)
	36	-14.20 to 75.82	-36.78 to 0.24	-41.56 to 6.67	Prasad (1999)
	-	-	-	9.74 to 12.66	Shukla *et al.* (1999)
	24	-	Upto 29.03	Upto 55.0	Ahmed and Hurra (2000)
	28	-13.18 to 30.02	-34.49 to 15.67	-24.49 to 33.69	Kumar and Lal (2001)
	15	-	Upto 116.3	-	Mamedov and Pshynaja (2001)
	42	-	Upto 55.00	-	Singh and Hundal (2001b)
Fruit girth	45	-	Upto 47.07	-	Mishra *et al.* (1988)
	24	-	Upto 24.94	-	Ahmed and Hurra (2000)
	15	-	Upto 105.3	-	Mamedov and Pyshnaja (2001)
Fruit width	72	-	0.0 to 33.85	-	Sontakke (1981)
	6	7.12 to 10.13	3.62 to 7.36	-	Gopalakrishnan *et al.* (1987b)

Table 2. continued...

Fruit width	28	-13.2 to 43.20	-22.40 to 33.50	-	Patil (1990)
	72	-25.00 to 80.26	-40.00 to 50.00	-13.4 to 173.91	Gaddagimath (1992)
	36	-20.97 to 73.13	-33.34 to 80.62	-34.78 to 124.35	Prasad (1999)
	-	-	-	-12.17 to –4.76	Shukla *et al.* (1999)
	42	-	Upto 24.48	-	Singh and Hundal (2001b)
Number of seeds per fruit	12	-53.0 to 58.17	-69.45 to 4.83	-	Krishnakumari and Peter (1986)
	36	5.196 to 69.197	2.21 to 80.11	-	Nair *et al.* (1986)
	45	-	Up to 80.01	-	Mishra *et al.* (1988)
	72	-22.86 to 129.92	-28.91 to 123.81	-27.76 to 91.02	Gaddagimath (1992)
	45	-52.17 to 206.75	-36.24 to 139.26	-35.38 to 108.09	Lohithaswa (1997)
	60	-29.64 to 55.75	-37.32 to 50.43	-34.21 to 54.39	Patil (1997)
	28	-24.2 to 66.35	-32.7 to 60.24	-31.46 to 37.45	Kumar and Lal (2001)
Seed weight	45	-	Upto 51.85	-	Mishra *et al.* (1988)
	28	29.6 to 43.3	-36.9 to 41.40	-20.7 to 41.40	Kumar and Lal (2001)
Plant height	28	-	-10.29 to 9.15	-	Mishra *et al.* (1977)
	45		-11.82 to 44.63	-	Sharma and Saini (1977)
	72	-	0.0 to 16.17	-	Sontakke (1981)
	36	Upto 30.0	Upto 30.60	-	Nair *et al.* (1986)
	45	-	Upto 22.43	-	Mishra *et al.* (1988)
	28	-14.5 to 30.5	-25.8 to 17.3	-	Patil (1990)
	72	-16.80 to 41.84	-21.66 to 41.13	-33.57 to 10.19	Gaddagimath (1992)
	54	42.5 to 50.4	19.4 to 44.3	-	Mulge (1992)
	60	-	26.7 to 9.26	-5.98 to 20.20	Jagadeesh (1995)
	45	-21.94 to 49.18	-37.84 to 50.00	-24.46 to 87.5	Lohithaswa (1997)
	60	-47.13 to 66.51	-57.27 to 44.35	-29.23 to 112.31	Patil (1997)
	36	-16.46 to 52.40	-29.59 to 8.80	-0.29 to –0.13	Prasad (1999)
	45	-	-	Upto 138.69	Echeverri *et al.* (1998)
	24	-	Upto 43.31	Upto 56.94	Ahmed and Hurra (2000)
	28	-20.31 to 28.54	-23.76 to 12.45	-20.75 to 3.15	Kumar and Lal (2001)
Capsaicin content	36	Upto 9.70	Upto 61.20	-	Nair *et al.* (1986)
	45	-34.97 to 243.08	-98.88 to 172.09	-7.45 to 447.84	Lohithaswa (1997)

Table 3. Literature on gene action for quantitative and qualitative traits in chilli (*Capsicum annuum* L.)

Characters	Gene action: Additive	Gene action: Non-additive	Reference
Days to flower initiation	+	+	Singh and Singh (1977a)
	+	+	Gopalakrishnan *et al*. (1987b)
	+	-	Cao and Su (1988)
	+	+	Bhagyalakshmi *et al*. (1991)
	+	-	Gaddagimath (1992)
	-	+	Mulge (1992)
	-	+	Jagadeesh (1995)
	+	Over dominance	Lazic (1997)
	+	+	Echeverri *et al*. (1998)
	-	+	Shukla *et al*. (1999)
	-	Dominance	Anandanayaki and Natarajan (2000)
	+	+	Lohithaswa *et al*. (2000)
	-	+	Nandadevi and Hosamani (2003b)
Number of branches per plant	+	-	Bhat (1981)
	+	-	Khadi (1983)
	+	+	Milkova (1984)
	+	+	Cao and Su (1988)
	+	+	Joshi (1988)
	-	Complementary and duplicate epistasis	Joshi (1990)
	+	-	Patil (1990)
	+	+	Bhagyalakshmi *et al*. (1991)
	-	+	Gaddagimath (1992)

Table 3. continued…

Number of branches per plant	-	+	Mulge (1992)
	-	+	Pandian and Shanmugavelu (1992)
	-	+	Jagadeesh (1995)
	-	+	Patil (1997)
	-	+	Shukla *et al.* (1999)
	+	Over dominance	Anadanayaki and Natarajan (2000)
	-	Over dominance	Doshi and Shukla (2000)
	-	+	Ahmed *et al.* (2003)
Number of fruits per plant	-	+	Khalf-Allah *et al.* (1975)
	+		Lippert (1975)
	+	-	Pandey *et al.* (1981b)
	+	-	Sontakke (1981)
	-	+	Gopalakrishnan *et al.* (1987b)
	+	-	Gaddagimath *et al.* (1988)
	+	+	Joshi (1988)
	-	+	Miranda *et al.* (1988a)
	-	+	Kaul and Sharma (1988b)
	+	+	Sahoo *et al.* (1989)
	-	Additive x additive, dominance x dominance	Joshi (1990)
	-	+	Patil (1990)
	-	+	Salazar and Vallejo (1990)
	+	+	Bhagyalakshmi *et al.* (1991)
	+	-	Gaddagimath (1992)
	+	+	Mulge (1992)
	-	+	Pandian and Shanmugavelu (1992)
	+	-	Nowaczyk *et al.* (1993)

Table 3. continued...

	+	Dominance, additive x additive, additive x dominance, dominance x dominance	Ahmed *et al.* (1994)
	-	Dominance	Jadhav and Dhumal (1994)
	-	+	Jagadeesh (1995)
	+	-	Pitchaimuthu and Pappiah (1995)
	+	Partial dominance	Bal and Singh (1997)
	-	Partial dominance	Krishnamurthy and Deshpande (1997)
	+	+	Lohithaswa (1997)
	+	-	Lazic (1997)
	+	Dominance and interaction components	Murthy and Deshpande (1997)
Number of fruits per plant	-	+	Patil (1997)
	+	+	Ahmed *et al.* (1999)
	+	-	Devi and Arumugam (1999b)
	-	+	Shukla *et al.* (1999)
	-	Dominance	Anandanayaki and Natarajan (2000)
	+	Over dominance	Doshi and Shukla (2000)
	-	+	Ibrahim *et al.* (2001)
	-	+	Jadhav *et al.* (2001)
	+	-	Rathod *et al.* (2002)
	-	+	Ahmed *et al.* (2003)
	-	+	Nandadevi and Hosamani (2003b)
Average fruit weight	-	+	Khalf-Allah *et al.* (1975)
	-	+	Dikii and Anikeenko (1981)
	+	-	Dolgikh and Sviridova (1983)
	+	-	Gopalakrishnan *et al.* (1987b)

Table 3. continued...

Average fruit weight	+	+	Joshi (1988)
	+	-	Miranda and Costa (1988)
	-	+	Salazar and Vallejo (1990)
	+	-	Gaddagimath (1992)
	+	-	Nowaczyk *et al.* (1993)
	+	Dominance, additive x additive, additive x dominance, dominance x dominance	Ahmed *et al.* (1994)
	+	+	Lohithaswa (1997)
	+	+	Patil (1997)
	+	+	Ahmed *et al.* (1999)
	+	-	Devi and Arumugam (1999b)
	-	+	Shukla *et al.* (1999)
	+	-	Chaim and Paran (2000)
	+	Partial dominance	Doshi and Shukla (2000)
	-	Over dominance,	Todorova (2000)
	-	+	Jadhav *et al.* (2001)
	-	+	Ahmed *et al.* (2003)
Fruit yield per plant	-	+	Khalf-Allah *et al.* (1975)
	+	-	Lippert (1975)
	+	-	Pandey *et al.* (1981b)
	-	+	Gaddagimath *et al.* (1988)
	+	-	Kaul and Sharma (1988b)
	-	+	Miranda *et al.* (1988c)
	+	-	Gopalakrishnan *et al.* (1987b)
	+	+	Joshi (1988)

Table 3. continued...

Fruit yield per plant	-	Dominance, additive x additive, additive x dominance, dominance x dominance	Joshi (1990)
	+	-	Patil (1990)
	-	+	Salazar and Vallejo (1990)
	+	+	Bhagyalakshmi *et al*. (1991)
	-	+	Gaddagimath (1992)
	-	+	Pandian and Shanmugavelu (1992)
	+	-	Nowaczyk *et al*. (1993)
	+	Dominance, additive x additive, additive x dominance, dominance x dominance	Ahmed *et al*. (1994)
	-	Dominance	Jadhav and Dhumal (1994)
	-	+	Jagadeesh (1995)
	-	+	Lohithaswa (1997)
	+	-	Lazic (1997)
	+	Dominance, Epistasis	Murthy and Despande (1997)
	-	+	Patil (1997)
	+	+	Echeverri *et al*. (1998)
	+	+	Legesse (2000)
	+	Over dominance	Doshi and Shukla (2000)
	+	+	Ahmed *et al*. (1999)
	-	+	Shukla *et al*. (1999)
	+	-	Rathod *et al*. (2002)
	-	+	Jadhav *et al*. (2001)
	-	+	Lohithaswa *et al*. (2001)
	-	+	Ahmed *et al*. (2003)
	-	+	Nandadevi and Hosamani (2003b)

Table 3. continued...

Fruit length	+	-	Lippert (1975)
	+	+	Gopalakrishnan *et al.* (1987b)
	-	Dominance	Joshi (1988)
	+	-	Kaul and Sharma (1988a)
	+	-	Miranda *et al.* (1988a)
	-	Dominance, all 3 interactions	Joshi (1990)
	+	+	Patil (1990)
	+	+	Bhagyalakshmi *et al.* (1991)
	+	-	Gaddagimath (1992)
	-	+	Mulge (1992)
	+	-	Ahmed *et al.* (1994)
	+	-	Jadhav and Dhumal (1994)
	-	+	Jagadeesh (1995)
	+	-	Pitchaimuthu and Pappiah (1995)
	-	Partial dominance	Krishnamurthy and Despande (1997)
	+	-	Lazic (1997)
	+	+	Lohithaswa (1997)
	-	+	Patil (1997)
	+	Dominance, Epistasis	Murthy and Deshpande (1997)
	+	+	Echeverri *et al.* (1998)
	+	-	Sundaram and Irulappan (1998)
	+	+	Ahmed *et al.* (1999)
	+	+	Bal and Singh (1999)
	+	-	Shukla *et al.* (1999)
	+	-	Chaim and Paran (2000)
	+	Over dominance	Doshi and Shukla (2000)
	-	+	Ibrahim *et al.* (2001)

Table 3. continued...

Fruit length	-	+	Jadhav *et al.* (2001)
	+	+	Ahmed *et al.* (2003)
	+	-	Nandadevi and Hosamani (2003b)
Fruit girth	-	Dominance	Joshi (1988)
	-	Dominance, all 3 interactions	Joshi (1990)
	+	+	Jadhav and Dhumal (1994)
	+	-	Pitchaimuthu and Pappiah (1995)
	+	-	Sundaram and Irulappan (1998)
	+	-	Shukla *et al.* (1999)
	+	Over dominance	Doshi and Shukla (2000)
	-	+	Ahmed *et al.* (2003)
Fruit width	-	+	Lipert (1975)
	+	-	Milkova (1979)
	+	-	Gopalakrishnan *et al.* (1987b)
	+	-	Kaul and Sharma (1988b)
	-	+	Patil (1990)
	+	+	Bhagyalakshmi *et al.* (1991)
	+	-	Gaddagimath (1992)
	-	+	Jagadeesh (1995)
	+	+	Lohithaswa (1997)
	+	Dominance, Epistasis	Murthy and Deshpande (1997)
	+	+	Patil (1997)
	-	+	Krishnamurthy and Deshpande (1997)
	+	-	Lazic (1997)
	+	+	Echeverri *et al.* (1998)

Table 3. continued...

Number of seeds per fruit	+	-	Martin and Lipert (1975)
	-	+	Singh and Singh (1982)
	+	+	Milkova (1984)
	-	+	Gaddagimath *et al.* (1988)
	+	+	Bhagyalakshmi *et al.* (1991)
	+	-	Gaddagimath (1992)
	-	+	Pandian and Shanmugavelu (1992)
	+	+	Patil (1997)
	+	+	Lohithaswa (1997)
	-	+	Patil (1997)
	-	+	Mishra *et al.* (1991)
	+	-	Jabeen *et al.* (1999)
	+	-	Nandadevi and Hosamani (2003b)
Seed weight	+	-	Lipert (1975)
	+	+	Mishra *et al.* (1991)
	+	+	Bhagyalakshmi *et al.* (1991)
	+	-	Gaddagimath (1992)
Plant height	+	-	Pandey *et al.* (1981b)
	+	+	Ahmed *et al.* (1982)
	+	+	Cao and Su (1988)
	-	+	Gaddagimath *et al.* (1988)
	+	Dominance	Joshi (1988)
	+	+	Sahoo *et al.* (1989)
	-	Dominance, additive x additive, dominance x dominance, dominance	Joshi (1990)
	+	-	Patil (1990)

Table 3. continued...

Plant height	+	+	Bhagyalakshmi *et al.* (1991)
	-	+	Gaddagimath (1992)
	-	+	Pandian and Shanmugavelu (1992)
	+	+	Jadhav and Dhumal (1994)
	-	+	Jagadeesh (1995)
	+	+	Patil (1997)
	+	+	Echeverri *et al.* (1998)
	+	+	Ahmed *et al.* (1999)
	-	+	Shukla *et al.* (1999)
	+	+	Gandhi and Navale (2000)
	+	+	Lohithaswa *et al.* (2000)
	+	Partial dominance	Doshi and Shukla (2000)
	-	+	Anandanayaki and Natarajan (2000)
	-	+	Ibrahim *et al.* (2001)
	-	+	Jadhav *et al.* (2001)
	+	-	Rathod *et al.* (2002)
	-	+	Ahmed *et al.* (2003)
Capsaicin content	+	-	Park and Takahashi (1980)
	+	-	Ahmed *et al.* (1982)
	+	-	Hui *et al.* (1995)
	+	+	Lohithaswa (1997)
	-	+	Patil (1997)
	+	Partial dominance	Doshi and Shukla (2000)
	+	-	Singh and Hundal (2001a)
Oleoresin content	-	+	Singh and Hundal (2001a)

+Predominant - Not predominant

2.7.1 Symptomatology

Chilli leaf curl is characterized by stunting of the plants with upward and downward curling of leaves. The newly formed leaves exhibit chlorosis. The old, curled leaves become leatherly and brittle. Shortening of internodes leads to dwarfing of the plant (Mishra *et al.*, 1963).

Dhanraj and Seth (1968) reported downward curling, dark green colour and oval to rounded shape of leaves, pronounced vien-thickening and leafy outgrowths or enations on the under surface of leaves. The diseased plants produced fewer flowers and fruits.

In severe cases, axillary buds were stimulated to produce small cluster of leaves. Flower and fruit formation were also reduced (Nair and Menon, 1983).

2.7.2 Etiology

Chilli leaf curl is a complex disease caused by separate or combined infection of mites, thrips and viruses (Tewari, 1983 and Nawalagatti *et al.*, 1999).

Ayyar *et al.* (1935) observed that *Scirtothrips dorsalis* was involved in the disease while Khodawe and Taley (1978) reported that involvement of *Hemitarsonemus latus* in the development of leaf curl symptom. *Scirtothrips dorsalis* (thrips) and *Polyphagotarsonemus latus* (mite) also produce leaf curl symptom (Amin, 1979; Mallapur, 2000); Reddy *et al.*, 2000).

2.7.3 The virus

The virus causing leaf curl in chillies is commonly referred to as chilli leaf curl virus or tobacco leaf curl virus.

Fernando and Peiris (1957) found that the transparent kroepoek strain of tobacco leaf curl virus was involved in chilli leaf curl complex.

Dhanraj and Seth (1968) reported the presence of two distinct strains of the leaf curl virus, and found that one of the strains produced severe enation in chilli and other solanaceous hosts.

Brown *et al.* (1993) found that pepper plants infected by sinaloa tomato curl virus showed a splotchy green mottle on leaves.

Pepper mottle virus was reported to be involved in the leaf curl disease complex (Peter, 1998).

Infection by tomato leaf curl virus in *C. annuum* plants resulted in interveinal and marginal chlorosis and upward curling of the leaflet margin (Reina *et al.*, 1999).

A new virus named as pepper yellow leaf curl virus was found to cause yellow leaf curl disease in *C. annuum* plants in Thailand (Samretwanich *et al.*, 2000).

Gonzalez *et al.* (1993) observed that all the *Capsicum* varieties inoculated with tomato yellow leaf curl bigemini virus showed resistance. But Dalmon and Marchoux (2000) reported the tomato yellow leaf curl virus could also infect Paprika (*Capsicum annuum*). But Gonzalex *et al.* (1993) observed that all the Capsicum varieties inoculated with tomato yellow leaf curl bigemini virus showed resistance.

2.7.4 Breeding for resistance

Resistant donors identified by screening the varieties under field and or artificial conditions were utilized in breeding programmes to develop resistant varieties.

Mishra *et al.* (1963) screened 67 varieties of chilli against leaf curl virus and found that all were susceptible except Puri Red and Puri Orange.

Twenty three mutants of the variety NP 46-A along with Puri Red and Puri Orange were screened against the enation strain of leaf curl virus and 100 per cent infection was obtained in all genotypes (Dhanraj *et al.*, 1968).

Singh (1973) on screening 105 chilli varieties found that seven of them *viz.*, EC 4020, EC 7277, EC 7338, EC 6589, EC 9293, Puri Red and Puri Orange were free from infection by leaf curl virus.

Tewari (1977) found that four varieties *viz.*, Sel 4, 6, 7 and 15 obtained from advanced generations of the cross NP 46 A x Puri Red were superior and tolerant to the disease. Among these, Sel 4 was developed into the high yielding leaf curl virus-resistant variety Pusa Jwala. This was confirmed by Tewari and Anand (1977) who obtained higher fruit yield and high degree of resistance for Pusa Jwala as compared to the susceptible variety NP 46A.

Konai and Nariani (1980) observed that among 33 indigenous and exotic collections of chilli including five *Capsicum* spp. IC 31339 (*C.frutescens*), Pant C-1, Pant C-2 and *C.angulosum* were tolerant to leaf curl virus.

Singh and Kaur (1986) found that Punjab Lal selected from Perennial x Long Red were resistant to leaf curl virus.

Selections from the cross Pusa Jwala x Delhi Local *viz.*, 38-2-1, 38-3-19, 42-2-4, 52-1-6, 81-1-1, 96-4-8, 96-4-9, 96-4-9-3 and 101-2-33 were reported to be tolerant to tobacco leaf curl virus (Tewari and Viswanath, 1986).

Memane *et al.* (1987) on screening 69 varieties against leaf curl complex (caused by thrips and leaf curl virus) obtained lower disease incidence in Pant C-1 (40.22 %). Pant C-1, LIC 45 and NI 46 were regarded as moderately resistant to leaf curl.

Sangar *et al.* (1988) screened ten varieties of *Capsicum annuum* for resistance to tobacco mosaic tobamovirus (TMV) and tobacco leaf curl gemini virus under natural field conditions at Chhindwara. The varieties JCA 248, JCA 218, Pant C-1, NP 46A, Pusa Jwala and JCA 196 were resistant to leaf curl virus. JCA 31A, Selection 3, JCA 154 and Pandurna exhibited different degrees of susceptibility. All varieties showed some symptoms of TMV, TCA 248, JCA 218 and Pant C-1 were the least affected.

Brar *et al.* (1989) screened 33 genotypes against leaf curl mosaic viruses and obtained six lines tolerant to both disease.

Naitam *et al.* (1990) evaluated seven chilli varieties for resistance against leaf curl and reported that Jwala and Pant C-1 had showed least leaf curl incidence (25 %).

The selection PSP 11, named 'Pusa Sadabahar' developed from Pusa Jwala x IC 31339 was found to have high degree of tolerance to leaf curl virus (Tewari, 1991).

Pant C-1 and Pant C-2 (derived from NP 46A x Kandhari) and Jawahar 218 (obtained from Kalipeeth x Pusa Jwala) were found to be tolerant/resistant to leaf curl virus (Singh, 1993).

In a study on genetic control of virus resistance against chilli mosaic and leaf curl viruses (most commonly tomato mosaic, tabamovirus, cucumber mosaic cocumo virus, potato Y potyvirus and tobacco leaf curl bigemini virus). Bal *et al.* (1995) observed that susceptibility to mosaic as well as leaf curl was dominant and resistance controlled by monogenic recessive genes. The conventional method of back crossing was suitable for transferring resistant genes to commercial varieties with acceptable fruit size.

Among 35 cultivars of *Capsicum annuum* screened against tomato leaf curl bigemini virus causing leaf curl disease, five were found to be highly resistant (Gandhi *et al.*, 1995).

Arora *et al.* (1996) reported that Hisar Vijay (HC 28) and Hisar Shakti (HC 44) identified from among 11 pure breeding lines were resistant to leaf curl virus.

Munshi and Sharma (1996) screened 66 cultivars for resistance to leaf curl complex and reported that six lines *viz.*, Pusa Sadabahar, RHRC Clustering Erect, RHRC Clustering Pendula, LGP-8-1, LGP-18-2-4-3 and LGP-18-10-12 were resistant to the disease.

Singh *et al.* (1998) screened seven varieties of chilli against sucking pests and leaf curl virus and observed that no variety was free from infection. But Pusa Sadabahar, JM-218 and Pant C-2 showed only traces of infection.

Among 37 chilli genotypes evaluated for incidence of pepper leaf curl virus, three (Pusa Jwala, Suryamukhi and Japani Loungi) were rated resistant, two moderately resistant, nineteen susceptible and thirteen highly susceptible (Kumar *et al.*, 1999).

Albejo (1999) evaluated 34 pepper cultivars for resistance to pepper leaf curl geminivirus and found that PCBO 67 was moderately resistant while 26 lines were moderately susceptible.

Screening of 33 chilli genotypes against leaf curl caused by thrips and mites showed that Sel 7-11-13-1 exhibited highest tolerance to leaf curl while the lowest incidence was recorded by Sel 4-1, followed by 7-11, 11-9 and 1-12 (Reddy *et al.*, 2000).

Jadhav *et al.* (2000) reported that "Phule Sai' (GCH-8) selected from advanced generations of Pant C1 x Kamandalow was moderately resistant to leaf curl virus under field conditions.

In a variability study, Acharyya *et al.* (2002) reported high heritability with enhanced genetic advance for leaf curl incidence indicating the greater properties of additive genetic variance and consequently a high genetic gain expected from selection. High heritability coupled with high genetic advance for total fresh yield per plant was noticed under both leaf curl infected and non-infected condition.

Nandadevi and Hosamani (2003b) in a study on 6 x 6 diallel analysis reported that RHRC-Cluster-Erect, Pant C-1 and PMR-52/88/K had significant *gca* effects for resistance to leaf curl complex. The magnitude of estimated components of dominant variance was more than additive variance for resistance to leaf curl complex indicating the predominance of non-additive gene effects.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2003 as three major experiments with a view to study the genetic basis and inheritance pattern of important quantitative and qualitative characters including yield and leaf curl virus resistance in vegetable chilli (*Capsicum annuum* L.). The details of materials used and methods adopted for the study are presented below.

3.1 EXPERIMENT I: CROSSING PROGRAMME

3.1.1 Materials

The materials for the study consisted of five susceptible high yielding types (Jwalamukhi (L_1), Kottikulam local (L_2), Mangalapuram local (L_3) Koothali local (L_4) and Pollakada local (L_5)) and three resistant types (Haripuram local (T_1), Alampady local (T_2) and Neyyatinkara local (T_3)) identified from previous experiment conducted (Jose, 2001) in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani were selected for crossing in L x T pattern.

3.1.2 Methods

The five high yielding, leaf curl virus susceptible types and three low yielding resistant types, identified from the previous experiment conducted (Jose, 2001) in the Department were selected as parental lines (L) and testers (T) respectively for developing F_1s. The five lines and three testers were raised in L x T crossing block during rabi 2001 and fifteen F_1 hybrids were produced. The technique followed for the production of selfed and crossed seeds were as follows.

3.1.2.1 Selfing

For getting selfed seeds mature flower buds which would open on the next day were covered with paper bags and labelled in the evening. The paper bags were retained till the beginning of fruit setting.

3.1.2.2 Crossing

In the female parents (L) the mature flower buds, which would open on the next day were selected in the evening and emasculation was done by standard manual method using forceps. The emasculated flower buds were covered with paper bags. Mature flower buds were kept covered in the male parents (T) also. Next morning, the pollen from the protected flower of the male parents was transferred to the stigma of emasculated flower either from mature undehisced anthers by scooping it out through the lateral sutures with the needle or by touching a freshly dehisced anther to the stigma with the forceps. After pollination, the flowers were protected with paper bags. Labels with the details of crossing were attached and kept till the fruits ripen.

The fully ripened fruits of both selfed and crossed flowers were harvested and seeds were extracted separately.

3.2 EXPERIMENT II: F_1 HYBRIDS AND PARENTS (SUMMER SEASON)

3.2.1 Materials

The materials for this experiment consisted of eight parents (five lines and three testers) and fifteen line x tester hybrids.

3.2.2 Methods

3.2.2.1 Design and layout

The experiment was conducted in Randomized Block Design (RBD) with three replications (Plate 1). Plot size was 2.25 x 0.90 m^2 with a spacing of 45 x 45 cm. Ten plants were maintained in each plot.

Plate 1. Field view of experiment II

3.2.2.2 Sowing and cultural operations

Seeds were sown on raised nursery beds during February 2002. The seedlings were transplanted during March when they were one month old with one seedling per pit.

Cultural operations were carried out as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1996).

Spraying of insecticides in the field was avoided in order to permit the growth and spread of *Bemisia tabaci*, the vector of leaf curl virus.

3.2.2.3 Inoculation of leaf curl virus

The leaf curl virus was introduced into the field using viruliferous white flies.

3.2.2.3.1 Mass culture of Bemisia tabaci

Brinjal being a good breeding host for *B.tabaci*, the pure culture of *B.tabaci* was reared and maintained on brinjal plants. Insect proof wooden cages (65 x 65 x 70 cm) were used. Brinjal plants grown in pots were placed in the cages and *B.tabaci* were released into the cages for its multiplication. The old plants inside the cages were replaced periodically with healthy and fresh ones. Care was taken to keep the cages free of the predators of white flies.

An aspirator consisting of a glass tube (30 cm long and 0.5 cm in diameter) was used for handling whiteflies. By turning the leaves slightly upwards, the white flies were gently sucked into the glass tube of the aspirator. White flies, thus collected were subsequently used either for acquisition access feeding on infected plants or for inoculation access feeding.

3.2.2.3.2 Acquisition and inoculation access feeding

Acquisition and inoculation access feeding were carried out in a single stage in an insect proof cage. Leaf curl virus infected plants and disease free seedling (one month old) were kept together. The pure culture of white flies reared on brinjal plants were released into this cage for transmitting the virus from infected to healthy one. White flies were released periodically into the cages to maintain an uniform population for transmission.

3.2.2.3.3 Acquisition feeding of whiteflies for release into the field

For acquisition feeding, plastic transmission cages designed by Nene (1972) were used. The top portion of either the main stem or fresh branches showing typical symptoms was introduced into the cage through the rectangular slit or the mouth of the cage. The transmission cage was covered by a black cloth except at the region of the wire netting which was kept facing the light source while releasing the whiteflies. The cap of the cage was immediately screwed on. The remaining portion of the rectangular slit of the cage was closed with cotton wool. The cages were kept in position by two bamboo slivers and a rubber band. After the desired feeding period the cotton wool was removed and the plant was disturbed by gently tapping it with a needle to disturb the whiteflies. This induced the whiteflies to move to the side of the cage facing the light source. The cages were then taken to the field and viruliferious whiteflies released.

3.2.2.3.4 Inoculation of mainfield

The diseased seedling were transplanted in the field along the border. To maintain the vector population and to ensure uniform spread of the virus in the field, viruliferious white flies were released on alternate days. This was continued for a period of one month.

3.2.2.4 Biometric observations

In each genotype, five plants were selected at random in each plot for recording the following biometric observations. The data for statistical analysis were obtained as mean values worked out there after for each replication.

3.2.2.4.1 Days to first flowering

Number of days taken from sowing to the appearance of first flower was recorded.

3.2.2.4.2 Days to 50 per cent flowering

Number of days taken for 50 per cent of the plants to flower was recorded.

3.2.2.4.3 Number of primary branches

Branches arising from the main stem were counted and recorded as number of primary branches.

3.2.2.4.4 Number of secondary branches

The branches borne on primary branches were counted and recorded as number of secondary branches.

3.2.2.4.5 Number of fruits per plant

The number of fruits at each harvest was recorded for each observational plant to calculate the total number of fruits per plant.

3.2.2.4.6 Green fruit weight

Weight of ten fruits of the second harvests from the observational plants was taken and the mean weight was recorded as the mean single fruit weight in grams.

3.2.2.4.7 Fruit yield per plant

The weight of fresh fruits collected from the five observational plants was recorded in grams at each harvest. Total yield per plant was obtained by adding the weight of fruits at each harvest and taking the mean.

3.2.2.4.8 Fruit length

Average fruit length of ten ripe fruits of second harvest at random from the observational plants was recorded, the average worked out and expressed in cm. Length was measured from the base of the peduncle to the tip of the fruit.

3.2.2.4.9 Fruit girth

The circumference at the broadest part of fruits selected for recording length was taken, averaged and expressed in cm.

3.2.2.4.10 Number of seeds per fruit

The seeds were extracted from ten fruits and the total number was counted, the average worked out and recorded.

3.2.2.4.11 Hundred seed weight

Seeds were extracted from a random sample of ten ripe fruits and dried uniformly. The weight of the 100 fully developed seeds was recorded and expressed in grams.

3.2.2.4.12 Plant height

Height was measured in cm from the base of the plant to the tip of the largest branch before the last harvest of fruits.

3.2.2.4.13 Duration of the crop

Number of days from sowing to last harvest of fruits was considered as duration of the crop.

3.2.2.4.14 Harvest index

It was calculated by

$$\text{Harvest index} = \frac{\text{Fruit yield}}{\text{Total biological yield}} \times 100$$

3.2.2.4.15 Capsaicin content

The capsaicin content was determined by Folin-Dennis method. The pungent principle reacts with Folin-Dennis reagent to give a bluish complex, which was estimated colorimetrically (Mathew *et al.*, 1971).

Reagents : Folin-Dennis Reagent, Aqueous sodium-carbonate solution (25 %).

Preparation of Folin-Dennis Reagent

Reflux 750 ml distilled water, 100 g sodium tungstate, 20 g phosphomolybdic acid and 50 ml phosphoric acid for two hours. Cool and dilute to 1000 ml with distilled water.

Procedure

The fruits harvested at red ripe stage were dried in a hot air oven at 50°C and powdered finely in a mixer grinder. Five hundred milligram of each of the samples was weighed into test tubes. Added 10 ml acetone to it and kept overnight. Aliquots of 1 ml were pipetted into 100 ml conical flasks, added 25 ml of folin-Dennis reagent and allowed to stand for 30 minutes. Added 25 ml of freshly prepared sodium carbonate solution and shake vigourously. The volume was made up for 100 ml distilled water and optical density was determined after 30 minutes at 725 nm against reagent blank (1 ml acetone + 25 ml Folin-Dennis reagent + 25 ml aqueous sodium carbanate solution) using a UV spectrophotometer.

To determine the per cent value for pure capsaicin, a stock solution of standard capsaicin (200 mg L^{-1}) was prepared by dissolving 20 mg in 100 ml acetone. From this a series of solution of different concentration were prepared and their optical density measured at 725 nm. Standard graph was prepared and calculated the content of capsaicin in the samples.

3.2.2.4.16 Oleoresin content

Oleoresin in chilli was extracted in Soxhlet apparatus using solvent acetone (Sadasivam and Manickam, 1992)

Procedure

Chilli fruits harvested at red ripe stage were dried in a hot air oven at 50°C, powdered finely in a mixer grinder. Two grams of chilli powder was weighed and packed in filter paper and placed in a Soxhlet apparatus.

Two hundred ml of acetone was taken in the round bottom flask of the apparatus and heated in a water bath. The temperature was maintained at the boiling point of solvent. After complete extraction the solvent was evaporated to dryness under vacuum.

Yield of oleoresin on dry weight basis was calculated using the formula

$$\text{Oleoresin, \%} = \frac{\text{Weight of oleoresin}}{\text{Weight of sample}} \times 100$$

3.2.2.4.17 Vulnerability Index

Leaf curl disease scoring was done at 30th, 45th and 60th days after planting (DAP). The observations on 45th DAP was used for computation of vulnerability index, during the peak fruiting period of the crop. The scoring was based on a scale of 0 to 4 developed by Rajamony *et al.* (1990) with slight modification (Plate 2). The score based on the severity of symptom manifestation is as follows.

Score	Symptoms
0	No symptoms
1	Slight curling of terminal leaves
2	Curling of terminal and adjacent lower leaves
3	Curling and appearance of blisters on leaves
4	Severe curling and puckering of leaves, stunted appearance of plants

The individual plant score was utilized to workout the 'severity index' or 'vulnerability index' so as to measure the degree of resistance. The index was calculated using an equation adopted by Silbernagel and Jafri (1974) for measuring the degree of resistance in snap bean (*Phaseolus vulgaris*) to beet curly top virus and modified later by Bos (1982).

$$VI = \frac{0n_0 + 1n_1 + 2n_2 + 3n_3 + 4n_4}{n_t (n_c - 1)} \times 100$$

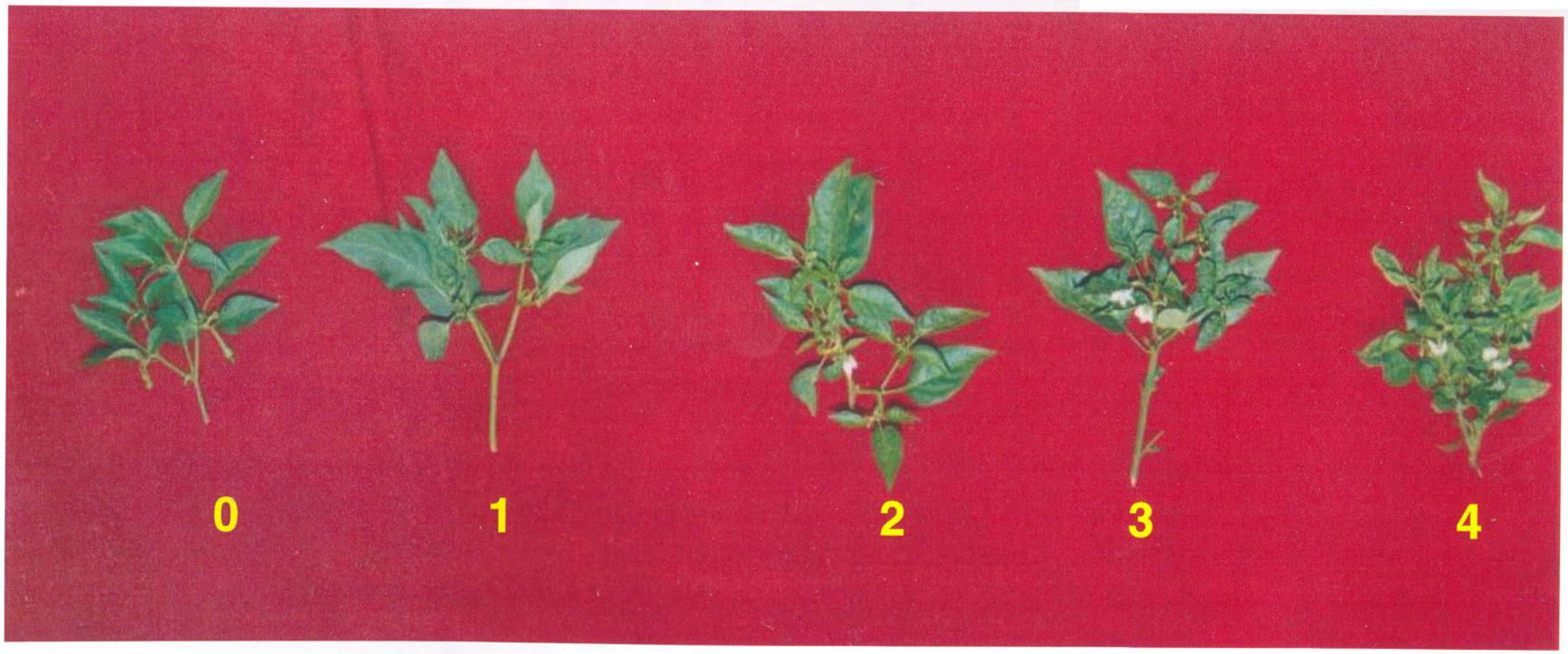


Plate 2. Scoring scale based on the severity of leaf curl disease

Where VI = Vulnerability index

$n_0, n_1, \ldots, n_4$ = Number of plants in the category 0, 1, ...,4.

n_t = total number of plants

n_c = Total number of categories

The genotypes were classified according to vulnerability index as

VI	Category
0.00	Resistant (R)
1.00 – 25.00	Tolerant (T)
25.01 – 50.00	Susceptible (S)
> 50.00	Highly susceptible (HS)

3.2.2.5 Statistical Analysis

3.2.2.5.1 Analysis of variance (ANOVA)

The biometric observations recorded were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison among various treatments and to estimate variance components as follows.

Source of variation	Degrees of freedom	Mean square	F
Replication	(r-1)	MSR	MSR/MSE
Treatment	(t-1)	MST	MST/MSE
Error	(r-1) (t-1)	MSE	
Total	(rt-1)		

Where, r = number of replications, t = number of treatments, MSR = Replication mean square, MST = Treatment mean square, MSE = Error variance.

$$\text{Critical difference (CD)} = t_\alpha \sqrt{\frac{2MSE}{r}}$$;

Where, t_α is the student's t table value at error degrees of freedom and K is the level of significance.

3.2.2.5.2 Estimation of genetic parameters

a. *Genetic components of variance*

For each character, the phenotypic and genotypic components of variance were estimated by equating the expected value of mean squares (MS) to the respective variance components (Jain, 1982). Based on this, the following variance components were estimated.

i. Genotypic variance (V_G)

$$V_G = \frac{MST - MSE}{r}$$

ii. Environmental variance (V_E)

$$V_E = MSE$$

iii. Phenotypic variance (V_P)

$$V_P = V_G + V_E$$

b. *Coefficients of variation*

Genotypic and phenotypic coefficients of variation were worked out using the estimates of V_G and V_P and expressed in percentage for each trait.

i. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{V_P}}{(\overline{X})} \times 100$$

ii. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{V_G}}{(\overline{X})} \times 100$$

iii. Error coefficient of variation (ECV)

$$ECV = \frac{\sqrt{V_E}}{(\overline{X})} \times 100$$

X is the mean of each character estimated over all the treatments.

c. Heritability

For each trait, heritability (broad sense) was calculated as the ratio of genotypic variance to phenotypic variance and expressed as percentage (Jain, 1982).

$$\text{Heritability } (H^2) = \frac{V_G}{V_P} \times 100$$

Heritability was categorised as :

< 30 % → low

31 – 60 % → moderate

>60 % → high (Johnson *et al.*, 1955)

d. Genetic advance

Genetic advance which is the measure of genetic gain under selection, depends upon standardised selection differential, heritability and phenotypic standard deviation (Allard, 1960).

$$\text{Genetic advance (GA)} = k.\ H^2 \sqrt{V_P}$$

Where k is the standardised selection differential (2.06 at 5 % selection).

$$\text{GA as percentage of mean} = \frac{k.\ H^2 \sqrt{V_P}}{\bar{X}} \times 100$$

Genetic advance (as % of mean) was categorised as :

< 10 % → low

11 – 20 % → moderate

> 20 % →high (Johnson *et al.*, 1955)

3.2.2.5.3 Association analyses

Correlations

Phenotypic, genotypic and environmental correlation coefficients were calculated using the respective variances and co-variances of the characters which showed significant variation in the ANOVA.

Phenotypic correlation coefficient, $r_{Pxy} = \sqrt{\dfrac{Cov_P(x,y)}{V_P(x).\ V_P(y)}}$

Genotypic correlation coefficient, $r_{Gxy} = \sqrt{\dfrac{Cov_G(x,y)}{V_G(x).\ V_G(y)}}$

Environmental correlation coefficient, $r_{Exy} = \sqrt{\dfrac{Cov_E(x,y)}{V_E(x).\ V_E(y)}}$

Where, $Cov_P(x,y)$, $Cov_G(x,y)$ and $Cov_E(x,y)$ denote the phenotypic, genotypic and error co-variances between the two traits x and y respectively.

$V_P(x)$, $V_G(x)$ and $V_E(x)$ denote phenotypic, genotypic and error variance respectively for x and $V_P(y)$, $V_G(y)$ and $V_E(y)$ denote phenotypic, genotypic and error variance respectively for y.

3.2.2.5.4 Combining ability analysis

Following the L x T method (Kempthrone, 1957) the general combining ability (*gca*) of parents and the specific combining ability (*sca*) of hybrids were estimated. The mean squares due to various sources of variation and their genetic expectations were computed as follows:

Source	df	Mean square	Expected MS
Replication	(r – 1)		
Line	(l – 1)	M_1	MSE + r (C_{OV} F.S. – 2 C_{OV} H.S.) + rt (C_{OV} H.S.)
Tester	(t – 1)	M_2	MSE + r (C_{OV} F.S. – 2 C_{OV} H.S.) + rl (C_{OV} H.S)
Line x Tester	(l – 1) (t – 1)	M_3	MSE + r (C_{OV} F.S. – 2 C_{OV} H.S.)
Error	(r – 1) (lt – 1)	M_4	MSE
Total	(rlt – 1)		

Where,

r = number of replications

g = number of genotypes

l = number of lines

t = number of testers

General combining ability (*gca*) effect of parents and specific combining ability (*sca*) effect of hybrids were estimated using the following model.

$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$

Where,

μ = Population mean

g_i = *gca* effect of i^{th} line

g_j = *gca* effect of j^{th} tester

s_{ij} = *sca* effect of ij^{th} hybrid

e_{ijk} = error associated with ijk^{th} observation

$i = 1,2,\ldots,l$

$j = 1,2,\ldots, t$

$k = 1,2,\ldots,r$

The individual effects were estimated as follows :

$$\text{Mean} = \frac{x_{...}}{rlt}$$

i. *gca* effect of lines

$$g_i = \frac{x_{i..}}{rt} - \frac{x_{...}}{rlt} \quad i=1,2,\ldots,l$$

ii. *gca* effect of testers

$$g_j = \frac{x_{.j.}}{rl} - \frac{x_{...}}{rlt} \quad j= 1,2,\ldots,t$$

iii. *sca* effect of hybrids

$$s_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{rt} - \frac{x_{.j.}}{rl} + \frac{x_{...}}{rlt}$$

Where,

$x_{...}$ = Total of all hybrids over 'r' number of replications

$x_{i..}$ = Total of all hybrids involving i^{th} line as one parent over 't' testers and 'r' replications

$x_{.j.}$ = Total of all hybrids involving j^{th} tester as one parent over 'l' lines and 'r' replications

$x_{ij.}$ = Total of the hybrids between i^{th} line and j^{th} tester over 'r' replications

Significance of combining ability effects was tested as follows :

1. SE of *gca* (lines) = $\sqrt{\frac{MSE}{rt}}$

2. SE of *gca* (testers) = $\sqrt{\frac{MSE}{rl}}$

3. SE of *sca* of hybrids = $\sqrt{\frac{MSE}{r}}$

The significance of these effects were tested by computing critical values as effect / (SE of the effect) and were compared with Student 't' table values at error degrees of freedom at 5 per cent level of significance.

3.2.2.5.5 Proportional contribution

Proportional contribution of lines, testers and their interaction to total variance was calculated (Singh and Chaudhary, 1985).

$$\text{Contribution of lines} = \frac{\text{SS (lines)}}{\text{SS (hybrids)}} \times 100$$

$$\text{Contribution of testers} = \frac{\text{SS (testers)}}{\text{SS (hybrids)}} \times 100$$

$$\text{Contribution of interaction} = \frac{SS\ (l \times t)}{SS\ (\text{hybrids})} \times 100$$

3.2.2.5.6 Genetic components of variance

$$\text{GCA variance. } \sigma^2gca = \frac{1}{4}(1 + F)\,\sigma^2a$$

$$\text{SCA variance. } \sigma^2sca = \frac{1}{2}(1 + F)^2\,\sigma^2d$$

When F = 0

$$\sigma^2gca = \frac{\sigma^2a}{4}$$

$$\sigma^2sca = \frac{\sigma^2d}{2}$$

When F = 1

$$\sigma^2gca = \frac{\sigma^2a}{2}$$

$$\sigma^2sca = 2\,\sigma^2d$$

Where F = coefficient of inbreeding

σ^2a = additive genetic variance

σ^2d = dominance genetic variance

3.2.2.5.7 Heterosis

Extent of heterosis was computed for all the fifteen hybrids as relative heterosis (RH), standard heterosis (SH) and heterobeltiosis (HB) using the following formulae and expressed as percentage. For estimating standard heterosis, Jwalamukhi was used as the standard variety. Standard heterosis for leaf curl virus resistance was calculated taking Pant C1 also as standard parent.

$$\text{i. Relative heterosis (RH)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{ii. Standard heterosis (SH)} = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

iii. Heterobeltiosis (HB) = $\dfrac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

Where.

$\overline{F_1}$ = Mean value of hybrid

$\overline{MP}$ = Mid parental value

$\overline{SV}$ = Mean of standard variety

$\overline{BP}$ = Mean of better parent in that particular cross

The significance of different types of heterosis was tested by the 't' test.

't' for RH = $\dfrac{\left| \overline{F_1} - \overline{MP} \right|}{\sqrt{\dfrac{3\,MSE}{2r}}}$

't' for SH = $\dfrac{\left| \overline{F_1} - \overline{SV} \right|}{\sqrt{\dfrac{2\,MSE}{r}}}$

't' for HB = $\dfrac{\left| \overline{F_1} - \overline{BP} \right|}{\sqrt{\dfrac{2\,MSE}{r}}}$

Where,

MSE = estimate of error variance

r = number of replications

3.3 EXPERIMENT III A :DEVELOPMENT OF SEGREGATING GENERATIONS

Based on Experiment II results, two superior F_1s (Pollakkada local x Alampady local and Pollakkada local x Neyyatinkara local) were selected. These were backcrossed to their respective parents to produce B_1 and B_2 generations during rabi 2002. Simultaneously, the F_1s were selfed to develop F_2 generation. Thus six generations were generated for each cross (P_1, P_2, F_1, F_2, B_1 and B_2).

3.4 EXPERIMENT III B: EVALUATION OF GENERATIONS

3.4.1 Materials

The materials for this experiment consisted of P_1, P_2, F_1, F_2, B_1 and B_2 of the each F_1 hybrid.

3.4.2 Methods

3.4.2.1 Design and layout

Same as described on experiment II was followed.

The six generations (P_1, P_2, F_1, F_2, B_1 and B_2) of each F_1 hybrid combination (11 treatments) were evaluated during summer 2003 in a randomized block design with three replications.

3.4.2.2 Sowing and cultural operations

The same cultural practices as described in Experiment II was followed.

3.4.2.3 Inoculation of leaf curl virus

The same methodology as described in Experiment II was followed.

3.4.2.4 Biometrical observation

From every replication, five plants each were selected at random for recording observations in P_1, P_2 and F_1 generations, fifteen plants each were selected for B_1 and B_2 generations and thirty plants each were selected in F_2 as observational plants. The method of measuring the different characters are same as described earlier.

3.4.2.5 Statistical analysis

Six parameter model (Hayman, 1958) was used for the analysis which consisted of the following steps.

i. Development of scales

Using the scaling test proposed by Mather (1949), estimation of additive (D) and dominance (H) components of genetic variance were made using the mean and variance of six generations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2.

$$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1$$

$$V_A = 4\ V(\bar{B}_1) + V(\bar{P}_1) + V(\bar{F}_1)$$

$$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$$

$$V_B = 4\ V(\bar{B}_2) + V(\bar{P}_2) + V(\bar{F}_1)$$

$$C = 4(\bar{F}_2) - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$$

$$V_C = 16\ V(\bar{F}_2) + 4\ V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$$

$$D = 2(\bar{F}_2) - \bar{B}_1 - \bar{B}_2$$

$$V_D = 4\ V(\bar{F}_2) + V(\bar{B}_1) + V(\bar{B}_2)$$

Where $\bar{P}_1$, $\bar{P}_2$, $\bar{F}_1$, $\bar{F}_2$, $\bar{B}_1$ and $\bar{B}_2$ are the means of respective generations over all replications and $V(P_1)$, $V(P_2)$, $V(F_1)$, $V(F_2)$, $V(B_1)$ and $V(B_2)$ are the respective variances. The standard errors of A, B, C and D obtained as square root of V_A, V_B, V_C and V_D.

ii. Testing for epistasis

Significance of any of the four scales indicates the inadequacy of additive-dominance model and presence of epistasis. For testing the significance of A, B, C and D scales, 't' test was employed.

$$t_A = \frac{A}{\sqrt{V_A}}$$

$$t_B = \frac{B}{\sqrt{V_B}}$$

$$t_C = \frac{C}{\sqrt{V_C}}$$

$$t_D = \frac{D}{\sqrt{V_D}}$$

If the calculated 't' value of these scales is higher than 1.96, it is considered as significant. Significance of each of these scales reveals the presence of specific type of epistasis as detailed below :

a. The significance of either one or both of A and B scales indicates the presence of all three types of non-allelic interaction *viz.*, additive x additive (i), additive x dominance (j) and dominance x dominance (l)

b. The significance of scale C denotes dominance x dominance type of non-allelic interaction

c. The significance of scale D reveals additive x additive type of gene interaction

d. The significance of both C and D scales depicts additive x additive and dominance x dominance type of epistasis.

iii. Estimation of genetic components

When the scales A, B, C and D were significantly different from zero, a digenic interaction model was assumed and the following six parameters were estimated (Jinks and Jones, 1958).

$$m = \bar{F}_2$$

$$d = \bar{B}_1 - \bar{B}_2$$

$$h = \bar{F}_1 - 4\,\bar{F}_2 - \tfrac{1}{2}\,\bar{P}_1 - \tfrac{1}{2}\,\bar{P}_2 + 2\,\bar{B}_1 + 2\,\bar{B}_2$$

$$i = 2\,\bar{B}_1 + 2\,\bar{B}_2 - 4\,\bar{F}_2$$

$$j = (\bar{B}_1 - \tfrac{1}{2}\,\bar{P}_1) - (\bar{B}_2 - \tfrac{1}{2}\,\bar{P}_2) = \bar{B}_1 - \tfrac{1}{2}\,\bar{P}_1 - \bar{B}_2 + \tfrac{1}{2}\,\bar{P}_2$$

$$l = \bar{P}_1 + \bar{P}_2 + 2\,\bar{F}_1 + 4\,\bar{F}_2 - 4\,\bar{B}_1 - 4\,\bar{B}_2$$

Where,

m= mean

d= additive effect

h= dominance effect

i= additive x additive interaction

j= additive x dominance interaction

l= dominance x dominance interaction

The variances of these six genetic parameters were computed as follows :

$$V(m) = V(\overline{F_2})$$

$$V(d) = V(\overline{B_1}) + V(\overline{B_2})$$

$$V(h) = V(\overline{F_1}) + 16V(\overline{F_2}) + \tfrac{1}{4}V(\overline{P_1}) + \tfrac{1}{4}V(\overline{P_2}) + 4V(\overline{B_1}) + 4V(\overline{B_2})$$

$$V(i) = 4V(\overline{B_1}) + 4V(\overline{B_2}) + 16V(\overline{F_2})$$

$$V(j) = V(\overline{B_1}) + \tfrac{1}{4}V(\overline{P_1}) + V(\overline{B_2}) + \tfrac{1}{4}V(\overline{P_2})$$

$$V(l) = V(\overline{P_1}) + V(\overline{P_2}) + 4V(\overline{F_1}) + 16V(\overline{F_2}) + 16V(\overline{B_1}) + 16V(\overline{B_2})$$

The above genetic parameters were tested for significance using 't' test as in the case of scaling test.

3.4.2.6 Transgressive segregants (%)

$$\text{Transgressive segregants (\%)} = \frac{\text{Number of plants better than superior parent}}{\text{Total number of } F_2 \text{ plants}} \times 100$$

RESULTS

4. RESULTS

The results obtained from various experiments are furnished below.

4.1 EVALUATION OF PARENTS AND F_1 HYBRIDS

4.1.1. Analysis of variance (ANOVA)

The results of analysis of variance (ANOVA) for seventeen characters which were used to compare the performance of twenty three treatments (8 parents and 15 F_1 hybrids) are presented in Table 4.

Table 4. Analysis of variance for seventeen characters in 23 treatments (8 parents and 15 F_1 hybrids) of Chilli (*Capsicum annuum* L.)

Sl. No.	Characters	Mean square	
		Genotypes (df=22)	Error (df = 44)
1.	Days to first flowering	36.35**	1.76
2.	Days to 50 % flowering	43.05**	1.25
3.	Number of primary branches	7.41**	0.09
4.	Number of secondary branches	105.42**	3.21
5.	Number of fruits per plant	174.81**	10.50
6.	Green fruit weight	2.68**	0.05
7.	Fruit yield per plant	8771.72**	54.31
8.	Fruit length	6.64**	0.07
9.	Fruit girth	1.50**	0.06
10.	Number of seeds per fruits	734.70**	8.85
11.	Hundred seed weight	0.02**	0.0002
12.	Plant height	338.01**	2.18
13.	Duration of the crop	107.09**	2.49
14.	Harvest index	231.69**	4.11
15.	Capsaicin content	0.09**	0.0005
16.	Oleoresin content	7.42**	0.01
17.	Vulnerability index	1500.69**	10.33

Significant differences were detected on the genotypes with respect to all characters.

4.1.2 *Per se* performance of parents and hybrids

Per se performance of the five lines, three testers and their fifteen hybrids with respect to seventeen characters is presented in Table 5.

4.1.2.1 Days to first flowering

The earliest flowering line and tester were L_5 (65.67 days) and T_1 (68.00 days) respectively while L_1 and L_3 (71.00 days each) and T_3 (72.67days) took maximum days for flowering within their respective groups. Among the hybrids the minimum days to flowering was observed for L_2 x T_1 and L_4 x T_3 (62.00 days), which was on par with L_3 xT_2 (63.00 days), L_3 x T_3 (64.00 days), L_4 x T_2 (62.67 days), L_5 x T_2 (62.67 days) and L_5 x T_3 (63.33 days) whereas maximum days was recorded by L_5 x T_1 (71.67 days).

4.1.2.2 Days to 50 per cent flowering

The number of days to 50 per cent flowering was minimum for L_2 and L_4 (73 days), among lines while T_2 took minimum number of days to 50 per cent flowering (76.67 days) among the testers. Among the hybrids, L_4 x T_2 (65.00 days) took minimum number of days, which was on par with L_4 x T_3 (66.67 days) and L_5 x T_1 (77.67 days) took maximum days.

4.1.2.3 Number of primary branches

The number of primary branches was maximum for L_5 (4.53) and minimum for L_2 and L_3 (3.53) among lines while the maximum and minimum positions among testers were occupied by T_3 (6.53) and T_1 (5.47) respectively. The maximum number of primary branches was observed for L_5 x T_3 (8.67) among hybrids, which was on par with L_5 x T_2 (8.53) and minimum value was for L_2 x T_1 (3.33).

4.1.2.4 Number of secondary branches

The number of secondary branches was maximum for L_1 (21.07) and minimum for L_3 (13.07) among lines while these positions among testers were occupied by T_2 (25.27) and T_1 (23.40) respectively. Among

Table 5. Mean values of seventeen character in chilli (*Capsicum annuum* L.)

Sl. No.	Treatments	Days to first flowering	Days to 50 % flowering	No. of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight, g	Fruit yield per plant, g	Fruit length, cm
1.	Jwalamukhi (L1)	71.00	77.67	4.00	21.07	41.07	4.29	144.43	7.92
2.	Kottikulam Local (L2)	67.33	73.00	3.53	15.47	50.40	2.48	114.07	2.77
3.	Mangalapuram Local (L3)	71.00	77.33	3.53	13.07	58.47	3.13	151.26	3.89
4.	Koothali Local (L4)	69.00	73.00	3.93	15.20	54.67	1.97	92.47	6.09
5.	Pollakkada Local (L5)	65.67	73.67	4.53	20.13	35.53	3.33	98.88	6.13
6.	Haripuram Local (T1)	68.00	77.67	5.47	23.40	49.33	2.30	87.61	6.89
7.	Alampady Local (T2)	69.33	76.67	6.40	25.27	55.80	1.92	101.16	6.21
8.	Neyyattinkara Local (T3)	72.67	81.00	6.53	24.60	45.13	2.57	99.59	6.83
9.	L_1xT_1	70.33	75.00	6.20	24.47	57.47	2.93	153.79	6.81
10.	L_1xT_2	64.33	68.33	5.33	14.14	33.40	2.44	59.78	6.35
11.	L_1xT_3	64.67	70.67	6.07	22.40	47.53	4.55	188.06	7.05
12.	L_2xT_1	62.00	72.67	3.33	18.27	52.53	2.49	116.59	5.68
13.	L_2xT_2	66.00	71.67	6.33	13.33	45.53	3.31	148.15	5.35
14.	L_2xT_3	70.67	73.33	6.07	15.87	54.46	2.68	143.32	5.32
15.	L_3xT_1	68.33	72.00	4.33	12.87	51.73	2.09	94.63	4.80
16.	L_3xT_2	63.00	71.67	3.73	12.40	52.07	1.98	92.06	3.65
17.	L_3xT_3	64.00	75.33	6.53	18.67	50.73	2.32	106.56	4.24
18.	L_4xT_1	68.67	73.67	6.53	22.27	52.80	1.90	91.99	4.49
19.	L_4xT_2	62.67	65.00	4.73	19.13	59.60	2.23	125.56	5.41
20.	L_4xT_3	62.00	66.67	7.07	22.47	58.60	2.02	107.87	3.93
21.	L_5xT_1	71.67	77.67	7.47	24.13	50.73	2.02	95.72	4.48
22.	L_5xT_2	62.67	71.00	8.53	31.53	56.93	5.02	270.04	8.52
23.	L_5xT_3	63.33	70.67	8.67	35.07	66.40	4.47	278.26	7.60
	CD (5 %)	2.17	1.83	0.50	2.93	5.30	0.36	12.07	0.44
	SE	0.77	0.65	0.18	1.03	1.87	0.13	4.26	0.15

Table 5. continued...

Sl. No.	Treatments	Fruit girth,g	Number of seeds per fruit	100-seed weight,g	Plant height,cm	Duration of the crop	Harvest index,%	Capsaicin content, %	Oleoresin content, %	Vulnerability index, %
1.	Jwalamukhi (L1)	5.23	53.47	0.5894	49.40	181.33	66.86	0.40	10.31	65.00
2.	Kottikulam Loca(L2)	5.38	74.27	0.4556	34.06	176.00	67.49	0.15	10.77	80.00
3.	Mangalapuram Local (L3)	4.30	101.07	0.4505	36.53	178.33	75.41	0.75	11.93	76.67
4.	Koothali Local (L4)	3.43	49.97	0.4381	46.67	178.67	56.66	0.26	10.22	80.00
5.	Pollakkada Local(L5)	4.25	67.07	0.5139	40.17	179.33	62.97	0.27	9.68	76.67
6.	Haripuram Local (T1)	3.02	50.67	0.6533	61.95	182.67	51.31	0.30	13.50	23.33
7.	Alampady Local (T2)	2.47	41.33	0.3931	58.57	181.33	62.23	0.48	10.92	15.00
8.	Neyyattinkara Local (T3)	3.56	45.67	0.5142	57.37	182.33	55.23	0.53	7.33	21.67
9.	L_1xT_1	3.29	49.33	0.6297	55.17	179.33	60.82	0.21	12.44	56.67
10.	L_1xT_2	4.06	43.20	0.4407	34.45	166.33	37.81	0.21	9.59	83.33
11.	L_1xT_3	4.54	57.40	0.5496	55.16	179.67	66.61	0.49	10.62	50.00
12.	L_2xT_1	4.13	51.07	0.5782	59.53	181.33	47.27	0.40	13.20	46.67
13.	L_2xT_2	3.88	64.20	0.4779	47.46	178.00	55.59	0.19	9.08	60.00
14.	L_2xT_3	4.47	79.00	0.4489	47.00	180.33	48.40	0.48	11.78	51.67
15.	L_3xT_1	4.56	84.00	0.6699	42.79	166.33	63.71	0.56	10.35	81.67
16.	L_3xT_2	4.48	65.07	0.4392	39.28	165.33	64.91	0.17	9.39	81.67
17.	L_3xT_3	4.51	83.53	0.5588	34.93	176.33	50.77	0.30	13.89	75.00
18.	L_4xT_1	3.39	43.87	0.4711	54.35	173.33	60.61	0.29	9.22	78.33
19.	L_4xT_2	4.38	62.93	0.4509	48.37	168.67	58.11	0.34	11.01	71.67
20.	L_4xT_3	4.55	62.07	0.5004	45.98	165.67	61.85	0.46	10.32	70.00
21.	L_5xT_1	3.38	52.00	0.5523	45.46	168.67	63.15	0.29	12.17	73.33
22.	L_5xT_2	4.79	77.93	0.4990	68.88	179.33	71.79	0.76	9.69	23.33
23.	L_5xT_3	4.45	69.53	0.4550	71.53	179.33	70.15	0.53	10.07	35.00
	CD (5 %)	0.38	4.87	0.0229	2.42	2.59	3.32	0.04	0.17	5.29
	SE	0.14	1.72	0.0081	0.85	0.91	0.17	0.01	0.06	1.86

the hybrids, maximum number of secondary branches was noticed for L_5 x T_3 (35.07) and minimum value was for L_3 x T_2 (12.40).

4.1.2.5 Number of fruits per plant

Among lines, the highest and the lowest number of fruits per plant was recorded by L_3 (58.47) and L_5 (35.53) respectively. T_2 (55.80) and T_3 (45.13) plants produced the maximum and minimum number of fruits among testers. The best hybrid with respect to fruit production was L_5 x T_3 (66.40) whereas the lowest producer was L_1 x T_2 (33.4).

4.1.2.6 Green fruit weight

Among the lines, L_1 (4.29 g) had maximum average fruit weight while L_4 (1.97 g) had minimum value. T_3 (2.57 g) and T_2 (1.92 g) were the testers, which possessed the maximum and minimum values for the character. Green fruit weight among hybrids was maximum for L_5 x T_2 (5.02 g) while it was minimum for L_4 x T_1 (1.90 g).

4.1.2.7 Fruit yield per plant

The best yielding line and tester were L_3 (151.26 g) and T_2 (101.16 g) respectively, while L_4 (92.47 g) and T_1 (87.61 g) were the lowest yielder among their respective groups. Among the hybrids fruit yield per plant was maximum for L_5 x T_3 (278.26 g), which was on par with L_5 x T_2 (270.04 g).

4.1.2.8 Fruit length

The longest fruits were produced by L_1 (7.92 cm) among the lines and T_1 (6.89) among the testers. The line L_2 (2.77cm) and the tester T_2 (6.21 cm) produced shortest fruits among lines and testers respectively. Fruit length among hybrids was maximum for L_5 x T_2 (8.52 cm).

4.1.2.9 Fruit girth

Fruit girth was maximum for the line L_2 (5.38 cm) and minimum for L_4 (3.43 cm). Among testers, T_3 (3.56 cm) and T_2 (2.47 cm) respectively possessed the highest and lowest values for these characters. Among the hybrids, maximum fruit girth was recorded by L_5 x T_2 (4.79 cm), which was on par with L_1 x T_3 (4.54 cm), L_2 x T_3 (4.47 cm), L_3 x T_1 (4.56 cm), L_3 x T_2 (4.48 cm), L_3 x T_3 (4.51 cm), L_4 x T_3 (4.55 cm) and L_5 x T_3 (4.45 cm).

4.1.2.10 Number of seeds per fruit

Among the lines, L_3 (101.07) had the maximum number of seeds per fruit while L_4 (49.97) had the minimum. T_1 (50.67) and T_2 (41.33) were the testers, which had the maximum and minimum values respectively for this trait. Among the hybrids, L_3 x T_1 (84.00) recorded maximum number of seeds, which was on par with L_3 x T_3 (83.53) and L_2 x T_3 (79.00). The hybrid L_1 x T_2 (43.20) possessed minimum number of seeds per fruit.

4.1.2.11 Hundred seed weight

Among the lines, L_1 (0.5894 g) had the maximum hundred seed weight while L_4 (0.4381 g) had minimum value. The testers, T_1 (0.6533 g) and T_2 (0.3931 g) possessed maximum and minimum hundred seed weight respectively within their group. Among the hybrids, the maximum value was observed in L_3 x T_1 (0.6699 g) while it was minimum for L_3 x T_2 (0.4392 g).

4.1.2.12 Plant height

Among the lines, maximum and minimum plant height were noticed in L_1 (49.40 cm) and L_2 (34.06 cm) respectively. T_1 (61.95 cm) and T_3 (57.37 cm) had the maximum and minimum height among the testers. Among the hybrids, maximum and minimum height were recorded by L_5 x T_3 (71.53 cm) and L_1 x T_2 (34.45) respectively.

4.1.2.13 Duration of the crop

Crop duration was the shortest and the longest in L_2 (176 days) and L_1 (181.33 days) among lines and T_2 (181.33 days) and T_1 (182.67days) among testers respectively. Among the hybrids, minimum duration was recorded by L_3 x T_2 (165.33 days), which was on par with L_1 x T_2 (166.33 days), L_3 x T_1 (166.33 days) and L_4 x T_3 (165.67 days). The longest duration among the hybrids was recorded by L_2 x T_1 (181.33 days).

4.1.2.14 Harvest index

Maximum harvest index and minimum harvest index were noticed in L_3 (75.41 %) and L_4 (56.66 %) among lines and T_2 (62.23 %) and T_1 (51.31 %) among testers respectively. Among the hybrids maximum harvest index was recorded by L_5 x T_2 (71.79%) which was on par with L_5 x T_3 (70.15%) whereas the hybrid L_1 x T_2 (37.81%) recorded minimum value for the trait.

4.1.2.15 Capsaicin content

Capsaicin content was maximum in L_3 (0.75 %) and minimum in L_2 (0.15 %) among lines, while these positions among testers were occupied by T_3 (0.53 %) and T_1 (0.30 %) respectively. The maximum capsaicin content was recorded by L_5 x T_2 (0.76 %) among hybrids, while the value was minimum in L_3 x T_2 (0.17%).

4.1.2.16 Oleoresin content

Oleoresin content was maximum in L_3 (11.93 %) and minimum in L_5 (9.68 %) among lines while these positions among testers were occupied by T_1 (13.50 %) and T_3 (7.33 %) respectively. The maximum oleoresin content was recorded by L_3 x T_3 (13.89 %) among hybrids while it was minimum in L_2 x T_2 (9.08 %).

4.1.2.17 Vulnerability index

The lines L_2 and L_4 (80.00) had maximum vulnerability index while it was minimum in L_1 (65.00). Among testers T_2 (15.00) and T_1 (23.33) had minimum and maximum vulnerability index respectively. Among hybrids vulnerability index was minimum for L_5 x T_2 (23.33) while it was maximum in L_1 x T_2 (83.33).

4.1.3 Genetic parameters

The genetic parameters *viz.*, the phenotypic and genotypic coefficient of variation, heritability and genetic advance in each character estimated are presented in Table 6.

Table 6. Components of total variance for seventeen traits in chilli (*Capsicum annuum* L.)

Sl. No.	Characters	PCV, %	GCV, %	Heritability, %	Genetic advance, (as % of mean)
1.	Days to first flowering	5.45	5.08	86.75	9.75
2.	Days to 50 % flowering	5.32	5.09	91.77	10.05
3.	Number of primary branches	28.40	27.86	96.25	56.43
4.	Number of secondary branches	30.17	28.84	91.40	56.87
5.	Number of fruits per plant	15.73	14.41	83.91	27.22
6.	Green fruit weight	34.25	33.32	94.66	66.79
7.	Fruit yield per plant	42.25	41.86	98.17	85.43
8.	Fruit length	26.53	26.11	96.83	52.91
9.	Fruit girth	17.84	16.90	89.76	33.09
10.	Number of seeds per fruit	25.50	25.04	96.47	50.66
11.	Hundred seed weight	14.97	14.71	96.64	29.41
12.	Plant height	21.65	21.44	98.09	43.75
13.	Duration of the crop	3.47	3.35	93.32	6.68
14.	Harvest index	14.91	14.52	94.87	29.14
15.	Capsaicin content	45.29	44.91	98.33	92.11
16.	Oleoresin content	14.63	14.60	99.56	30.02
17.	Vulnerability index	37.62	37.23	97.96	75.92

PCV- Phenotypic coefficient of variation GCV-Genotypic coefficient of variation

Maximum variability was observed in capsaicin content (45.29 and 44.91 at phenotypic and genotypic levels respectively. Minimum variability at phenotypic and genotypic levels was observed for duration of the crop (3.47 and 3.35 respectively).

For all the characters, the PCV and GCV values were found to be closer indicating the predominant influence of genetic component over the environmental effect in their phenotype.

Heritability and genetic advance are presented in Fig. 1. Maximum heritability (99.56 %) was observed in oleoresin content and minimum (83.91 %) for number of fruits per plant. Allard (1960) classified heritability low (10-30 %), medium (30-60 %) and high (above 60 %). In the present study, the heritability estimates were high for all the characters. Maximum genetic advance (% of mean) was observed for capsaicin content (92.11 %) followed by yield per plant (85.43 %) and vulnerability index (75.92 %).

4.1.4 Association analysis

4.1.4.1 Phenotypic correlation

Phenotypic correlation coefficients estimated for the seventeen characters are furnished in Table 7.

Days to first flower showed positive association with days to 50 per cent flowering alone. Positive correlation was noticed for days to 50 per cent flowering with duration of the crop while its correlation was negative with fruit girth and vulnerability index.

The number of primary branches had positive association with number of secondary branches, fruit yield per plant, fruit length, plant height and duration of the crop whereas the associations was negative with number of seeds per fruit and vulnerability index. The association of number of secondary branches with number of fruit per plant, green fruit weight, fruit yield per plant, fruit length, plant height and duration of the crop was positive while it was negative with vulnerability index.

Number of fruits per plant had positive correlation with number of secondary branches, fruit yield per plant, plant height, harvest index and capsaicin content. Green fruit weight had positive correlation with number of secondary branches, fruit yield per plant, fruit length, fruit girth, plant height, duration of the crop, harvest index and capsaicin content whereas negative with vulnerability index.

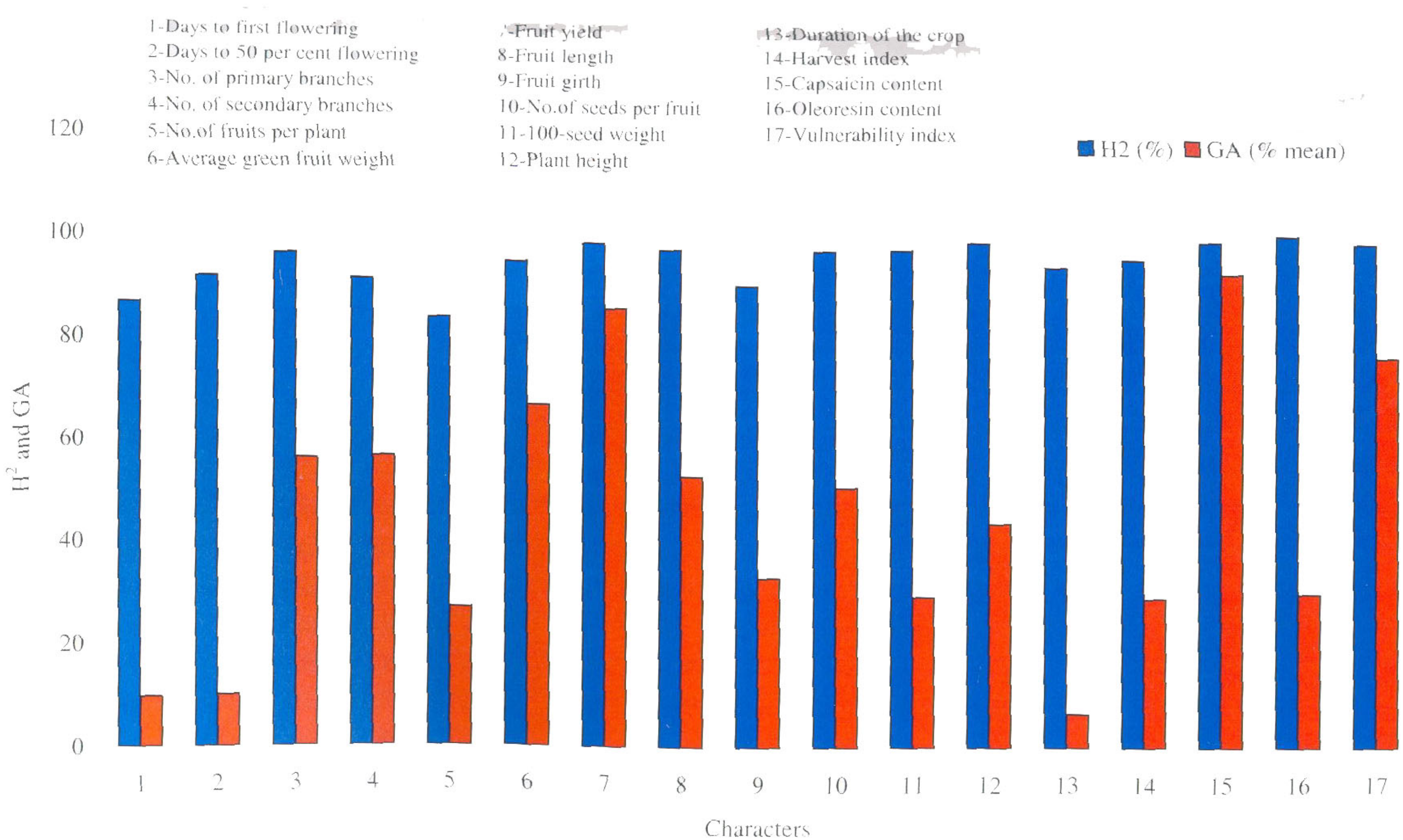


Fig. 1. Heritability and genetic advance

Table 7. Phenotypic correlation coefficient

Sl. No.	Days to first flowe-ring	Days to 50% flowe-ring	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight, g	Fruit yield per plant, g	Fruit length, cm	Fruit girth, cm	Number of seeds per fruits	Hundred seed weight, g	Plant height, cm	Duration of the crop	Harvest index HI	Cap-sacin content	Ole-resin content	Vulnerability index
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.000																
2	0.7418**	1.000															
3	-0.0787	-0.0482	1.000														
4	-0.0743	0.1074	0.7250**	1.000													
5	-0.1039	-0.1770	0.2715	0.3100*	1.000												
6	-0.1434	-0.0540	0.3033	0.4429**	-0.0039	1.000											
7	-0.2355	-0.1641	0.5012**	0.5850**	0.4789**	0.8305**	1.000										
8	0.0264	0.1074	0.3601*	0.6040**	-0.0897	0.6386**	0.5083**	1.000									
9	-0.3240	-0.3499*	-0.2086	-0.1617	-0.0337	0.4159**	0.3344*	-0.1018	1.000								
10	-0.1277	-0.1064	-0.4065**	-0.2531	0.2831	0.2482	0.3530*	-0.3381*	0.5658**	1.000							
11	0.1402	0.2682	-0.0431	0.0839	-0.1406	0.0889	-0.0570	0.2185	0.0272	-0.0122	1.000						
12	-0.0742	0.0683	0.5451**	0.7754**	0.3800*	0.4266**	0.5939**	0.7033**	-0.2876	-0.3262*	0.1495	1.000					
13	0.2994	0.5299**	0.0511	0.3604*	-0.0124	0.4484**	0.3512*	0.5278**	-0.1782	-0.0751	0.1017	0.4907**	1.000				
14	0.0775	0.0901	0.0789	0.2766	0.4099**	0.4333**	0.5352**	-0.0047	0.2783	0.4090**	-0.0613	0.1502	.0456	1.000			
15	0.0589	0.0942	0.2748	0.3469*	0.3725*	0.4369**	0.5419**	0.3190*	0.1567	0.4329**	0.0125	0.4045**	0.2356	0.4219**	1.000		
16	-0.0235	0.1369	-0.1284	-0.0368	0.2513	-0.1693	-0.0616	-0.1550	-0.0932	0.1943	0.4036**	-0.0562	0.1556	-0.1815	-0.0527	1.000	
17	-0.0713	-0.3063*	-0.4069**	-0.6496**	-0.2141	-0.3400*	-0.4296**	-0.6259**	0.3496*	0.2490	-0.0604	-0.8129**	-0.6274**	-0.0196	-0.4423**	-0.0069	1.000

Association of fruit yield per plant with number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit length, fruit girth, number of seeds, plant height, duration of the crop, harvest index and capsaicin content was positive while it was negative with vulnerability index. Fruit length was observed to be correlated positive with number of primary branches, green fruit weight, fruit weight per plant, plant height, duration of the crop and capsaicin content and negatively correlated with number of seeds per fruit and vulnerability index.

Fruit girth showed positive association with green fruit weight, fruit yield per plant, number of seeds and vulnerability index whereas the association was negative with number of primary branches.

The number of seeds per fruit exhibited positive association with fruit yield per plant, fruit girth, harvest index and capsaicin content whereas negative association was observed with number of primary branches, fruit length and plant height. Hundred seed weight had positive correlation with oleoresin content alone.

Plant height had positive correlation with number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, fruit length, duration of the crop and capsaicin content whereas it was negative with number of seeds per plant and vulnerability index.

The duration of crop exhibited positive association with days to 50 per cent flowering, number of secondary branches per plant, green fruit weight, fruit yield per plant, fruit length, plant height and harvest index whereas negative association with vulnerability index.

The harvest index had positive association with number of fruits per plant, green fruit weight, fruit yield per plant, number of seeds per fruit, duration of the crop and capsaicin content.

Capsaicin content showed positive association with number of secondary branches, number of fruit per plant, green fruit weight, fruit yield per plant, fruit length, number of seeds per fruit, plant height and harvest index whereas the association was negative with vulnerability index. Oleoresin content had positive association with hundred seed weight alone.

Vulnerability index disease showed negative association with days to 50 per cent flowering, number of primary branches, number of secondary branches, green fruit weight, fruit yield per plant, fruit length, plant height, duration of the crop and capsaicin content whereas it was positive with fruit girth alone.

4.1.4.2 Genotypic correlation

Genotypic correlation coefficient among the seventeen characters are presented in Table 8.

Days to first flower was associated positively with days to 50 per cent flowering and duration of the crop and negatively with fruit girth. Days to 50 per cent flowering followed the same trend of correlations as that of days to first flower except in the case of vulnerability index (significant negative association).

The number of primary and secondary branches are positively correlated with each other and both the traits had positive correlation with number of fruits per plant, green fruit weight, fruit yield per plant and plant height and negative correlation with vulnerability index. In addition, the number of secondary branches were found to be positively correlated with duration of the crop, harvest index and capsaicin content.

The number of fruits and green fruit weight had positive correlation with number of primary branches, number of secondary branches, fruit yield per plant, plant height, harvest index and capsaicin content. Moreover, green fruit weight had significant positive correlation with fruit length, fruit girth and duration of the crop and significant negative

Table 8. Genotypic correlation coefficient

Sl. No.	Days to first flowering	Days to 50% flowering	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight, g	Fruit yield per plant, g	Fruit length, cm	Fruit girth, cm	Number of seeds per fruit	Hundred seed weight, g	Plant height, cm	Duration of the crop	Harvest index, HI	Capsaicin content	Oleoresin content	Vulnerability index
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.0000																
2	0.8034**	1.0000															
3	-0.0932	-0.0469	1.000														
4	-0.0746	0.1013	0.7845**	1.0000													
5	-0.1453	-0.1955	0.3097*	0.3782**	1.0000												
6	-0.1763	-0.0465	0.3205*	0.4853*	-0.0237	1.0000											
7	-0.2529	-0.1780	0.5176**	0.6263**	0.4868*	0.8573**	1.0000										
8	0.0133	0.1041	0.3782**	0.6273**	-0.1225	0.6763**	0.5161*	1.0000									
9	-0.4029**	-0.3948**	-0.2205	-0.2003	-0.0712	0.4634**	0.3471*	-0.1608	1.0000								
10	-0.1218	-0.1074	-0.1087	-0.2583	0.2923	0.2417	0.3490*	-0.3417*	0.6178**	1.0000							
11	0.1376	0.2865	-0.0524	0.0859	-0.1638	0.0844	-0.0567	0.2134	0.0076	-0.0126	1.0000						
12	-0.0770	0.0868	0.5547**	0.8827**	0.4355**	0.4434**	0.6098**	0.7176**	-0.3150*	-0.3310*	0.1495	1.0000					
13	0.3403*	0.5709**	0.0700	0.3531*	0.0060	0.4628**	0.3737**	0.5517**	-0.2011	-0.0808	0.1073	0.5118*	1.0000				
14	0.0997	0.0898	0.0908	0.3136*	0.4151**	0.4507**	0.5328**	-0.0100	0.2992	0.4142**	-0.0579	0.1618	0.0603	1.0000			
15	0.0585	0.0967	0.2822	0.3672*	0.4064**	0.4528**	0.5531**	0.3238*	0.1579	0.4422**	0.0133	0.4123**	0.2487	0.4406*	1.0000		
16	-0.0256	0.1461	-0.1304	-0.0393	0.2655	-0.1760	-0.0658	-0.1597	-0.1034	0.1987	0.4092**	-0.0546	0.1638	-0.1912	-0.0505	1.0000	
17	-0.0713	-0.3235*	-0.4968**	-0.6899**	-0.2371	-0.3497*	-0.4385**	-0.6459**	0.3729*	-0.2579	-0.0716	-0.8299**	-0.6614**	-0.0193	0.4499**	-0.0083	1.000

correlation with incidence of leaf curl. The fruit yield per plant had positive association with fruit length, plant height, duration of the crop, harvest index and capsaicin content and negative association with vulnerability index.

Positive association was observed for fruit length with number of primary branches, number of secondary branches, green fruit weight, fruit yield per plant, plant height, duration of the crop and capsaicin content and negative association with number of seeds and leaf curl vulnerability index. Fruit girth had positive association with fruit weight, fruit weight per plant, number of seeds and leaf curl disease incidence and negative association with days to flowering, days to 50 per cent flowering, and plant height.

Number of seeds per fruit had positive association with fruit yield per plant, fruit girth, harvest index and capsaicin content and negative association with fruit length and plant height. Hundred seed weight exhibited positive association with oleoresin content.

Plant height showed positive association with number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, fruit length, duration of the crop and capsaicin content and negative association with fruit girth, number of seeds per fruit and vulnerability index.

The duration of the crop showed positive association with days to flowering, days to 50 per cent flowering, number of secondary branches, green fruit weight, fruit yield per plant, fruit length and plant height and negative association with leaf curl incidence.

Harvest index had positive correlation with number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, number of seeds per fruit and capsaicin content.

Capsaicin content exhibited positive correlation with number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, fruit length, number of seeds per fruit, plant height, harvest index whereas negative correlation with vulnerability index.

Oleoresin content showed positive and significant correlation with hundred seed weight alone.

The incidence of leaf curl disease had negative correlation with days to 50 per cent flowering, number of primary branches, number of secondary branches, green fruit weight, fruit yield per plant, fruit length, plant height, duration of the crop and capsaicin content whereas positive association with fruit girth.

4.1.4.3 Environmental correlation

Environmental correlation coefficients were estimated for the seventeen characters and are presented in Table 9. Majority of the environmental correlations were non significant.

Days to 50 per cent flowering had negative correlation with plant height.

Number of primary branches had negative association with duration of the crop. The number of secondary branches exhibited positive association with duration of the crop.

Number of fruits per plant exhibited positive association with fruit weight per plant, harvest index and oleoresin content. Green fruit weight had positive association with number of seeds alone.

Fruit yield per plant had positive association with number of fruits per plant, number of seeds per fruit, harvest index and oleoresin content.

Fruit length and fruit girth are positively associated with each other and also showed positive association with hundred seed weight.

Number of seeds per fruit had positive association with green fruit weight and fruit yield per plant. Hundred seed weight exhibited positive correlation with fruit length, fruit girth and vulnerability index.

Table 9. Environmental correlation coefficient

Sl. No.	Days to first flowe-ring	Days to 50% flowe-ring	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight,	Fruit yield per plant,	Fruit length,	Fruit girth, cm	Number of seeds per fruits	Hundred seed weight,	Plant height	Duration of the crop	Harvest index, HI	Capsaicin content	Ole-resin content	Vulnerability index
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.000																
2	0.2399	1.000															
3	0.0907	-0.0747	1.000														
4	-0.0738	0.1734	-0.1902	1.000													
5	01375	-0.0470	-0.0885	-0.1806	1.000												
6	0.1945	-0.1612	-0.0580	-0.1254	0.1860	1.000											
7	-0.0433	0.1246	-0.0708	-0.2065	0.6833**	0.1318	1.000										
8	0.2192	0.1817	-0.1460	0.2667	0.2902	-0.2148	0.2107	1.000									
9	0.2705	0.0915	-0.0583	0.2100	0.2195	-0.1532	0.1986	0.8454**	1.000								
10	-0.2384	-0.0985	-0.0482	-0.1922	0.2673	0.3983*	0.5245**	-0.2346	-0.1504	1.000							
11	0.2134	-0.0301	0.2091	0.0587	0.0939	0.1919	-0.0696	0.3700*	0.3436*	-0.0012	1.000						
12	-0.0631	-0.3533*	0.2269	-0.0893	-0.2732	-0.0224	-0.2403	0.1596	0.1813	-0.1324	0.1579	1.000					
13	-0.0718	0.0217	-0.3047*	0.4515**	-0.1715	0.2237	-0.1852	0.0730	0.0707	0.0324	-0.0050	0.0280	1.000				
14	-0.1574	0.0984	-0.1792	-0.2315	0.4345**	0.1188	0.6852**	0.1197	0.0302	0.3004*	-0.1409	-0.1878	-0.1895	1.000			
15	0.1029	0.0628	0.0103	-0.0315	0.0657	0.0016	-0.0832	0.1314	0.2012	0.0887	-0.0182	0.0234	-0.0785	-0.1272	1.000		
16	0.0141	-0.1480	-0.0589	0.0352	0.3229*	0.1012	0.3763*	0.1485	0.2132	-0.0382	0.01843	-0.2420	-0.0699	0.2877	-0.3205*	1.000	
17	-0.1074	0.0093	0.0546	0.0758	0.0145	-0.0957	0.0199	0.1244	-0.0005	-0.0634	0.3533*	0.0299	0.1363	-0.0297	-0.0371	0.1445	1.000

Capsaicin and oleoresin were negatively correlated with each other. Besides, the oleoresin content showed positive association with number of fruits and fruit weight per plant.

The incidence of leaf curl disease had positive association with hundred seed weight.

4.1.5 Combining ability analysis

The combining ability effects of lines, testers and hybrids were evaluated and the results are presented below.

The analysis of variance for combining ability was carried out for seventeen characters and are presented in Table 10. The general combining ability (*gca*) and specific combining ability (*sca*) effects were found to be significant for most of the characters.

Significant treatment effects were observed among genotypes in all the characters and hence subjected to combining ability analysis in a line x tester model.

Among the parents and among the crosses there were significant differences in all the characters studied. In parents Vs crosses there were significant differences observed for all the characters except number of secondary branches and green fruit weight.

Lines varied significantly only in number of primary branches and number of secondary branches while testers exhibited significant variation for fruit girth, hundred seed weight and capsaicin content alone. Line x Tester interaction mean square was significant for all the characters.

The general combining ability (*gca*) effects of parents and specific combining ability (*sca*) effects of hybrids in seventeen characters are given in the Tables 11 and 12 respectively.

Table 10. ANOVA for combining ability for various characters in chilli (*Capsicum annuum*)

Source	df	Mean square								
		Days to first flowering	Days to 50 per cent flowering	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight	Fruit yield per plant	Fruit length	Fruit girth
Replication	2	7.94*	9.83**	3.74**	58.24**	106.47**	1.13**	752.44**	0.99**	0.40**
Treatments	22	36.35**	43.05**	7.41**	105.42**	174.81**	2.66**	8771.72**	6.64**	1.50**
Parents	7	15.41**	23.88**	4.57**	65.52**	183.84**	1.90*	1719.48**	8.54**	3.17**
Crosses	14	34.71**	32.45**	7.41**	132.34**	165.76**	3.23**	12110.74**	6.09**	0.72**
Parents Vs crosses	1	206.01**	325.61**	27.3**	7.88	238.33**	0.10	11391.09**	1.08**	0.88**
Lines	4	6.20	34.08	15.31*	341.44**	213.29	5.27	18880.14	13.02	0.37
Testers	2	80.16	83.09	7.62	84.09	138.20	3.50	11054.78	1.40	2.32*
Line x Testers	8	37.60**	18.98**	3.40**	39.85**	148.88**	2.14**	8990.02**	3.80**	0.49**
Error	44	1.76	1.25	0.09	3.21	10.50	0.69	54.31	0.07	0.06

*Significant at 5 % level **Significant at 1 % level

Table 10. continued...

Source	df	Mean squares							
		Number of seeds per fruit	100 seed weight	Plant height	Duration of the crop	Harvest index	Capsaicin content	Oleoresin content	Vulnerability index
Replication	2	174.41**	0.0031**	42.33**	36.13**	33.23**	0.005**	0.81**	39.49**
Treatments	22	734.70**	0.0171**	338.01**	107.09**	231.69**	0.0888**	7.42**	1500.69**
Parents	7	1166.90**	0.0221**	336.19**	15.90**	181.13**	0.1087**	9.44**	2572.47**
Crosses	14	563.69**	0.0156**	358.73**	118.27**	259.82**	0.0850**	6.85**	1004.60**
Parents Vs crosses	1	103.51**	0.0030**	58.50**	588.94**	191.66**	0.0029*	1.16**	943.47**
Lines	4	992.45	0.0097	605.21	188.06	401.49	0.068	1.96	1903.61
Testers	2	763.17	0.0545*	62.41	84.00	15.11	0.064*	13.73	477.22
Line x Testers	8	299.44**	0.0088**	309.57**	91.44**	250.17**	0.0989**	7.58**	686.95**
Error	44	8.85	0.0002	2.18	2.49	4.11	0.0005	0.01	10.33

*Significant at 5 % level **Significant at 1 % level

Table 11. General combining ability (*gca*) effects of lines and testers for seventeen characters

	Days to first flowering	Days to 50 per cent flowering	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight	Fruit yield per plant	Fruit length	Fruit girth
Lines									
L_1	0.82	-0.36	-0.19	-0.06	-6.57**	0.48**	-4.28	1.16**	-0.23**
L_2	0.60	0.87*	-0.82**	-4.66**	-1.85	-0.003	-2.14	-0.13	-0.03
L_3	-0.51	1.31**	-1.2**	-5.84**	-1.19	-0.7**	-40.41*	-1.35**	0.33**
L_4	-1.18*	-3.24**	0.05	0.80	4.30**	-0.78**	-29.68*	-0.97**	-0.08
L_5	0.27	1.42**	2.16**	9.76	5.32**	1.01**	76.51**	1.29**	0.02
SE	0.44	0.37	0.10	0.60	1.08	0.07	2.46	0.09	0.08
CD (Lines)	1.26	1.06	0.29	1.70	3.08	0.21	7.00	0.25	0.22
Testers									
T_1	2.58**	2.51**	-0.49**	-0.08	0.35	-0.54**	-27.61*	-0.33**	-0.44**
T_2	-1.89**	-2.16**	-0.33**	-2.32**	-3.20**	0.17**	0.96	0.28**	0.13**
T_3	-0.69*	-0.36	0.82**	2.41**	2.84	0.38**	26.66**	0.05	0.31**
SE	0.34	0.29	0.08	0.46	0.84	0.06	1.90	0.07	0.06
CD (Testers)	0.98	0.82	0.23	1.32	2.38	0.16	5.42	0.20	0.17

*Significant at 5 % level   **Significant at 1 % level

Table 11. continued...

	Number of seeds per fruit	100 seed weight	Plant height	Duration of the crop	Harvest index	Capsaicin content	Oleoresin content	Vulnerability index
Lines								
L_1	-13.03**	0.03**	-1.76**	1.24**	-3.69**	-0.08**	0.03	0.78
L_2	1.75	-0.01	1.31*	6.02**	-8.35**	-0.02**	0.50**	-9.78**
L_3	14.52**	0.04**	-11.02**	-4.53**	1.03	-0.04**	0.36**	16.89**
L_4	-6.72**	-0.04**	-0.46	-4.64**	1.42*	-0.02**	-0.67**	10.78**
L_5	3.48**	-0.01	11.94**	1.91**	9.59**	0.15**	-0.21	-18.67**
SE	0.99	0.005	0.49	0.53	0.68	0.007	0.03	1.07
CD (Lines)	2.83	0.01	1.40	1.50	1.92	0.02	0.10	3.05
Testers								
T_1	-6.96**	0.07**	1.44**	-0.07	0.34	-0.03**	0.62**	4.78**
T_2	-0.34	-0.05**	-2.33**	-2.33**	-1.13*	-0.05**	-1.10**	1.44
T_3	7.30**	-0.01*	0.90*	2.40**	0.79	0.07**	0.48**	-6.22**
SE	0.77	0.004	0.38	0.41	0.52	0.006	0.03	0.83
CD (Testers)	2.19	0.01	1.09	1.16	1.49	0.02	0.08	2.36

*Significant at 5 % level **Significant at 1 % level

Table 11 a. High per se performance and desirable *gca* effect of parents of various traits.

	Days to first flowering	Days to 50 Per cent flowering	Number of primary Branches	Number of Secondary Branches	Number of Fruits per Plant	Green Fruit weight	Fruit Yield Per Plant	Fruit length	Fruit grith	Number of seeds per fruit	Hundred seed weight	Plant height	Duration of the crop	Harvest index	**Capsaicin content**	**Oleoresin content**	**Vulnerability index**
L_1				P		P, G	P	P	P,G		P, G	P					P
L_2	P	P							P			G	P			G	G
L_3					P, G		P		G	P,G	G		P, G	P	P	P, G	
L_4	G	P, G			P, G								G	G			
L_5	P	P	P,G	P	G	G	G	G		G		G		G	G		G
T_1	P	P		P		P		P		P	P, G	P, G	P			G	
T_2	P, G	P, G	P	P	P	G	P	G	G				P, G	P			P
T_3	G		P, G	P,G		P,G	P,G	P	P,G	G		G	P		P, G	G	G

P-. High per se performance
G – Significant desirable *gca* effect.

Table 11 a. High per se performance and desirable *gca* effect of parents of various traits.

	Days to first flowering	Days to 50 Per cent flowering	Number of primary Branches	Number of Secondary Branches	Number of Fruits per Plant	Green Fruit weight	Fruit Yield Per Plant	Fruit length	Fruit grith	Number of seeds per fruit	Hundred seed weight	Plant height	Duration of the crop	Harvest index	**Capsaicin content**	**Oleoresin content**	**Vulnerability index**
1				**P**		**P, G**	**P**	**P**	**P,G**		**P, G**	**P**					**P**
2	**P**	**P**							**P**			**G**	**P**			**G**	**G**
3					**P, G**		**P**		**G**	**P,G**	**G**		**P, G**	**P**	**P**	**P, G**	
4	**G**	**P, G**			**P, G**								**G**	**G**			
5	**P**	**P**	**P,G**	**P**	**G**	**G**	**G**	**G**		**G**		**G**		**G**	**G**		**G**
T1	**P**	**P**		**P**		**P**		**P**		**P**	**P, G**	**P, G**	**P**			**G**	
T2	**P, G**	**P, G**	**P**	**P**	**P**	**G**	**P**	**G**	**G**				**P, G**	**P**			**P**
T3	**G**		**P, G**	**P,G**		**P,G**	**P,G**	**P**	**P,G**	**G**		**G**	**P**		**P, G**	**G**	**G**

P-. High per se performance
G – Significant desirable *gca* effect.

Table 12. Specific combining ability (*sca*) effects of line x tester hybrids for seventeen characters

Sl. No.	Hybrids	Days to first flowering	Days to 50 per cent flowering	Number of primary branches	Number of secondary branches	Number of fruits per plant	Green fruit weight	Fruit yield per plant	Fruit length	Fruit girth
1	L_1 x T_1	1.31	1.16	0.82**	4.13**	10.98**	0.17	47.53**	0.40*	-0.23
2	L_1 x T_2	-0.22	-0.84	-0.20	-3.70**	-9.54**	-1.03**	-75.06**	-0.66**	-0.03
3	L_1 x T_3	-1.09	-0.31	-0.62**	-0.43	-1.44	0.87**	27.53**	0.27	0.26
4	L_2 x T_1	-6.80**	-2.4**	-1.42**	2.53*	1.34	0.21	8.18	0.56**	0.41**
5	L_2 x T_2	1.67*	1.27	1.41**	-0.16	-2.12	0.32*	11.18*	-0.38*	-0.41**
6	L_2 x T_3	5.13**	1.13	0.004	-2.36*	0.78	-0.53**	-19.36**	-0.18	-0.0004
7	L_3 x T_1	0.64	-3.51**	-0.04	-1.69	-0.13	0.50**	24.5**	0.90**	0.48**
8	L_3 x T_2	-0.22	0.82	-0.80**	8.00**	3.75	-0.32*	-6.65	-0.86**	-0.16
9	L_3 x T_3	-0.42	2.69**	0.85**	1.61	-3.62	-0.19	-17.84**	-0.04	-0.32*
10	L_4 x T_1	1.64*	2.71**	0.91**	1.06	-4.55*	0.39**	11.13*	0.21	-0.27
11	L_4 x T_2	0.11	-1.29	-1.05**	0.17	5.8**	0.01	16.13**	0.52**	0.14
12	L_4 x T_3	-1.76*	-1.42*	0.14	-1.23	-1.24	-0.41**	-27.26**	-0.73**	0.13
13	L_5 x T_1	3.20**	2.04**	-0.27	-6.03**	-7.64**	-1.27**	-91.34**	-2.06**	-0.39**
14	L_5 x T_2	-1.33	0.04	0.64**	3.61**	2.11	1.02**	54.41**	1.38**	0.46**
15	L_5 x T_3	-1.87*	-2.09**	-0.37*	2.41*	5.53**	0.26	36.93**	0.68**	-0.07
	SE	0.77	0.65	0.18	1.03	1.87	0.13	4.25	0.15	0.14
	CD	2.18	1.84	0.51	2.95	5.33	0.36	12.12	0.44	0.39

*Significant at 5 % level **Significant at 1 % level

Table 12. continued...

Sl. No.	Hybrids	Number of seeds per fruit	100 seed weight	Plant height	Duration of the crop	Harvest index	Capsaicin content	Oleoresin content	Vulnerability index
1	$L_1 \times T_1$	6.31**	0.02*	5.47**	4.29**	5.4**	-0.06**	0.93**	-11.44**
2	$L_1 \times T_2$	-6.44**	-0.05**	-11.48**	-6.44**	-16.14**	-0.05**	-0.19**	18.56**
3	$L_1 \times T_3$	0.12	0.02*	6.00**	2.16	10.75**	0.11**	-0.75**	-7.11**
4	$L_2 \times T_1$	-6.73**	0.01	6.76**	1.51	-3.49**	0.07**	1.23**	-10.89**
5	$L_2 \times T_2$	-0.21	0.03**	-1.54	0.44	6.3**	-0.12**	-1.17**	5.78**
6	$L_2 \times T_3$	6.95**	-0.04**	-5.23**	-1.96*	-2.80*	0.05**	-0.06	5.11**
7	$L_3 \times T_1$	13.42**	0.05**	2.36**	-2.93**	3.57**	0.25**	-1.48**	-2.56
8	$L_3 \times T_2$	-12.12**	-0.06**	2.61**	-1.67	6.24**	-0.13**	-0.72**	0.78
9	$L_3 \times T_3$	-1.3	0.02*	-4.97**	4.60	-9.81**	-0.12**	2.20**	1.78
10	$L_4 \times T_1$	-5.47**	-0.07**	3.34**	4.18**	0.08	-0.05**	-1.59**	0.22
11	$L_4 \times T_2$	6.99**	0.03**	1.14	1.78	-0.95	0.02	1.93**	-3.11
12	$L_4 \times T_3$	-1.52	0.04**	-4.48**	-5.96**	0.87	0.02	-0.34**	2.89
13	$L_5 \times T_1$	-7.53**	-0.02*	-17.94**	-7.04**	-5.56**	-0.21**	0.91**	24.67**
14	$L_5 \times T_2$	11.79**	0.05**	9.26**	5.89**	4.56**	0.28**	0.15*	-22.00**
15	$L_5 \times T_3$	-4.25*	-0.03**	8.68**	1.16	1.0	-0.07**	-1.05**	-2.67
	SE	1.72	0.008	0.85	0.91	1.17	0.01	0.06	1.86
	CD (sca)	4.89	0.02	2.43	2.60	3.33	0.04	0.17	5.29

*Significant at 5 % level **Significant at 1 % level

4.1.5.1 Days to first flowering

Among lines significant negative *gca* effects were observed in L_4 (-1.18) and among the testers for T_2 (-1.89) and T3 (-0.69) whereas T_1 had significant positive value (2.58). Significant negative *sca* effects were noticed for L_2 x T_1 (-6.80), L_4 x T_3 (-1.76) and L_5 x T_3 (-1.87) whereas significant positive *sca* effect were exhibited by L_2 x T_2 (1.67), L_2 x T_3 (5.13), L_4 x T_1 (1.64) and L_5 x T_1 (3.2).

4.1.5.2 Days to 50 per cent flowering

Among lines, L_2 (0.87), L_3 (1.31) and L_5 (1.42) had positive significant *gca* effects while L_4 exhibited significant negative value (-3.24). Among the testers, T_1 (2.51) and T_2 (-2.16) exhibited significant positive and negative values respectively. Significant positive *sca* effects were exhibited by L_3 x T_3 (2.69), L_4 x T_1 (2.71) and L_5 x T_1 (2.04) where significant negative *sca* effects were noted for L_2 x T_1 (-2.4), L_3 x T_1 (-3.51), L_4 x T_3 (-1.42) and L_5 x T_3 (-2.09).

4.1.5.3 Number of primary branches

Among lines, the *gca* effect was positive and significant in L_5 (2.16) alone whereas significant negative values were exhibited by L_2 (-0.82) and L_3 (-1.2). Among testers T3 (0.82) alone exhibited significant and positive *gca* effect. But T_1 (-0.49) and T_2 (-0.33) exhibited negative and significant *gca* effect. Out of the fifteen hybrids, L_1 x T_1 (0.82), L_2 x T_2 (1.41), L_3 x T_3 (0.85), L_4 x T_1 (0.91) and L_5 x T_2 (0.64) expressed significant and positive *sca* effects. Significant and negative *sca* effects were recorded by the hybrids L_1 x T_3 (-0.62), L_2 x T_1 (-1.42), L_3 x T_2 (-0.80), L_4 x T_2 (-1.05) and L_5 x T_3 (-0.37).

4.1.5.4 Number of secondary branches

None of the lines showed significant positive effect for this trait. Lines L_2 (-4.66) and L_3 (-5.84) had significant negative *gca* effect. Among testers T_3 (2.41) exhibited significant positive *gca* effect whereas significant negative value was expressed by T_2 (-2.32). In the hybrid category, significant and positive *sca* effects were observed in L_1 x T_1 (4.13), L_2 x T_1 (2.53), L_3 x T_2 (8.00), L_5 x T_2 (3.61) and L_5 x T_3 (2.41) whereas the *sca* effects were significant and negative in L_1 x T_2 (-3.7), L_2 x T_3 (-2.36) and L_5 x T_1 (-6.03).

4.1.5.5 Number of fruits per plant

Positive and significant *gca* effects were observed in L_4 (4.30) and L_5 (5.32) among lines. The *gca* effect was negative and significant in L_1 (-6.57). None of the testers showed significant positive *gca* effect whereas T_2 alone exhibited significant negative *gca* effect (-3.20). Among the hybrids, positive significant *sca* effects were observed in L_1 x T_1 (10.98), L_4 x T_2 (5.80) and L_5 x T_3 (5.53). Significant and negative *sca* effects were recorded by L_1 x T_2 (-9.54), L_4 x T_1 (-4.55) and L_5 x T_1 (-7.64).

4.1.5.6 Green fruit weight

Among lines, L_1 (0.48) and L_5 (1.01) exhibited significant positive *gca* effects whereas significant negative values were noted in L_3 (-0.70) and L_4 (-0.78). Among testers T_2 (0.17) and T_3 (0.38) had significant positive *gca* effect whereas T_1 (-0.54) had significant negative *gca* effect. The *sca* effects were positive and significant in hybrids L_1 x T_3 (0.87), L_2 x T_2 (0.32), L_3 x T_1 (0.50), L_4 x T_1 (0.39) and L_5 x T_2 (1.02) whereas significant negative *sca* was shown by L_1 x T_2 (-1.03), L_2 x T_3 (-0.53), L_3 x T_2 (-0.32), L_4 x T_3 (-0.41) and L_5 x T_1 (-1.27).

4.1.5.7 Fruit yield per plant

The line, L_5 (76.51) alone expressed significant positive *gca* effect for the character. Significant negative *gca* effects were displayed by L_3 (-40.41) and L_4 (-29.68). Among the testers, only T_3 (26.66) recorded significant positive *gca* effect whereas significant negative value was expressed by T_1 (-27.61). All the hybrids except L_2 x T_1 and L_3 x T_2 exhibited significant *sca* effects. Among these, significant positive *sca* effects were exhibited by L_1 x T_1 (47.53), L_1 x T_3 (27.53), L_2 x T_2 (11.18), L_3 x T_1 (24.50), L_4 x T_1 (11.13), L_4 x T_2 (16.13), L_5 x T_2 (54.41) and L_5 x T_3 (36.93) and significant negative values was noticed for L_1 x T_2 (-75.06), L_2 x T_3 (-19.36), L_3 x T_3 (-17.84), L_4 x T_3 (-27.26) and L_5 x T_1 (-91.34).

4.1.5.8 Fruit length

Among lines *gca* effects were significant and positive in L_1 (1.16) and L_5 (1.29) whereas negative in L_3 (-1.35) and L_4 (-0.97). Among testers, T_2 (0.28) alone exhibited significant *gca* effect whereas T_1 exhibited significant negative *gca* effects. Significant positive *sca* effects were displayed by L_1 x T1 (0.40), L_2 x T_1 (0.56), L_3 x T_1 (0.90), L_4 x T_2 (0.52), L_5 x T_2 (1.38) and L_5 x T_3 (0.68). Hybrids, L_1 x T_2 (-0.66), L_2 x T_2 (-0.38), L_3 x T_2 (-0.86), L_4 x T_3 (-0.73) and L_5 x T_1 (-2.06) showed significant negative values for *sca*.

4.1.5.9 Fruit girth

Among lines, significant positive *gca* effect was exhibited by L_3 (0.33) whereas L_1 expressed significant negative value (-0.23). All the testers expressed significant *gca* effects. Among these, T_2 (0.13) and T_3 (0.31) exhibited positive values and T_1 (-0.44) had negative value. Significant positive *sca* effect was displayed by L_2 x T_1 (0.41), L_3 x T_1 (0.48) and L_5 x T_2 (0.46) whereas L_2 x T_2 (-0.41), L_3 x T_3 (-0.32) and L_5 x T_1 (-0.39) exhibited significant negative values.

4.1.5.10 Number of seeds per fruit

Positive and significant *gca* effects for the character were displayed by L_3 (14.52) and L_5 (3.48) whereas L_1 (-13.03) and L_4 (-6.72) expressed significant negative values. Among testers, T_3 (7.30) and T_1 (-6.96) showed significant positive and negative *gca* effects respectively. Five hybrids *viz*., L_1 x T_1 (6.31), L_2 x T_3 (6.95), L_3 x T_1 (13.42), L_4 x T_2 (6.99) and L_5 x T_2 (11.79) displayed positive and significant *sca* values.

Negative *sca* effects were observed in six crosses *viz.*, L1 x T2 (-6.44), L_2 x T1 (-6.73), L_3 x T_2 (-12.12), L_4 x T_1 (-5.47), L_5 x T_1 (-7.53) and L_5 x T_3 (-4.25).

4.1.5.11 Hundred seed weight

Positive and significant *gca* effects were expressed by L_1 (0.03) and L_3 (0.04) whereas L_4 (-0.04) displayed negative value for the trait. Among testers, T_1 (0.07) exhibited significant and positive *gca* effect whereas negative values were noticed in T_2 (-0.05) and T_3 (-0.01). All hybrids except L_2 x T_1 exhibited significant *sca* effects. The values were positive in L_1 x T_1 (0.02), L_1 x T_3 (0.02), L_2 x T_2 (0.03), L_3 x T_1 (0.05), L_3 x T_3 (0.02), L_4 x T_2 (0.03), L_4 x T_3 (0.04) and L_5 x T_2 (0.05) and negative in L_1 x T_2 (-0.05), L_2 x T_3 (-0.04), L_3 x T_2 (-0.06), L_4 x T_1 (-0.07), L_5 x T_1 (-0.02) and L_5 x T_3 (-0.03).

4.1.5.12 Plant height

Among lines, significant positive *gca* effects for plant height were observed in L_2 (1.31) and L_5 (11.94) whereas significant negative *gca* effects were expressed by L_1 (-1.76) and L_3 (-11.02). Among the testers T_1 (1.44) and T_3 (0.90) exhibited significant positive *gca* effects and T_2 (-2.33) expressed significant negative value. The *sca* effects were positive and significant in L_1 x T_1 (5.47), L_1 x T_3 (6.00), L_2 x T_1 (6.76), L_3 x T_1 (2.36), L_3 x T_2 (2.61), L_4 x T_1 (3.34), L_5 x T_2 (9.26) and L_5 x T_3 (8.68). Significant negative *sca* effects were shown by L_1 x T_2 (-11.48), L_2 x T_3 (-5.23), L_3 x T_3 (-4.97), L_4 x T_3 (-4.48) and L_5 x T_1 (-17.94).

4.1.5.13 Duration of the crop

The lines L_1 (1.24), L_2 (6.02) and L_5 (1.91) exhibited significant positive *gca* effects for crop duration while L_3 (-4.53) and L_4 (-4.64) had significant negative values for the trait. Among testers T_3 (2.40) and T_2 (-2.33) expressed significant positive and negative *gca* effects respectively. Three hybrids showed significant positive *sca* values *viz.*, L_1 x T_1 (4.29),

L_5 x T_2 (5.89) and L_4 x T_1 (4.18). Five crosses *viz*., L_1 x T_2 (6.44), L_2 x T_3 (-1.96), L_3 x T_1 (-2.93), L_4 x T_3 (-5.96) and L_5 x T_1 (-7.04) had significant negative values for the trait.

4.1.5.14 Harvest index

For harvest index *gca* effect was significant and positive in L_4 (1.42) and L_5 (9.59) whereas significant and negative in L_1 (-3.69) and L_2 (-8.35). Among testers, T_2 (-1.13) alone exhibited significant *gca* effect. Six crosses exhibited significant positive *sca* values *viz*., L_1 x T_1 (5.40), L_1 x T_3 (10.75), L_2 x T_2 (6.30), L_3 x T_1 (3.57), L_3 x T_2 (6.24) and L_5 x T_2 (4.56). Five crosses *viz*., L_1 x T_2 (-16.14), L_2 x T_1 (-3.49), L_2 x T_3 (-2.80), L_3 x T_3 (-9.81) and L_5 x T_1 (-5.56) had significant negative values for this trait.

4.1.5.15 Capsaicin content

All the parents showed significant *gca* effect. Among lines, L5 alone showed significant positive *gca* effect whereas L_1 (-0.08), L_2 (-0.02), L_3 (-0.04) and L_4 (-0.02) showed significant negative values. Among testers T_3 (0.07) exhibited significant positive *gca* value and T_1 (-0.03) and T_2 (-0.05) had significant negative values. Five hybrids showed significant positive *sca* values *viz*., L_1 x T_3 (0.11), L_2 x T_1 (0.07), L_2 x T_3 (0.05), L_3 x T_1 (0.25) and L_5 x T_2 (0.28). Eight crosses *viz*., L_1 x T_1 (-0.06), L_1 x T_2 (-0.05), L_2 x T_2 (-0.12), L_3 x T_2 (-0.13), L_3 x T_3 (-0.12), L_4 x T_1 (-0.05), L_5 x T_1 (-0.21) and L_5 x T_3 (-0.07) had significant negative values for this trait.

4.1.5.16 Oleoresin content

Two lines, L_2 (0.50) and L_3 (0.36) recorded significant positive *gca* effects for oleoresin content whereas L4 (-0.67) exhibited significant negative *gca* effect. Among testers T_1 (0.62) and T_3 (0.48) recorded significant positive effects while significant negative effect was noticed for T_2 (-1.10). Six hybrids *viz*., L_1 x T_1 (0.93), L_2 x T_1 (1.23), L_3 x T_3

(2.20), L_4 x T_2 (1.93), L_5 x T_1 (0.91) and L_5 x T_2 (0.15) showed significant positive *sca* values. Eight crosses *viz*., L_1 x T_2 (-0.19), L_1 x T_3 (-0.75), L_2 x T_2 (-1.17), L_3 x T_1 (-1.48), L_3 x T_2 (-0.72), L_4 x T_1 (-1.59), L_4 x T_3 (-0.34) and L_5 x T_3 (-1.05) had significant negative values for the trait.

4.1.5.17 Vulnerability index

In leaf curl incidence, L_5 (-18.67) and L_2 (-9.78) exhibited significant negative *gca* effects, whereas significant positive values were expressed by L_3 (16.89) and L_4 (10.78). Among testers, T_3 (-6.22) alone expressed significant negative *gca* effect whereas significant positive value was displayed by T_1 (4.78).

Among hybrids, significant negative *sca* effects were recorded by L_1 x T_1 (-11.44), L_1 x T_3 (-7.11), L_2 x T_1 (-10.89) and L_5 x T_2 (-22.00). The crosses, L_1 x T_2 (18.56), L_2 x T_2 (5.78), L_2 x T_3 (5.11) and L_5 x T_1 (24.67) recorded positive significant effects

4.1.6 Proportional contribution of parents and hybrids

Proportional contribution of lines, testers and line x tester hybrids to total variance was estimated and presented in Table 13 and Fig. 2. Among different characters proportional contribution of lines ranged from 5.11 per cent for days to first flowering to 73.71 for number of secondary branches per plant. In testers proportional contribution varied from 0.83 per cent for harvest index to 49.94 per cent for hundred seed weight. In line x tester hybrids the range was from 17.21 per cent for number of secondary branches to 66.45 per cent for capsaicin content.

4.1.7 Genetic components of variance

The additive variance (σ^2a) and dominance variance (σ^2d) estimated are presented in Tables 14 and 15. The dominance variance was greater than additive variance for all the characters studied. When F=0, the additive to dominance variance ratio ranges from 0.004 (for harvest index) to 0.27 (for number of secondary branches per plant). Likewise when F=1,

Table 13. Proportional contribution of lines, testers and hybrids to the total variance

Sl. No.	Character	Line (%)	Tester (%)	Hybrids
1	Days to first flowering	5.11	32.99	61.90
2	Days to 50 per cent flowering	30.00	36.58	33.42
3	Number of primary branches	59.06	14.70	26.24
4	Number of secondary branches	73.71	9.08	17.21
5	Number of fruits per plant	36.77	11.91	51.32
6	Green fruit weight	46.63	15.50	37.86
7	Fruit yield per plant	44.54	13.04	42.42
8	Fruit length	61.03	3.29	35.68
9	Fruit girth	14.92	46.28	38.79
10	Number of seeds per fruit	50.30	19.34	30.35
11	Hundred seed weight	17.80	49.94	32.26
12	Plant height	48.20	2.49	49.31
13	Duration of the crop	45.43	10.15	44.42
14	Harvest index	44.15	0.83	55.02
15	Capsaicin content	22.85	10.70	66.45
16	Oleoresin content	8.19	28.63	63.17
17	Vulnerability index	54.13	6.79	39.07

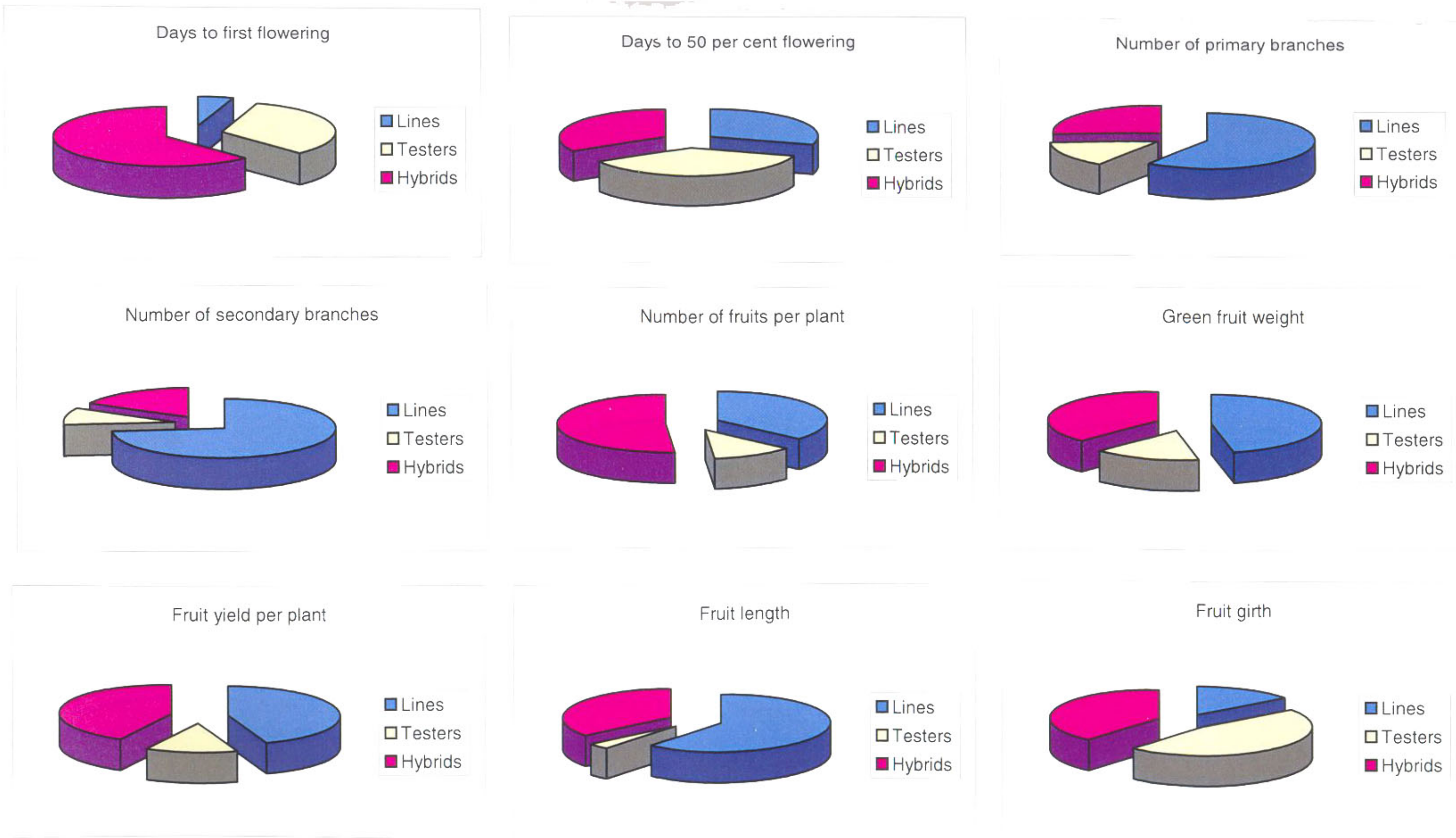


Fig. 2. Proportional contribution of parents and hybrids

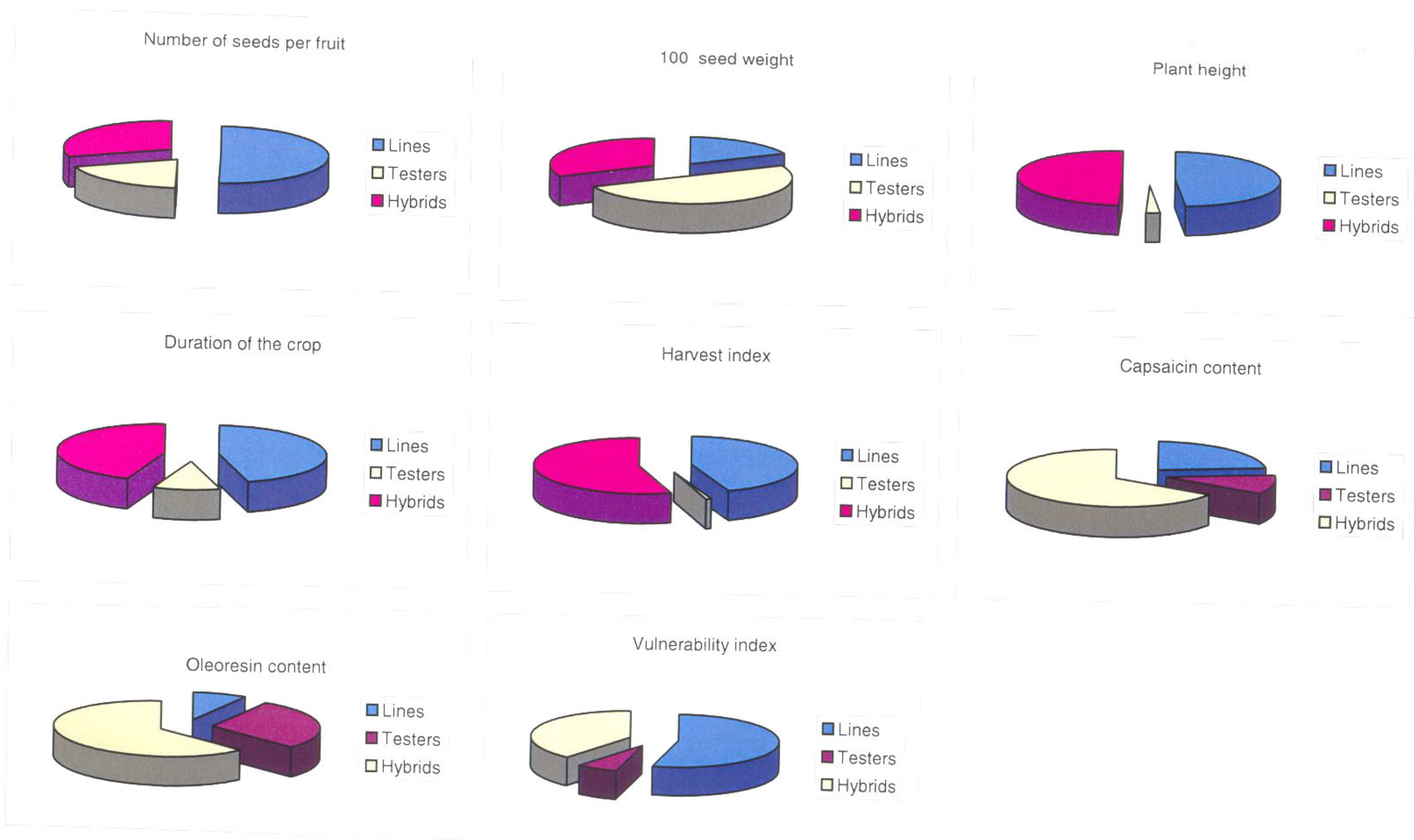


Fig. 2. Proportional contribution of parents and hybrids (Continued…)

Table 14. Genetic components of variance (when F = 0)

Sl. No.	Character	Additive variance $\sigma^2 a$	Dominance variance $\sigma^2 d$	$\sigma^2 a / \sigma^2 d$
1	Days to first flowering	0.41	47.78	0.01
2	Days to 50 per cent flowering	1.91	23.64	0.08
3	Number of primary branches	0.57	4.41	0.13
4	Number of secondary branches	13.08	48.86	0.27
5	Number of fruits per plant	2.39	184.50	0.01
6	Green fruit weight	0.15	2.79	0.05
7	Fruit yield per plant	441.31	11914.28	0.04
8	Fruit length	0.32	4.98	0.06
9	Fruit girth	0.03	0.57	0.05
10	Number of seeds per fruit	37.37	387.46	0.10
11	Hundred seed weight	0.001	0.011	0.09
12	Plant height	6.95	409.85	0.02
13	Duration of the crop	3.72	119.26	0.03
14	Harvest index	1.37	328.09	0.004
15	Capsaicin content	0.002	0.131	0.02
16	Oleoresin content	0.10	10.09	0.01
17	Vulnerability index	44.92	902.16	0.05

Table 15. Genetic components of variance (when F = 1)

Sl. No.	Character	Additive variance σ^2a	Dominance variance σ^2d	σ^2a / σ^2d
1	Days to first flowering	0.20	11.95	0.02
2	Days to 50 per cent flowering	0.95	5.91	0.16
3	Number of primary branches	0.28	1.10	0.25
4	Number of secondary branches	6.54	12.22	0.54
5	Number of fruits per plant	1.19	46.13	0.03
6	Green fruit weight	0.08	0.70	0.11
7	Fruit yield per plant	220.66	2978.57	0.07
8	Fruit length	0.16	1.24	0.13
9	Fruit girth	0.02	0.14	0.14
10	Number of seeds per fruit	18.68	96.86	0.19
11	Hundred seed weight	0.0005	0.0029	0.17
12	Plant height	3.48	102.46	0.03
13	Duration of the crop	1.86	29.81	0.06
14	Harvest index	0.68	82.02	0.008
15	Capsaicin content	0.001	0.033	0.03
16	Oleoresin content	0.05	2.52	0.02
17	Vulnerability index	22.46	225.54	0.10

additive to dominance variance ranges from 0.008 to 0.54 for the characters respectively.

4.1.8 Heterosis

Relative heterosis, heterobeltiosis and standard heterosis were estimated for fifteen hybrids with respect to seventeen characters and the results are furnished in the Table 16 and Fig. 3. Standard heterosis was calculated for each characters based on the standard ruling variety Jwalamukhi while it was estimated for vulnerability index over the check variety Pant C1 also.

4.1.8 1 Days to first flowering

Ten hybrids exhibited significant negative relative heterosis. They were L_1 x T_2 (-8.31), L_1 x T_3 (-9.98), L_2 x T_1 (-8.37), L_2 x T_2 (-3.41), L_3 x T_2 (-10.21), L_3 x T_3 (-10.91), L_4 x T_2 (-9.40), L_4 x T_3 (-12.47), L_5 x T_2 (-7.16) and L_5 x T_3 (-8.43). Significant negative heterobeltiostis was recorded by L_1 x T_2 (-7.21), L_1 x T_3 (-8.92), L_2 x T_1 (-7.92), L_3 x T_2 (-9.14), L_3 x T_3 (-9.86), L_4 x T_2 (-9.18), L_4 x T_3 (-10.15), L_5 x T_2 (-4.57), L_5 x T_3 (-3.55). Twelve hybrids *viz.*, L_1 x T_2 (-9.39), L_1 x T_3 (-8.92), L_2 x T_1 (-12.68), L_2 x T_2 (-7.04), L_3 x T_1 (-3.76), L_3 x T_2 (-11.27), L_3 x T_3 (-9.86), L_4 x T_1 (-3.29), L_4 x T_2 (-11.74), L_4 x T_3 (-12.68), L_5 x T_2 (-11.74) and L_5 x T_3 (-10.80) showed significant negative standard heterosis.

4.1.8.2 Days to 50 percent flowering

Significant negative relative heterosis was exhibited by 14 hybrids *viz.*, L_1 x T_1 (-3.43), L_1 x T_2 (-11.45), L_1 x T_3 (-10.92), L_2 x T_1 (-3.54), L_2 x T_2 (-4.23), L_2 x T_3 (-4.76), L_3 x T_1 (-7.10), L_3 x T_2 (-6.95), L_3 x T_3 (-4.84), L_4 x T_1 (-2.21), L_4 x T_2 (-13.14), L_4 x T_3 (-13.42), L_5 x T_2 (-5.54) and L_5 x T_3 (-8.62). Significant negative heterobeltiosis was recorded by L_1 x T_1 (-3.43), L_1 x T_2 (-10.87), L_1 x T_3 (-9.01), L_3 x T_1 (-6.90), L_3 x T_2 (-6.52), L_3 x T_3 (-2.59), L_4 x T_2 (-10.96), L_4 x T_3 (-8.68), L_5 x T_2 (-3.62) and L_5 x T_3 (-4.07). All the hybrids except L_5 x T_1 recorded negative and

Table 16. Estimation of percentage heterosis over mid, better and standard parents for various characters

Sl. No.	Hybrids	Days to first flowering			Days to 50 per cent flowering			No. of primary branches			No. of secondary branches		
		RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1.	$L_1 \times T_1$	1.20	3.43*	-0.94	-3.43**	-3.43**	-3.43**	30.99**	13.42**	55.00**	10.05	4.56	16.14*
2.	$L_1 \times T_2$	-8.31**	-7.21**	-9.39**	-11.45**	-10.87**	-12.02**	2.56	-16.67**	33.33**	-37.84**	-43.01**	-31.65**
3.	$L_1 \times T_3$	-9.98**	-8.92**	-8.92**	-10.92**	-9.01**	-9.01**	15.19**	-7.14	51.67**	-1.90	-8.94	6.33
4.	$L_2 \times T_1$	-8.37**	-7.92**	-12.68**	-3.54**	-0.46	-6.44**	-25.93**	-39.02**	-16.67*	-6.0	-21.94**	-13.29
5.	$L_2 \times T_2$	-3.41*	-1.98	-7.04**	-4.23**	-1.83	-7.72**	27.52**	-1.04	58.33**	-34.53**	-47.23**	-36.71**
6.	$L_2 \times T_3$	0.95	4.95**	-0.47	-4.76**	0.46	-5.58**	20.53**	-7.14	51.67**	-20.80*	-35.50**	-24.68**
7.	$L_3 \times T_1$	-1.68	0.49	-3.76*	-7.10**	-6.90**	-7.30**	-3.70	-20.73**	8.33	-29.43**	-45.01**	-38.92**
8.	$L_3 \times T_2$	-10.21**	-9.14**	-11.27**	-6.93**	-6.52**	-7.73**	-24.83**	-41.67**	-6.67	-35.30**	-50.92**	-41.14**
9.	$L_3 \times T_3$	-10.91**	-9.86**	-9.86**	-4.84**	-2.59*	-3.00**	29.80**	0.00	63.33**	-0.89	-24.12**	-11.39
10.	$L_4 \times T_1$	0.24	0.98	-3.29**	-2.21*	0.91	-5.15**	39.01**	19.51**	63.33**	15.37*	-4.84	5.70
11.	$L_4 \times T_2$	-9.40**	-9.18**	-11.74**	-13.14**	-10.96**	-16.31**	-8.39	-26.04**	18.33**	-5.44	-24.27**	-9.18
12.	$L_4 \times T_3$	-12.47**	-10.15**	-12.68**	-13.42**	-8.68**	-14.16**	35.03**	8.16*	76.67**	12.90*	-8.67	6.65
13.	$L_5 \times T_1$	7.23**	9.14**	0.94	2.64*	5.43**	0.00	49.33**	36.59**	86.67**	10.87	3.13	14.56*
14.	$L_5 \times T_2$	-7.16**	-4.57**	-11.74**	-5.54**	-3.62**	-8.58**	56.01**	33.33**	113.33**	38.91**	24.80**	49.68**
15.	$L_5 \times T_3$	-8.43**	-3.55*	-10.80**	-8.62**	-4.07**	-9.01**	56.63**	32.65**	116.67**	56.78**	42.55**	66.46**

Table 16. continued...

Sl. No.	Hybrids	Number of fruits per plant			Green fruit weight			Fruit yield per plant			Fruit length		
		RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1.	$L_1 \times T_1$	27.14**	16.49**	39.94**	-11.03*	-31.65**	-31.65**	32.56**	6.49	6.49	-8.10**	-14.06**	-14.06**
2.	$L_1 \times T_2$	-31.04**	-40.14**	-18.67**	-21.27**	-43.00**	-43.00**	-51.32**	-58.61**	-58.61**	-10.09**	-19.78**	-19.78**
3.	$L_1 \times T_3$	10.29	5.32	15.75**	32.56**	6.07	6.07	54.14**	30.21**	30.21**	-4.34	-10.94**	-10.94**
4.	$L_2 \times T_1$	5.35	4.23	27.92**	4.05	0.27	-41.99**	15.62**	2.20	-19.28**	17.60**	-17.60**	-28.28**
5.	$L_2 \times T_2$	-14.25**	-18.40**	10.88	50.61**	33.60**	-22.71**	37.67**	29.88**	2.58	19.23**	-13.84**	-32.41**
6.	$L_2 \times T_3$	14.03**	8.07	32.63**	6.07	4.15	-37.48**	34.15**	25.64**	-0.77	10.91**	-22.07**	-32.83**
7.	$L_3 \times T_1$	-4.02	-11.52*	25.97**	-22.90**	-33.12**	-51.17**	-20.77**	-37.44**	-34.48**	-11.00**	-30.37**	-39.39**
8.	$L_3 \times T_2$	-8.87*	-10.95*	26.79**	-21.45**	-36.64**	-53.73**	-27.06**	-39.14**	-36.26**	-27.84**	-41.31**	-53.96**
9.	$L_3 \times T_3$	-2.06	-13.23**	23.54**	-18.76**	-25.99**	-45.96**	-15.04**	-29.55**	-26.22**	-20.90**	-37.89**	-46.47**
10.	$L_4 \times T_1$	1.54	-3.42	28.57**	-11.08	-17.39*	-55.68**	2.17	-0.51	-36.30**	-30.87**	-34.91**	-43.35**
11.	$L_4 \times T_2$	7.91	6.81	45.13**	14.56	13.01	-47.98**	29.69**	24.12**	-13.06**	-12.09**	-12.98**	-31.73**
12.	$L_4 \times T_3$	17.44**	7.20	42.70**	-11.29	-21.63*	-52.96**	12.34*	8.32	-25.31**	-39.18**	-42.48**	-50.42**
13.	$L_5 \times T_1$	19.56**	2.84	23.54**	-28.36**	-39.44**	-52.96**	2.66	-3.20	-33.72**	-36.18**	-35.01**	-43.43**
14.	$L_5 \times T_2$	24.67**	2.03	38.64**	91.37**	50.85**	17.19**	169.99**	166.94**	86.97**	38.09**	37.12**	7.58**
15.	$L_5 \times T_3$	64.63**	47.12**	61.69**	51.53**	34.23**	4.20	180.41**	179.42**	92.67**	17.34**	11.33**	-4.04

Table 16. continued...

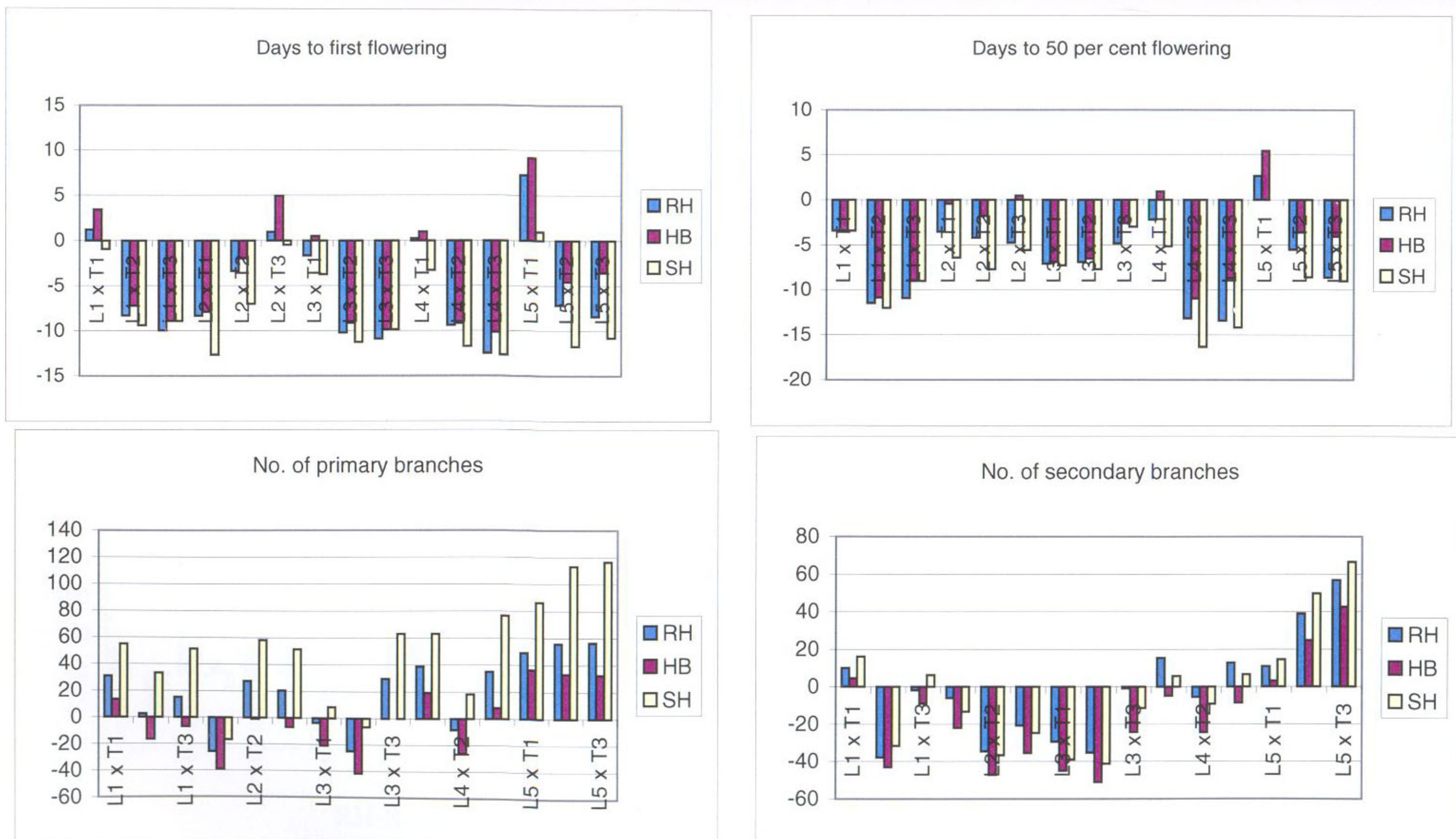
Sl. No.	Hybrids	Fruit girth			Number of seeds per fruit			Hundred seed weight			Plant height		
		RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1.	$L_1 \times T_1$	-20.19**	-37.07**	-37.07**	-5.25	-7.73	-7.73	1.34	-3.62*	6.83**	-0.92	-10.95**	11.67**
2.	$L_1 \times T_2$	5.46*	-22.42**	-22.42**	-8.86*	-19.20**	-19.21**	-10.28**	-25.22**	-25.22**	-36.19**	-41.18**	-30.27**
3.	$L_1 \times T_3$	3.26	-13.24**	-13.25**	15.80 **	7.36	7.36	-0.40	-6.75**	-6.75**	3.32	-3.36	11.66**
4.	$L_2 \times T_1$	-1.75	-23.30**	-21.15**	-18.25**	-31.24**	-4.49	4.28*	-11.50**	-1.90	24.01**	-3.91	20.51**
5.	$L_2 \times T_2$	-1.11	-27.88**	-25.86**	11.07**	-13.56**	20.08**	12.62**	4.89	-18.92**	2.48	-18.96**	-3.93
6.	$L_2 \times T_3$	0.08	-16.85**	-14.52**	31.74**	6.37	47.76**	-7.73**	-12.71**	-23.84**	2.81	-18.08**	-4.86
7.	$L_3 \times T_1$	24.59**	6.05	-12.87**	10.72**	-16.89**	57.11**	21.39**	2.55	13.66**	-13.09**	-30.93**	-13.37**
8.	$L_3 \times T_2$	32.41**	4.19	-14.40**	-8.61**	-35.62**	21.17**	4.12	-2.51	-25.49**	-17.39**	-32.93**	-29.30**
9.	$L_3 \times T_3$	14.84*	4.96	-13.76**	13.86**	-17.35**	56.23**	15.85**	8.67**	-5.20*	-25.61**	-39.12**	-20.49**
10.	$L_4 \times T_1$	5.17	-1.17	-35.16**	-12.82**	-13.42**	-17.96**	-13.67**	-27.89**	-20.07**	0.07	-12.28**	10.01**
11.	$L_4 \times T_2$	48.48**	27.57**	-16.31**	37.86**	25.95**	17.71**	8.49**	2.92	-23.50**	-8.07**	-17.41**	-2.08
12.	$L_4 \times T_3$	30.22**	27.90**	-12.99**	29.80**	24.22**	16.09**	5.09*	-2.68	-15.10**	-11.61**	-19.86**	-6.92**
13.	$L_5 \times T_1$	-6.97	-20.41**	-35.41**	-11.67**	-22.47**	-2.74	-5.37**	-15.47**	-6.30**	-10.97**	-26.62**	-7.97**
14.	$L_5 \times T_2$	42.80**	12.87**	-8.41*	43.79**	16.20**	45.76**	10.04**	-2.89	-15.33**	39.52**	17.61**	39.43**
15.	$L_5 \times T_3$	13.92**	4.71	-15.03**	23.36**	3.68	30.05**	-11.48**	-11.51**	-22.80**	46.67**	24.68**	44.80**

Table 16. continued...

Sl. No.	Hybrids	Duration of the crop			Harvest index			Capsaicin content			Oleoresin content		
		RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1.	$L_1 \times T_1$	-1.47**	-1.10	-1.10	2.97	-9.04**	-9.04**	-40.95**	-48.33**	-48.33**	4.50**	-7.85**	20.67**
2.	$L_1 \times T_2$	-8.27**	-8.27**	-8.27**	-41.42**	-43.45**	-43.45**	-53.03**	-56.94**	-48.33**	-9.63**	-12.18**	-6.92**
3.	$L_1 \times T_3$	-1.19	-0.92	-0.92	9.12**	-0.37	-0.374	5.04	-7.60*	21.67**	20.41**	3.04**	3.04**
4.	$L_2 \times T_1$	1.12	3.03**	0.00	-20.42**	-29.96**	-29.31**	79.10**	33.33**	0.00	8.81**	-2.20**	28.07**
5.	$L_2 \times T_2$	-0.37	1.14	-1.84*	-14.30**	-17.63**	-16.87**	-40.43**	-61.11**	-53.33**	-16.28**	-16.88**	-11.90**
6.	$L_2 \times T_3$	0.65	2.46**	-0.55	21.12**	-28.28**	-27.61**	42.57**	-8.87**	20.00**	30.17**	9.41**	14.30**
7.	$L_3 \times T_1$	-7.85**	-6.73**	-8.27**	0.56	-15.51**	-4.71	7.01*	-25.00**	40.00**	-18.60**	-23.31**	0.42
8.	$L_3 \times T_2$	-8.06**	-7.29**	-8.82**	-5.69*	-13.93**	-2.93	-72.83**	-77.68**	-58.33**	-17.81**	-21.29**	-8.86**
9.	$L_3 \times T_3$	-2.22**	-1.12	-2.76**	-22.27**	-32.67**	-24.06**	-52.88**	-59.82**	-25.00**	44.22**	16.43**	34.80**
10.	$L_4 \times T_1$	-4.06**	-2.99**	-4.41**	12.28**	6.98*	-9.35**	2.38	-4.44	-28.33**	-22.29**	-31.71**	-10.58**
11.	$L_4 \times T_2$	-6.30**	-5.60**	-6.99**	-2.25	-6.62*	-13.09**	-8.11	-29.17*	-15.00**	4.13**	0.79**	6.82**
12.	$L_4 \times T_3$	-8.22**	-7.28**	-8.64**	10.55**	9.15**	-7.50**	16.95*	-12.66**	15.00**	17.56**	0.95**	0.13**
13.	$L_5 \times T_1$	-6.81**	-5.95**	-6.99**	10.52**	0.29	-5.56*	1.18	-4.44	-28.33**	5.03**	-9.81**	18.11**
14.	$L_5 \times T_2$	-0.56	0.00	-1.10	14.69**	14.02**	7.37**	103.57**	58.33**	90.00**	-5.95**	-11.29**	-5.98**
15.	$L_5 \times T_3$	-0.83	0.00	-1.10	18.70**	11.41**	4.92	34.45**	1.27	33.33**	18.39**	4.03**	-2.26**

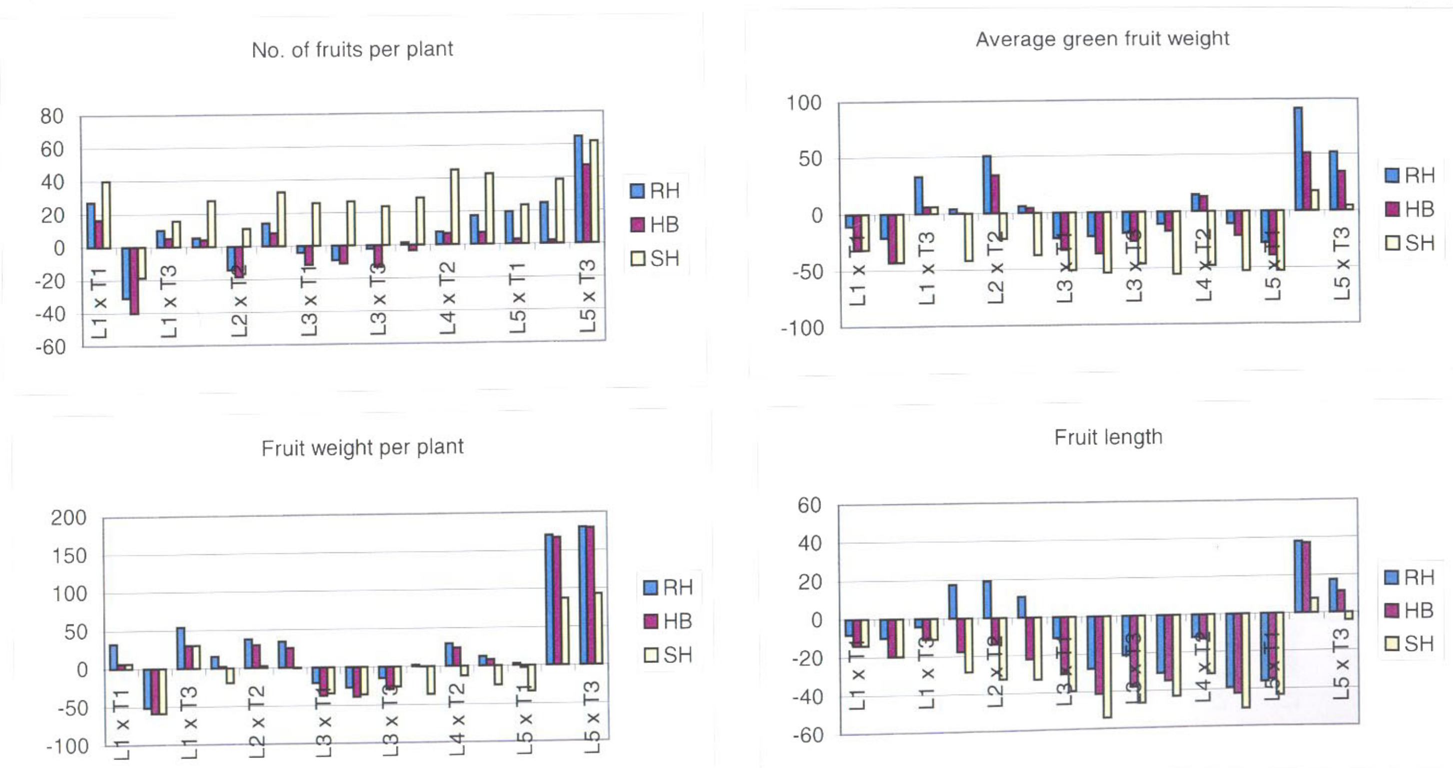
Table 16. continued...

Sl. No.	Hybrids	Vulnerability index			
		RH	HB	SH	
				Jwaiamukhi	PantC1
1.	$L_1 \times T_1$	28.30**	142.86**	-12.82**	78.94**
2.	$L_1 \times T_2$	108.33**	455.56**	28.21**	163.12**
3.	$L_1 \times T_3$	15.39**	130.77**	-23.08**	57.88**
4.	$L_2 \times T_1$	-9.68**	100.00**	-28.21**	57.36**
5.	$L_2 \times T_2$	26.32**	300.00**	-7.69	89.45**
6.	$L_2 \times T_3$	1.64	138.46**	-20.51**	63.15**
7.	$L_3 \times T_1$	63.33**	250.00**	25.64**	157.88**
8.	$L_3 \times T_2$	78.18**	444.44**	25.64**	157.88**
9.	$L_3 \times T_3$	52.54**	246.15**	15.39**	136.82**
10.	$L_4 \times T_1$	51.61**	235.71**	20.51**	147.33**
11.	$L_4 \times T_2$	50.88**	377.78**	10.26*	126.30**
12.	$L_4 \times T_3$	37.71**	223.08**	7.69	121.03**
13.	$L_5 \times T_1$	46.67**	214.29**	12.82**	131.54**
14.	$L_5 \times T_2$	-49.09**	55.56**	-64.10**	-23.33**
15.	$L_5 \times T_3$	-28.81**	51.54**	-46.15**	10.51



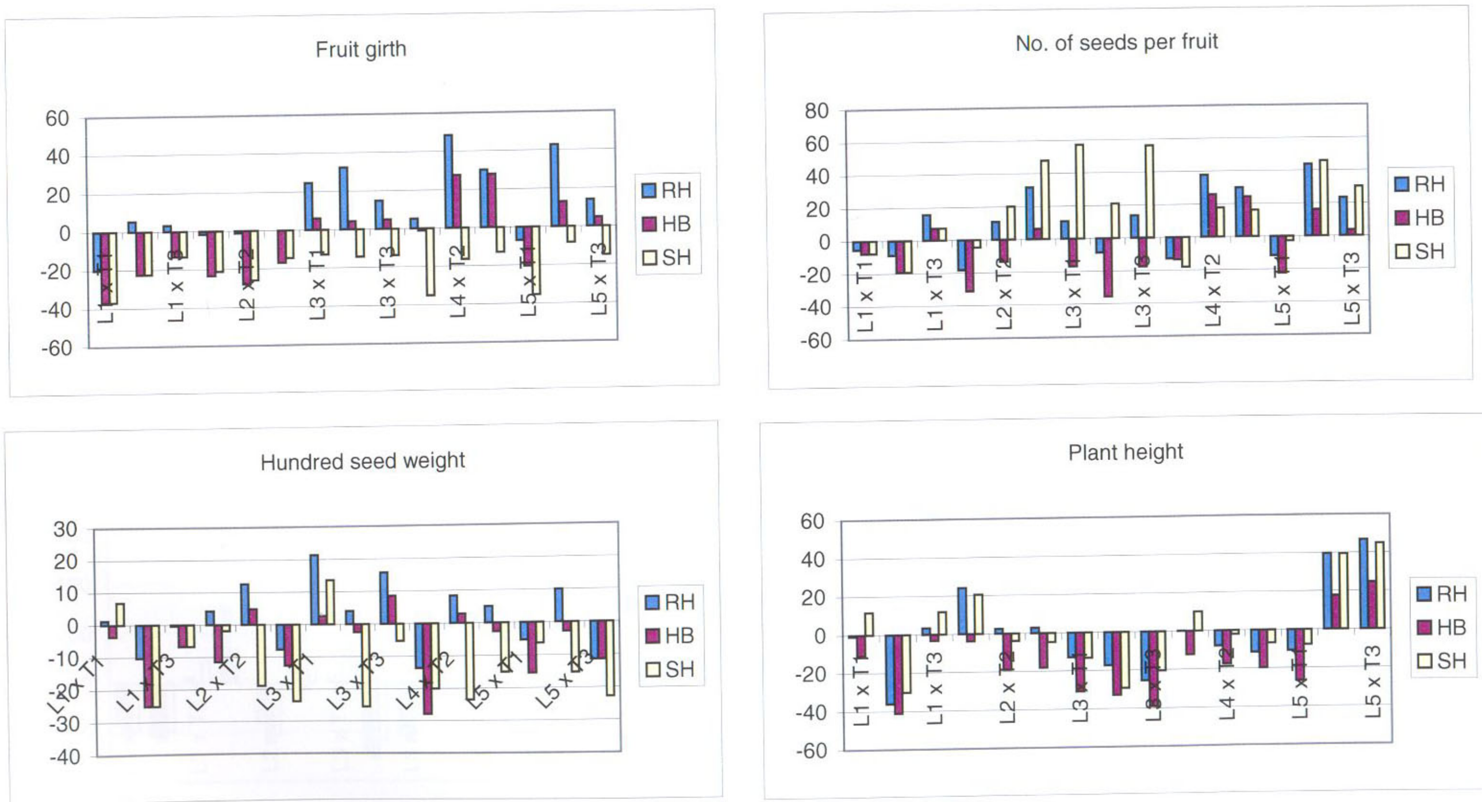
RH-Relative heterosis, HB-Heterobeltiosis, SH-standard heterosis

Fig. 3. Heterosis



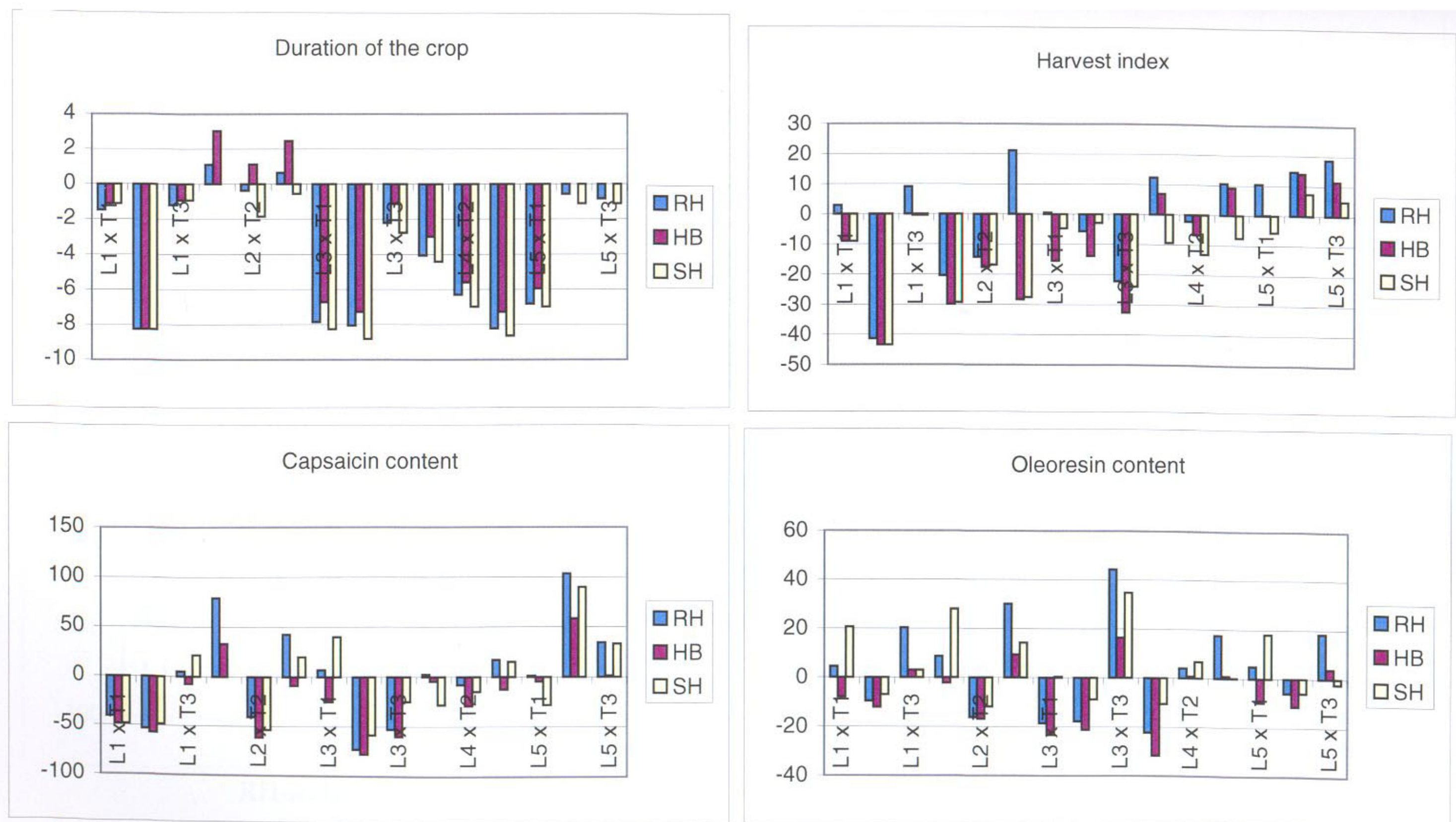
RH-Relative heterosis, HB-Heterobeltiosis, SH-standard heterosis

Fig. 3. Heterosis (continued…)



RH-Relative heterosis, HB-Heterobeltiosis, SH-standard heterosis

Fig. 3. Heterosis (continued…)



RH-Relative heterosis, HB-Heterobeltiosis, SH-standard heterosis

Fig. 3. Heterosis (continued…)

Fig. 3. Heterosis (continued…)

significant standard heterosis and among these L_4 x T_2 (-16.31) and L_3 x T_3 (-3.00) had the maximum and minimum negative values respectively.

4.1.8.3. Number of primary branches

Significant positive relative heterosis was exhibited by ten hybrids *viz.*, L_1 x T_1 (30.99), L_1 x T_3 (15.19), L_2 x T_2 (27.52), L_2 x T_3 (20.53), L_3 X T_3 (29.80), L_4 X T_1 (39.01), L_4 X T_3 (35.03), L_5 X T_1 (49.33), L_5 X T_2 (56.01) and L_5 X T_3 (56.63). Heterobeltiosis was significant and positive for L_1 x T_1 (13.42), L_4 x T1 (19.51), L_4 x T_3 (8.16), L_5 x T_1 (36.59), L_5 x T_2 (33.33) and L_5 x T_3 (32.65). Significant positive standard heterosis was exhibited L_1 x T_1 (55.00), L_1 x T_2 (33.33), L_1 x T_3 (51.67), L_2 x T_2 (58.33), L_2 x T_3 (51.67), L_3 x T_3 (63,33), L_4 x T1 (63.33), L_4 x T_2 (18.33), L_4 x T_3 (76.67), L_5 x T_1 (86.67), L_5 x T_2 (113.33) and L_5 x T_3 (116.67).

4.1.8.4 Number of secondary branches

Out of the nine hybrids exhibiting significant relative heterosis, only four hybrids *viz.*, L_4 x T_1 (15.37), L_4 x T_3 (12.90), L_5 x T_2 (38.91) and L_5 x T_3 (56.78) had positive values. Only two hybrids exhibited significant positive heterobeltiosis *viz.*, L_5 x T_2 (24.80) and L_5 x T_3 (42.55). The hybrids L_1 x T_1 (16.14), L_5 x T_1 (14 x.56), L_5 x T_2 (49.68) and L_5 x T_3 (66.46) expressed significant positive standard heterosis.

4.1.8.5 Number of fruits per plant

Significant positive relative heterosis were observed for L_1 x T_1 (27.14), L_2 x T_3 (14.03), L_4 x T_3 (17.44), L_5 x T_1 (19.56), L_5 x T_2 (24.67) and L_5 x T_3 (64.63). Only two hybrids *viz.*, L_1 x T_1 (16.49) and L_5 x T_3 (47.12) exhibited significant positive heterobeltiosis. All the hybrids except L_1 x T_2 and L_2 x T_2 showed significant positive standard heterosis. The highest significant standard heterosis was noticed for hybrid L_5 x T_3 (61.69).

4.1.8.6 Green fruit weight

Relative heterosis was positively significant for four hybrids *viz.*, $L_1 \times T_3$ (32.56), $L_2 \times T_2$ (50.61), $L_5 \times T_2$ (91.37) and $L_5 \times T_3$ (51.53). The hybrids $L_2 \times T_2$ (33.60), $L_5 \times T_2$ (50.85) and $L_5 \times T_3$ (34.23) had significant positive heterobeltiosis. Though thirteen hybrids showed significant standard heterosis only the hybrid $L_5 \times T_2$ (17.19) was in positive direction.

4.1.8.7 Fruit yield per plant

Nine hybrids recorded significant positive relative heterosis. They were $L_1 \times T_1$ (32.56), $L_1 \times T_3$ (54.14), $L_2 \times T_1$ (15.62), $L_2 \times T_2$ (37.67), $L_2 \times T_3$ (34.15), $L_4 \times T_2$ (29.69), $L_4 \times T_3$ (12.34), $L_5 \times T_2$ (169.99) and $L_5 \times T_3$ (180.41). The hybrids $L_1 \times T_3$ (30.21), $L_2 \times T_2$ (29.88), $L_2 \times T_3$ (25.64), $L_4 \times T_2$ (24.12), $L_5 \times T_2$ (166.94) and $L_5 \times T_3$ (179.42) expressed significant positive heterobeltiosis. Though twelve hybrids showed significant standard heterosis only three hybrids $L_1 \times T_3$ (30.21), $L_5 \times T_2$ (86.97) and $L_5 \times T_3$ (92.67) exhibited positive values.

4.1.8.8 Fruit length

All the hybrids except $L_1 \times T_3$ showed significant relative heterosis. Among these, only five hybrids *viz.*, $L_2 \times T_1$ (17.6), $L_2 \times T_2$ (19.23), $L_2 \times T_3$ (10.91), $L_5 \times T_2$ (38.09) and $L_5 \times T_3$ (17.34) had desirable positive and significant heterosis. Only two hybrids, $L_5 \times T_2$ (37.12) and $L_5 \times T_3$ (11.33) showed significant positive heterobeltiosis. Significant standard heterosis was expressed by the hybrid $L_5 \times T_2$ (7.58) alone.

4.1.8.9 Fruit girth

Relative heterosis was significant and positive for eight hybrids and the highest value and minimum value was recorded by $L_5 \times T_2$ (42.80) and $L_1 \times T_2$ (5.46). Three hybrids *viz.*, $L_4 \times T_2$ (27.57), $L_4 \times T_3$ (27.90) and $L_5 \times T_2$ (12.87) possessed significant positive heterobeltiosis. Though all the hybrids showed significant standard heterosis all of them were negative.

4.1.8.10 *Number of seeds per fruit*

All the hybrids except L_1 x T_1 expressed significant relative heterosis. Among these relative heterosis was significant and positive for nine hybrids *viz*., L_1 x T_3 (15.80), L_2 x T_2 (11.07), L_2 x T_3 (31.74), L_3 x T_1 (10.72), L_3 x T_3 (13.86), L_4 x T_2 (37.86), L_4 x T_3 (29.80), L_5 x T_2 (43.79) and L_5 x T_3 (23.36). Three hybrids *viz*., L_4 x T_2 (25 .95), L_4 x T_3 (24.22) and L_5 x T_2 (16.20) expressed significant positive heterobeltiosis. Significant and positive standard heterosis was recorded for L_2 x T_2 (20.08), L_2 x T_3 (47.76), L_3 x T_1 (57.11), L_3 x T_2 (21.17), L_3 x T_3 (56.23), L_4 x T_2 (17.71), L_4 x T_3 (16.09), L_5 x T_2 (45.76) and L_5 x T_3 (30.05).

4.1.8.11 *Hundred seed weight*

Relative heterosis was significant and positive for seven hybrids *viz*., L_2 x T_1 (4.28), L_2 x T_2 (12.62), L_3 x T_1 (21.39), L_3 x T_3 (15.85), L_4 x T_2 (8.49), L_4 x T_3 (5.09) and L_5 x T_2 (10.04). The hybrid L_3 x T_3 (8.67) alone expressed significant positive heterobeltiosis. Significant standard heterosis was recorded for only one hybrid L_1 x T_1 (6.83).

4.1.8.12 *Plant height*

Significant and positive relative heterosis was noticed for L_2 x T_1 (24.01), L_5 x T_2 (39.52) and L_5 x T_3 (46.67). Only two hybrids *viz*., L_5 x T_2 (17.61) and L_5 x T_3 (24.68) recorded positive and significant heterobeltiosis. Significant positive standard heterosis was expressed by L_1 x T_1 (11.67), L_1 x T_3 (11.66), L_2 x T_1 (20.51), L_4 x T_1 (10.01), L_5 x T_2 (39.43) and L_5 x T_3 (44.80).

4.1.8.13 *Duration of the crop*

Relative heterosis was significant and negative for nine hybrids *viz*., L_1 x T_1 (-1.47), L_1 x T_2 (-8.27), L_3 x T_1 (-7.85), L_3 x T_2 (-8.06), L_3 x T_3 (-2.22), L_4 x T_1 (-4.06), L_4 x T_2 (-6.30), L_4 x T_3 (-8.22) and L_5 x T_1 (-6.81). Significant and negative heterobeltiosis was recorded by L_1 x T_2 (-8.27), L_3 x T_1 (-6.73), L_3 x T_2 (-7.29), L_4 x T_1 (-2.99), L_4 x T_2 (-5.60), L_4

x T_3 (-7.28) and L_5 x T_1 (-5.95). Nine hybrids *viz.*, L_1 x T_2 (-8.27), L_2 x T_2 (-1.84), L_3 x T_1 (-8.27), L_3 x T_2 (-8.82), L_3 x T_3 (-2.76), L_4 x T_1 (-4.41), L_4 x T_2 (-6.99), L_4 x T_3 (-8.64) and L_5 x T_1 (-6.99) had significant and negative standard heterosis.

4.1.8.14 Harvest index

Significant and positive relative heterosis was recorded by L_1 x T_3 (9.12), L_2 x T_3 (21.12), L_4 x T_1 (12.28), L_4 x T_3 (10.55), L_5 x T_1 (10.52), L_5 x T_2 (14.69) and L_5 x T_3 (18.70). Out of the thirteen hybrids exhibiting significant heterobeltiosis only four hybrids *viz.*, L_4 x T_1 (6.98), L_4 x T_3 (9.15), L_5 x T_2 (14.02), and L_5 x T_3 (11.41) had positive values. Only one hybrid L_5 x T_2 showed significant positive standard heterosis.

4.1.8.15 Capsaicin content

Significant positive relative heterosis was recorded by L_2 x T_1 (79.10), L_2 x T_3 (42.57), L_3 x T_1 (7.01), L_4 x T_3 (16.95), L_5 x T_2 (103.57) and L_5 x T_3 (34.45). Only two hybrids *viz.*, L_2 x T_1 (33.33) and L_5 x T_2 (58.33) expressed significant positive heterobeltiosis. Six hybrids L_1 x T_3 (21.67), L_2 x T_3 (20.00), L_3 x T_1 (40.00), L_4 x T_3 (15.00), L_5 x T_2 (90.0) and L_5 x T_3 (33.33) recorded significant positive standard heterosis.

4.1.8.16 Oleoresin content

All the hybrids showed significant relative heterosis and heterobeltiosis. Among these nine hybrids *viz.*, L_1 x T_1 (4.50), L_1 x T_3 (20.41), L_2 x T_1 (8.81), L_2 x T_3 (30.17), L_3 x T_3 (44.22), L_4 x T_2 (4.13), L_4 x T_3 (17.56), L_5 x T_1 (5.03) and L_5 x T_3 (18.39) expressed significant positive relative heterosis whereas, only six hybrids *viz.*, L_1 x T_3 (3.04), L_2 x T_3 (9.41), L_3 x T_3 (16.43), L_4 x T_2 (0.79), L_4 x T_3 (0.95) and L_5 x T_3 (4.03) showed significant positive heterobeltiosis. Significant and positive standard heterosis was exhibited by L_1 x T_1 (20.67), L_1 x T_3 (3.04), L_2 x T_1 (28.07), L_2 x T_3 (14.30), L_3 x T_3 (34.80), L_4 x T_2 (6.82), L_4 x T_3 (0.13) and L_5 x T_1 (18.11).

4.1.8.17 Vulnerability index

Significant negative relative heterosis was exhibited by three hybrids *viz.*, L_2 x T_1 (-9.68), L_5 x T_2 (-49.09) and L_5 x T_3 (-28.81). None of the hybrids recorded significant negative heterobeltiosis. Six hybrids *viz.*, L_1 x T_1 (-12.82), L_1 x T_3 (-23.08), L_2 x T_1 (-28.21), L_2 x T_3 (-20.51), L_5 x T_2 (-64.10), L_5 x T_3 (-46.15) showed significant negative standard heterosis. The hybrids L_5 x T_2 (-23.33) alone had significant desirable standard heterosis when Pant C1 was used as check.

4.2 GENERATION MEAN ANALYSIS

Generation mean analysis (developed by Hayman, 1958 and Jinks and Jones, 1958) is based on six different generation of a cross namely parents, their F_1, F_2 and backcrosses ($B_1 = F_1$ x P_1 and $B_2 = F_1$ x P_2). This analysis is used for the estimation of genetic components of variation in the presence of epistasis or non-allelic interaction. In the present case generation mean analysis was done using two superior F_1 hybrids L_5 x T_2 (cross 1) and L_5 x T_3 (cross 2), their respective parents and the backcrosses and F_2 generations.

The results of generation mean analysis are presented in Table 17.

4.2.1 Days to first flowering

Among the generation, the lowest and the highest mean were recorded respectively by B_2 (59.00) and P_2 (67.33) in cross 1 and B_1 (60.67) and P_2 (70.67) in cross 2.

Significance of scale A in cross 2 and scale B in cross 1 indicated the presence of non-allelic interactions. Scale C was non significant in both the crosses. Significance of scale D was observed for cross 1.

Additive effect was found to be insignificant in both the crosses. Negative and significant dominance effect (h) was observed for both the crosses. Of the interaction effects significant additive x additive (i) additive x dominance (j) and dominance x dominance (l) effects were

Table 17. Generation means (±SE), scale values (± SE) and estimates of genetic components (± SE) in two selected crosses of chilli (*Capsicum annuum* L.)

	Days to first flowering		Days to 50 % flowering		No. of primary branches		No. of secondary branches		No. of fruits per plant		Green fruit weight	
	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2
Generation means.												
P_1	65.33 ±0.88	65.33 ±0.88	71.33 ±1.20	71.33 ±1.20	4.40 ±0.16	4.40 ±0.16	21.67 ±0.55	21.67 ±0.55	36.53 ±0.58	36.53 ±0.58	3.59 ±0.08	3.59 ±0.08
P_2	67.33 ±0.67	70.67 ±0.88	72.33 ±1.67	79.67 ±0.88	6.13 ±0.17	6.27 ±0.15	25.07 ±0.51	24.13 ±0.49	54.73 ±0.81	45.53 ±0.55	2.10 ±0.04	2.50 ±0.05
F_1	61.00 ±0.58	61.00 ±1.15	68.00 ±1.15	68.00 ±0.58	8.00 ±0.13	7.93 ±0.21	30.87 ±0.42	33.87 ±0.44	57.20 ±0.42	66.13 ±0.31	5.05 ±0.03	4.53 ±0.05
F_2	66.00 ±1.15	65.00 ±1.53	71.67 ±1.45	68.67 ±0.88	4.13 ±0.13	5.08 ±0.11	16.20 ±0.29	21.71 ±0.29	36.58 ±0.51	48.76 ±0.56	2.63 ±0.09	4.11 ±0.13
B_1	61.33 ±0.88	60.67 ±0.88	68.33 ±0.88	68.33 ±1.20	4.38 ±0.16	6.62 ±0.19	19.64 ±0.50	21.71 ±0.39	43.51 ±0.64	44.51 ±0.80	2.69 ±0.07	4.59 ±0.16
B_2	59.00 ±1.15	64.00 ±1.53	66.67 ±1.76	67.33 ±0.88	4.00 ±0.15	5.73 ±0.14	18.18 ±0.47	22.29 ±0.39	43.96 ±0.59	43.98 ±0.74	2.80 ±0.09	4.81 ±0.27
Scales												
A	-3.67 ±2.05	-5.00* ±2.29	-2.67 ±2.43	-2.67 ±2.75	-3.64** ±0.40	0.91 ±0.47	-13.24** ±1.22	-12.11** ±1.05	-6.71** ±1.47	-13.64** ±1.72	-3.26** ±0.17	1.06** ±0.33
B	-10.33** ±2.47	-3.67 ±3.38	-7.00 ±4.07	-13.00** ±2.05	-6.13** ±0.38	-2.73** ±0.37	-19.58** ±1.16	-13.42** ±1.01	-24.02** ±1.50	-23.71** ±1.61	-1.55** ±0.19	2.58** ±0.54
C	9.33 ±4.89	2.00 ±6.65	7.00 ±6.58	-12.33** ±4.00	-10.00** ±0.65	-6.22** ±0.63	-43.67** ±1.61	-26.38** ±1.62	-59.36** ±2.42	-19.31** ±2.45	-5.27** ±0.38	1.28* ±0.53
D	11.67** ±2.73	5.33 ±3.53	8.33* ±3.51	1.67 ±2.31	-0.11 ±0.33	-2.20** ±0.32	-5.42** ±0.90	-0.42 ±0.80	-14.31** ±1.35	9.02** ±1.56	-0.23 ±0.22	-1.18** ±0.40
Genetic components												
m	66.00** ±1.15	65.00** ±1.53	71.67** ±1.45	68.67** ±0.88	4.13** ±0.13	5.08** ±0.11	16.20** ±0.29	21.79** ±0.29	36.58** ±0.51	48.76** ±0.56	2.63** ±0.09	4.11** ±0.13
d	2.33 ±1.45	-2.33 ±1.76	1.67 ±1.97	1.00 ±1.49	0.38 ±0.22	9.89** ±0.24	1.47* ±0.69	-0.58 ±0.55	-0.44 ±0.87	0.53 ±1.09	-0.11 ±0.12	-0.21 ±0.31
h	-28.67** ±5.52	-17.67* ±7.18	-20.5* ±7.19	-10.83* ±4.71	2.96** ±0.70	7.00** ±0.68	18.34** ±1.88	11.81** ±1.69	40.19** ±2.77	7.06* ±3.16	2.66** ±0.44	3.86** ±0.81
i	-23.33** ±5.46	-10.67 ±7.06	-16.67* ±7.02	-3.33 ±4.62	0.22 ±0.67	4.40** ±0.63	10.84** ±1.79	0.84 ±1.59	28.62** ±2.70	18.04** ±3.12	0.45 ±0.44	2.37** ±0.81
j	3.33* ±1.55	-0.67 ±1.87	2.17 ±2.22	5.17** ±1.67	1.24** ±0.25	1.82** ±0.26	3.17** ±0.79	0.66 ±0.66	8.66** ±1.01	5.03** ±1.15	-0.85** ±0.13	-0.76** ±0.31
l	37.33** ±7.59	19.33* ±9.70	26.33* ±10.27	19.00** ±7.18	9.56** ±1.09	-2.58* ±-1.14	21.98** ±3.20	24.69** ±2.73	2.11 ±4.26	55.40** ±4.99	4.36** ±0.61	-6.01** ±1.35

Table 17. continued...

	Fruit yield per plant		Fruit length		Fruit girth		No. of seeds per fruit		Hundred seed weight		Plant height	
	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2
Generation means												
P_1	99.33 ±1.46	99.33 ±1.46	6.03 ±0.06	6.03 ±0.06	4.31 ±0.05	4.31 ±0.05	66.33 ±0.41	66.33 ±0.41	0.5233 ±0.0047	0.5233 ±0.0047	40.85 ±0.41	40.83 ±0.41
P_2	93.37 ±1.55	92.54 ±1.41	6.25 ±0.08	6.74 ±0.10	2.57 ±0.04	3.43 ±0.04	40.67 ±0.57	45.87 ±0.44	0.3929 ±0.0039	0.5179 ±0.0042	58.40 ±0.42	58.67 ±0.63
F_1	267.13 ±1.53	269.95 ±1.33	8.61 ±0.04	7.43 ±0.05	4.63 ±0.05	4.15 ±0.03	76.33 ±0.63	67.47 ±0.83	0.5118 ±0.0069	0.4558 ±0.0022	68.83 ±0.69	70.70 ±0.33
F_2	77.93 ±5.41	166.25 ±9.20	6.05 ±0.10	6.22 ±0.13	3.25 ±0.06	4.23 ±0.07	39.06 ±1.19	68.16 ±1.65	0.4431 ±0.0121	0.4709 ±0.0067	46.71 ±0.48	51.87 ±0.71
B_1	115.70 ±13.95	156.33 ±14.35	5.90 ±0.15	5.58 ±0.22	3.81 ±0.13	5.33 ±0.15	58.04 ±2.31	72.51 ±3.22	0.3923 ±0.0119	0.4604 ±0.0090	46.34 ±0.62	55.96 ±0.78
B_2	106.32 ±11.39	176.09 ±14.80	6.55 ±0.15	6.37 ±0.19	3.54 ±0.08	4.59 ±0.13	49.31 ±2.11	67.67 ±2.48	0.4164 ±0.0156	0.4829 ±0.0143	50.67 ±0.76	61.52 ±1.38
Scales												
A	-135.06** ±27.99	-56.62* ±28.77	-2.84** ±0.30	-2.30** ±0.44	-1.31** ±0.27	2.21** ±0.31	-26.58** ±4.67	11.22 ±6.50	-0.2505** ±0.0252	-0.0184 ±0.0383	-16.99** ±1.48	0.38 ±1.66
B	-147.86** ±22.88	-10.31 ±29.67	-1.75** ±0.31	-1.43** ±0.40	-0.14 ±0.18	1.60** ±0.27	-18.38** ±4.31	22.00** ±5.05	-0.0719* ±0.0322	-0.0080 ±0.0291	-25.88** ±1.72	-6.32* ±2.86
C	-415.27** ±21.94	-66.79 ±36.95	-5.38** ±0.43	-2.75** ±0.53	-3.16** ±0.29	0.88** ±0.29	-103.44** ±4.98	25.49** ±6.83	-0.1674** ±0.0507	-0.0694* ±0.0279	-50.05** ±2.45	-33.43** ±3.00
D	-66.17** ±21.01	0.07 ±27.63	-0.35 ±0.29	0.49 0.38	-0.86** ±0.20	-1.47** ±0.24	-29.24** ±3.93	-3.87 ±5.23	0.0775* ±0.0311	-0.0015 ±0.0273	-3.58** ±1.38	-13.74** ±2.15
Genetic components												
m	77.93** ±5.41	166.25** ±9.20	6.05** ±0.10	6.22** ±0.13	3.25** ±0.06	4.23** ±0.07	39.06** ±1.19	68.16** ±1.65	0.4430** ±0.2131	-0.4710** ±0.0067	46.71** ±0.48	51.87** ±0.71
d	9.38 ±18.01	-19.76 ±20.62	-0.65** ±0.21	-0.79** ±0.29	0.28 ±0.15	0.74** ±0.20	8.76** ±3.13	4.84 ±4.06	-0.0240 ±0.0196	-0.0230 ±0.2380	-4.33** ±0.98	5.56** ±1.59
h	303.13** ±42.06	173.87** ±55.29	3.16** ±0.59	0.07 ±0.77	2.90** ±0.41	3.21** ±0.49	81.32** ±7.90	19.10 ±10.5	-0.1010 ±0.0627	-0.0620 ±0.0548	26.37** ±2.85	48.42** ±4.29
i	132.35** ±42.02	-0.15 ±55.27	0.69 ±0.59	-0.98 ±0.77	1.71** ±0.40	2.93** ±0.49	58.49** ±7.86	7.73 ±10.46	-0.1550* ±0.0623	0.0030 ±0.0546	7.17** ±2.75	27.48** ±4.26
j	6.40 ±18.04	-23.16 ±20.64	-0.55* ±0.21	-0.44 ±0.30	-0.59** ±0.16	0.30 ±0.20	-4.10 ±3.15	-5.39 ±4.07	-0.0890** ±0.0198	-0.0250 ±0.0240	4.45** ±1.02	3.35* ±1.64
l	150.58* ±75.32	67.08 ±90.37	3.89** ±0.94	4.70** ±1.27	-0.26 ±0.68	-6.74** ±0.86	-13.53 ±13.46	-40.96* ±17.63	0.4770** ±0.0933	0.0630 ±0.0992	35.71** ±4.62	-21.54** ±7.04

Table 17. continued...

	Duration of the crop		Harvest index		Capsaicin content		Oleoresin content		Leaf curl incidence (VI)	
	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2	Cross 1	Cross 2
Generation means										
P_1	177.87 ±0.26	177.87 ±0.26	62.70 ±0.65	62.70 ±0.65	0.3556 ±0.0056	0.3556 ±0.0056	9.79 ±0.08	9.79 ±0.08	65.00 ±2.89	65.00 ±2.89
P_2	180.6 ±0.16	182.13 ±0.19	62.16 ±0.38	55.99 ±0.47	0.4756 ±0.0073	0.5133 ±0.0058	10.88 ±0.05	7.91 ±0.08	16.67 ±1.67	18.33 ±1.67
F_1	178.47 ±0.13	178.47 ±0.13	72.25 ±0.39	70.54 ±0.44	0.7467 ±0.0137	0.5089 ±0.0021	9.64 ±0.09	10.06 ±0.05	21.67 ±1.67	31.67 ±1.67
F_2	168.59 ±0.45	182.11 ±0.31	48.94 ±0.56	55.84 ±0.60	0.3527 ±0.0049	0.5067 ±0.0086	8.96 ±0.10	8.98 ±0.13	31.67 ±0.96	41.39 ±2.65
B_1	176.67 ±0.28	182.00 ±0.41	59.68 ±0.61	57.29 ±0.76	0.3093 ±0.0112	0.4800 ±0.0120	9.68 ±0.39	8.37 ±0.17	21.66 ±1.67	41.11 ±2.94
B_2	175.64 ±0.40	180.69 ±0.57	60.20 ±0.65	58.76 ±1.03	0.3333 ±0.0112	0.4707 ±0.0070	9.87 ±0.14	9.38 ±0.37	17.22 ±2.00	38.33 ±5.09
	Scales									
A	-3.00** ±0.64	7.67** ±0.87	-15.59** ±1.43	-18.65** ±1.72	-0.4836** ±0.0268	0.0956** ±0.0275	-0.08 ±0.79	-3.11** ±0.35	-43.34** ±4.71	-14.44* ±6.76
B	7.78** ±0.82	0.78 ±1.17	-14.00** ±1.40	-9.00** ±2.16	-0.5556** ±0.0272	-0.0809** ±0.0194	-0.79** ±0.30	0.80 ±0.75	-3.89 ±4.65	26.66* ±10.45
C	-41.04** ±1.85	11.51** ±1.29	-73.58** ±2.47	-36.42** ±2.68	-0.9138** ±0.0351	0.1400** ±0.0429	-4.11** ±0.45	1.89** ±0.55	1.67 ±6.08	18.88 ±11.59
D	-15.13** ±1.03	1.53 ±0.93	-21.99** ±1.42	-4.38* ±1.76	-0.0627** ±0.0186	0.0627** ±0.0222	-1.63** ±0.46	0.21 ±0.49	24.45** ±3.24	3.33 ±7.91
Genetic components										
m	168.59** ±0.45	182.11** ±0.31	48.94** ±0.56	55.84** ±0.60	-0.353** ±0.0049	0.5070** ±0.0086	8.96** ±0.10	8.98* ±0.13	31.67** ±0.96	41.39** ±2.65
d	1.02* ±0.49	1.31 ±0.70	-0.53 ±0.89	-1.47 ±1.29	-0.024 ±0.0158	0.0090 ±0.0139	0.19 ±0.42	-1.01* ±0.41	4.44 ±2.61	2.78 ±5.88
h	29.50** ±2.06	-4.60* ±1.88	53.81** ±2.90	19.96** ±3.57	0.206** ±0.040	-0.051 ±0.0462	2.56** ±0.93	0.80 ±0.98	68.07** ±6.89	-16.66 ±16.00
i	30.27** ±2.05	-3.07 ±1.87	43.99** ±2.85	8.76* ±3.52	0.124** ±0.0373	-0.125** ±0.0444	3.26** ±0.92	-0.41 ±0.98	-48.9** ±6.48	-6.66 ±15.83
j	2.39** ±0.51	3.44** ±0.72	-0.80 ±0.96	-4.83** ±1.35	0.036* ±0.0165	0.088** ±0.0145	0.36 ±0.42	-1.95** ±0.41	-19.72** ±3.09	-20.55** ±6.11
l	-19.49** ±2.69	-5.38 ±3.10	-14.4** ±4.33	18.9** ±5.80	1.164** ±0.0723	0.111 ±0.0703	-2.39 ±1.73	2.72 ±1.72	96.13** ±12.07	5.56 ±26.22

expressed by cross 1. Significant dominance x dominance (l) effect was noticed in cross 2.

4.2.2 Days to 50 per cent flowering

Among the generation, the lowest and the highest means were recorded by B_2 (66.67 in cross 1 and 67.33 in cross 2) and P_2 (72.33 in cross 1 and 79.67 in cross 2) in both the crosses.

Scale B and C were significant in cross 2 whereas significance of scale D was observed for cross 1.

Additive effect was found to be insignificant in both the crosses. Significance was observed for dominance effect in both the cross, additive x additive (i) interaction in cross 1 and additive x dominance (j) in cross 2. The dominance x dominance (l) interaction was significant and positive in both the crosses.

4.2.3 Number of primary branches

In both the crosses, the number of primary branches was the highest for F_1 (8.00 in cross 1 and 7.93 in cross 2) hybrids, while it was the lowest for B_2 (4.00) in cross 1 and P_1 (4.40) in cross 2.

The scale A was significant for cross 1 alone. Scales B and C were significant for both the crosses whereas scale D was significant only in cross 2.

Cross 1 displayed significant positive h, j and l effects whereas cross 2 exhibited significant positive d, h, i and j effect and negative 'l' effects.

4.2.4 Number of secondary branches

In both the crosses, mean values of the number of secondary branches was the highest for F_1 (30.87 in cross 1 and 33.87 in cross 2) hybrids, while it was the lowest for F_2 (16.20) in cross 1 and P_1 (21.67) in cross 2.

The *scales* A, B and C were significant in both the crosses while *scale* D was significant for cross 1 alone.

All kinds of gene effects *viz*., d, h, i, j and l were significant for cross 1, whereas cross 2 exhibited significance only in 'h' and 'l' effects.

4.2.5 Number of fruits per plant

In both the crosses, highest and lowest means were recorded by F_1 (57.20 in cross 1 and 66.13 in cross 2) and P_1 (36.53 in both the crosses) respectively.

The Scales A, B, C and D were significant for both the crosses. All values were negative except in cross 2 for which scale D was positive. The effect of m was significant in both the crosses. Additive effect (d) was found to be insignificant in both the crosses. Both the crosses, showed significant and positive h, i and j effects. The l effect was significant only in cross 2.

4.2.6 Green fruit weight

Maximum value of average fruit weight was observed for F_1 (5.05) in cross 1 and B_2 (4.81) in cross 2. Green fruit weight was minimum for P_2 (2.10 in cross and 2.50 in cross 2) in both the crosses.

Significance was noticed for the scales A, B and C in both the crosses, while scale D was significant for cross 2 alone.

Additive effect (d) was found to be insignificant in both the crosses. Positive and significant dominance effect (h) and negative and significant additive x dominance effect (j) were noticed in both the crosses. Additive x additive (i) effect was significant in cross 2 only. Dominance x dominance effect (l) was positive and significant in both the crosses but positive in cross 1 and negative in cross 2.

4.2.7 *Fruit yield per plant*

The highest fruit yield per plant was exhibited by F_1 (267.13 in cross 1 and 269.95 in cross 2) in both the crosses while it was lowest for F_2 (77.93) in cross 1 and P_2 (92.54) in cross 2.

Significance was noticed for scale A in both the crosses while scales B, C, D were significant for cross 1 only.

The additive and additive x dominance effects were found be insignificant in both the crosses. The dominance effect (h) was positive and significant in both the crosses. Besides, significant additive x additive (i) and dominance x dominance (l) interactions were observed in cross 1.

4.2.8 *Fruit length*

In both the crosses, longest and shortest fruits were recorded by F_1 (8.61 in cross 1 and 7.43 in cross 2) and B_1 (5.90 in cross 1 and 5.58 in cross 2) respectively.

In both the crosses, significance was noticed for scale A, B and C while scale D was non significant.

Significance was noticed for additive effect and dominance x dominance (l) effect in both the crosses whereas significance of dominance (h) effect and additive x dominance (j) effect was noted for cross 1 only. The additive x additive (i) effect was found to be insignificant in both the crosses.

4.2.9 *Fruit girth*

Maximum mean fruit girth was observed for F_1 (4.63) in cross 1 and B_1 (5.33) in cross 2 whereas P_2 (2.57 in cross 1 and 3.43 in cross 2) exhibited the minimum value in both the crosses.

Scales A, C and D were significant for both the crosses whereas scale B was significant for cross 2 only.

Additive (d) effect was significant in cross 2 alone. Dominance (h) effect and additive x additive effects (i) were significant in both the crosses. Additive x dominance (j) effect was significant in cross 1 and dominance x dominance effect (l) was significant in cross 2.

4.2.10. Number of seeds per fruit

Maximum and minimum mean values of number of seeds were observed respectively in F_1 (76.33) and F_2 (39.06) in cross 1 and B_1 (72.51) and P_2 (45.87) in cross 2.

Significance was recorded for scale A in cross 1, B and C in both the crosses and D in cross 1 alone.

Additive effect (d), dominance effect (h) and additive x additive effect (i) were significance in cross 1. Additive x dominance effect (j) was not significance in both the crosses. Dominance x dominance effect (l) was significant and negative in cross 2.

4.2.11 Hundred seed weight

The maximum hundred seed weight was exhibited by P_1 (0.5233) in both the crosses while it was minimum for B_1 (0.3933) in cross 1 and F_1 (0.4558) in cross 2.

All the scales were significant in cross 1 whereas cross 2 exhibited significance for scale C alone.

All the three kinds of interaction *viz*., additive x additive (i), additive x dominance (j) and dominance x dominance (l) were significant only in cross 1. The additive effect (d) and dominance effect (h) were not significant in both the crosses.

4.2.12 Plant height

In both the crosses, the maximum and minimum values for plant height was observed in F_1 (68.83 in cross 1 and 70.70 in cross 2) and P_1 (40.85 in cross 1 and 40.83 in cross 2) respectively.

Scale A was significant in cross 1. Significance was recorded for scales B, C and D in both the crosses.

All the allelic, (additive and dominance) and non-allelic (additive x additive, additive x dominance, and dominance x dominance) interactions were significant in both the crosses.

4.2.13 Duration of the crop

Plant duration was minimum in F_2 (168.59) in cross 1 and P_1 (177.87) in cross 2 whereas maximum value was observed for P_2 (180.60 in cross 1 and 182.13 in cross 2) in both the crosses.

All the four scales were significant in cross 1 whereas cross 2 exhibited significant scale A and C only.

All the allelic, (additive and dominance) and non-allelic (additive x additive, additive x dominance, and dominance x dominance) interactions were significant in cross 1. In cross 2, dominant effect (h) and additive cross dominant effect (j) alone were significant.

4.2.14 Harvest index

Maximum and minimum values for harvest index were noticed in F_1 (72.25 in cross 1 and 70.54 in cross 2) and F_2 (48.94 in cross 1 and 55.84 in cross 2) respectively in both the crosses.

All the four scales were significant in both crosses.

The dominance effect (h) was significant in both the crosses whereas additive effects were non significant. All the non-allelic interaction effects (i, j and l) were significant in both the cross except additive x dominance effect (j) in cross 1.

4.2.15. ***Capsaicin content***

The highest mean value for capsaicin content was observed for F_1 (0.7467) in cross 1 and P_2 (0.5133) in cross 2. This was the lowest in B_1 (0.3093) in cross 1 and P_1 (0.3556) in cross 2.

All the four scales (A, B, C and D) were significant in both the crosses.

Allelic effects were not significant in the crosses except dominance effect in cross 1. All the non-allelic interaction effects were significant in both the crosses except dominance x dominance (l) effects in cross 2.

4.2.16 Oleoresin content

Maximum and minimum values for the trait were noticed in P_2 (10.88) and F_2 (8.96) in cross 1 and F_1 (10.06) and P_2 (7.91) in cross 2 respectively.

Significance of scale A was observed in cross 2 whereas scale B exhibited significance in cross 1. Scale C was significant in both crosses and scale D in cross 1 only.

Significance of additive effect (d) was observed in cross 2 whereas significance of dominance effect (h) was noticed in cross 1. The additive x additive interaction (i) was significant in cross 1 while additive x dominance (j) was significant in cross 2. None of the crosses exhibited significance in dominance x dominance effect (l).

4.2.17 Vulnerability index

In both the crosses, minimum and maximum vulnerability index was noticed for P_2 (16.67 in cross 1 and 18.33 in cross 2) and P_1 (65.00) respectively.

The scale A was significant in both crosses whereas scale B was significant in cross 2 alone. Scale C was not significant in both the crosses. Significance for scale D was exhibited in cross 1.

Significance was observed for dominance effect (h), additive x additive effect (i) and dominance x dominance effect (l) in cross 1 and additive x dominance effect (j) in both crosses. Additive effect d is found to be insignificant in both the crosses.

4.3 TRANSGRESSIVE SEGREGANTS

Transgressive segregants observed for the characters in both the crosses L_5 x T_2 (cross 1) and L_5 x T_3 (cross 2) are presented in Table 18. In cross 1 the highest number of transgressive segregants was exhibited for duration of the crop (95.56 %) followed by fruit length (32.22 %) whereas in cross 2 the highest percentage was exhibited for number of fruits per plant and average green fruit weight (76.67) followed by fruit yield per plant (71.11).

Table 18. Transgressive segregants in two crosses of chilli

Sl.No.	Characters	Transgressive segregants	
		Cross 1	Cross 2
1	No. of primary branches	4.44	5.56
2	No. of secondary branches	0.00	12.22
3	No. of fruits per plant	0.00	76.67
4	Green fruit weight	16.67	76.67
5	Fruit yield per plant	23.33	71.11
6	Fruit length	32.22	27.78
7	Fruit girth	7.78	41.11
8	No. of seeds per fruit	4.44	55.56
9	Hundred seed weight	20.0	17.78
10	Plant height	1.11	14.44
11	Duration of the crop	95.56	6.67
12	Harvest index	0.00	8.89
13	Capsaicin index	0.00	43.33
14	Oleoresin content	0.00	16.67
15	Vulnerability index	17.78	18.89

DISCUSSION

5. DISCUSSION

Chillies form the indispensable adjunct in every house of tropical world. It is specially liked for its pungency and spicy taste, besides the appealing colour it adds to the food.

The cultivation of chilli is much constrained by various biotic stresses including diseases caused by viruses. One of the major virus diseases is caused by leaf curl virus, which is transmitted by whitefly (*Bemisia tabaci*). To a great extent this fly can be controlled by using chemicals but it is undesirable as it brings about a lot of environmental and health hazards.

Most of the cultivated varieties of chilli in India do not possess satisfactory resistance to leaf curl virus. Therefore an attempt was made with the objective to assess the magnitude of heterosis, to estimate combining ability, mode of inheritance of leaf curl resistance and other desirable economic traits for formulating future breeding programme in chilli to develop high yielding resistant varieties.

Results obtained in the present study are discussed as follows.

5.1 STUDIES ON VARIABILITY AND CHARACTER ASSOCIATION

The genetic parameters such as PCV, GCV, heritability, genetic advance and character association were studied and are discussed below.

5.1.1 Variability and Genetic parameters

The results of analysis of variance revealed highly significant differences among the genotypes for all the 17 characters *viz*., days to first flowering, days to 50 per cent flowering, number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, fruit length, fruit girth, number of seeds per fruit, hundred seed weight, plant height, duration of the crop, harvest index, capsaicin content, oleoresin content and vulnerability index calculated on the basis of virus disease scoring.

Selecting desirable plants from a genetically variable population is the basic step in crop improvement. The magnitude of genetic variability existing in a crop is the key to progress through selection. In this study the wide range of variation observed for the different characters indicated the scope for selection for improvement (Nayeema *et al.*, 1998; Devi and Arumugam, 1999b; Munshi and Behara, 2000; Rathod *et al.*, 2002; Jose and Khader, 2003).

The phenotypic coefficient of variation (PCV) was minimum (3.47) for duration of the crop and maximum for capsaicin content (45.29). High estimate of PCV was noticed for fruit yield per plant (42.25). This was in accordance with the report by Singh and Brar (1979), Rajput *et al.* (1981), Rani *et al.* (1996), Sreelathakumary and Rajamony (2002) and Nandadevi and Hosamani (2003a). Vulnerability index for leaf curl virus disease also had high values for PCV (37.62).

The genotypic coefficient of variation (GCV) describes the inherent genetic variation. GCV also showed similar trend as PCV. The genotypic coefficient of variation was minimum (3.35) for duration of the crop and maximum (44.91) for capsaicin content. High estimate of GCV was observed for fruit yield per plant (41.86). This was in line with the findings of Gopalakrishnan *et al.* (1987a), Rani *et al.* (1996), Sreelathakumary and Rajamony (2002) Rathod *et al.* (2002) and Nandadevi and Hosamani (2003a). Vulnerability index of leaf curl virus disease had high value for GCV (37.23).

Moderate values of PCV and GCV were observed for number of primary branches, number of secondary branches, number of fruits per plant, average green fruit weight, fruit length and girth, number of seeds per fruit, hundred seed weight, plant height, harvest index and oleoresin content.

For all the characters the PCV and GCV values were found to be closer indicating the predominant influence of genetic component over the environmental effect for their phenotype. Pichaimuthu and Pappiah

(1992) also reported a close association of the phenotypic and genotypic coefficients of variation.

High heritability values were observed for all the characters under study. Broad sense heritability estimates alone does not serve as a true indicator of genetic potentiality of genotypes. It is advisable to consider the predicated genetic advance along with heritability estimates as a tool in selection programme. High heritabililty coupled with high genetic advance was exhibited for number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit yield per plant, fruit length and girth, number of seeds per fruit, hundred seed weight, plant height, harvest index, capsaicin content, oleoresin content and vulnerability index. These findings were in accordance with those of Singh and Singh (1977b), Bavaji and Murthy (1982), Shah *et al.* (1986), Das *et al.* (1989), Varalakshmi and Babu (1991), Pitchaimuthu and Pappiah (1995), Nayeema *et al.* (1998), Devi and Arumugam (1999b), Rathod *et al.* (2002), Sreelathakumary and Rajamony (2002) and Nandadevi and Hosamani (2003a). High heritability and high genetic advance might be due to additive gene action.

The character days to 50 per cent flowering showed high heritability with moderate genetic advance. This might be due to the interacting non-additive and additive factors. High heritability and low genetic advance was exhibited by days to flowering and crop duration. This suggested that these characters might be conditioned by non-additive genes and selection for such characters may not be effective. This was supported by the findings of Nair *et al.* (1984).

5.1.2 Correlation analysis

Yield is a complex character influenced by a number of other component characters. For successful improvement through selection it is essential to ascertain the importance and the extent of inter-association of various components and their association with yield. The extent of relationship between yield and its component traits as well as among the component traits is revealed through correlation analysis. Improvement of the crop for characters with high correlation to yield can lead to significant increase in yield.

The genotypic correlations were higher than the phenotypic correlations for most of the characters indicating the reduced influence of environment for the various characters. Similar observations were made by Sundaram and Ranganathan (1978), Rao and Chhonkar (1981), Choudhary *et al.* (1985), Jose and Khader (2002).

The genotypic correlation of yield per plant was significant and positive for number of primary branches, number of secondary branches, number of fruits per plant, green fruit weight, fruit length and girth, number of seeds per fruit, plant height, duration of the crop, harvest index and capsaicin content while it was significant and negative for vulnerability index.

Green fruit weight exhibited significant and highest positive genotypic correlation with yield suggesting its importance in improving yield. Veerapa (1982), Gopalakrishnan *et al.* (1985), Choudhary *et al.* (1985), Miranda *et al.* (1988b), Ahmed *et al.* (1997), Subashri and Natarajan (1999) and Munshi *et al.* (2000) also got the same results.

Green fruit weight had significant positive genotypic correlation with fruit length and girth as observed by Munshi *et al.* (2000).

Another important economic trait showing high positive genotypic correlation with yield was number of fruits per plant. Similar result was reported by Sundaram and Ranganathan (1978), Rao *et al.* (1981), Bavaji and Murthy (1982), Bhagyalakshmi *et al.* (1990), Ali (1994), Rani (1995), Vallejo *et al.* (1997), Legesse *et al.* (1999), Aliyu *et al.* (2000) and Nandadevi and Hosamani (2003a).

Days to first flowering had significant positive correlation with days to 50 per cent flowering. Both these characters showed significant negative and positive correlation with fruit girth and duration of the crop respectively.

The number of primary and secondary branches were positively correlated with yield. Similar observation was made by Das *et al.* (1989), Rani (1995), Subashri and Natarajan (1999) and Das and Choudhary (1999a).

Significant positive genotypic correlation was observed between fruit length and fruit yield per plant. This is in conformity with the findings of Rajput *et al.* (1981), Gopalakrishnan *et al.* (1985), Ghai and Thakur (1987). Miranda (1988), Ahmed *et al.* (1997), Todorova and Todorova (1998) and Subashri and Natarajan (1999).

The genotypic correlation of fruit girth with yield was positive as reported earlier by Veerapa (1982) and Choudhary *et al.* (1985).

Number of seeds per fruit was positively associated with yield as reported earlier by Das *et al.* (1989) and Rani (1996 b).

Plant height showed significant positive association with yield. Similar observation was made by Rani (1995), Ahmed *et al.* (1997) and Ibrahim *et al.* (2001). However, Gopalakrishnan *et al.* (1985) and Ghai and Thakur (1987) observed significant negative association of plant height with yield.

Harvest index also had significant and positive correlation with yield as reported earlier by Rathod *et al.* (2002).

Capsaicin content exhibited significant positive correlation with yield. This is in contrary to the findings of Kohli and Chatterjee (2000).

Vulnerability index showed a negative correlation with yield indicating that lesser the susceptibility to the disease (leaf curl) higher would be the yield.

5.2 LINE x TESTER ANALYSIS

In the current research programme, line x tester analysis was undertaken with five high yielding lines and three leaf curl resistant testers selected from the previous experiments (Jose, 2001) in order to sort out the top ranking parents as well as crosses by examining their mean performance, general combining ability of parents and specific combining ability of crosses along with their heterosis estimates.

The salient results derived are discussed under two major sections *viz.*

i) Evaluation and selection of parents

ii) Evaluation and selection of hybrids

5.2.1 Evaluation and selection of parents

The performance of hybrids developed in a hybridization programme depend largely on the parental attributes. This emphasise that choice of parents should be based on their *per se* performance along with general combining ability estimates (Yadav and Murthy, 1966), which indicate the genetic potentiality of genotypes. Selection practised based on phenotypic performance alone may not always lead to derive success in crossing programmes. This pinpoints the relevance of the combined assessment of parents using both these criteria at a time.

5.2.1.1 Per se performance of parents

Among the five lines used, Jwalamukhi was found to be superior compared to other lines (Table 5) with respect to fruit yield and yield contributing characters *viz.*, green fruit weight, fruit length and fruit girth. Moreover, Jwalamukhi exhibited good per se performance for number of secondary branches, hundred seed weight, plant height and lowest leaf curl incidence. Likewise, Mangalapuram Local displayed superiority for fruit yield, number of fruits per plant, number of seeds per fruit, harvest index, capsaicin content, oleoresin content and duration of the crop. The best performance for days to first flowering and number of primary branches was recorded by Pollakkada Local and for days to 50 per cent flowering, fruit girth and duration of the crop by Kottikulam

Local. The lines Pollakkada Local and Kottikulam Local expressed noteworthy performance for four traits while Koothali Local exhibited good performance only for two traits.

Among the three testers used, Alampady Local and Neyyattinkara Local exhibited high performance for fruit yield per plant. Besides yield Alampady Local expressed good performance for eight traits *viz.*, days to first flowering, days to 50 per cent flowering, number of primary branches, number of secondary branches, number of fruits per plant, duration of the crop, harvest index and lowest vulnerability index. Similarly Neyyattinkara Local also expressed good performance for seven traits *viz.*, number of primary branches, number of secondary branches, green fruit weight, fruit length, fruit girth, duration of the crop, and capsaicin content. Although Haripuram Local showed good performance for nine traits, it recorded lowest value for fruit yield.

5.2.1.2 General combining ability effects of parents

The identification of parents having desirable genes and transfer of these genes to their progenies are very important for accumulation of more number of desirable characters in the hybrid combinations.

Among lines, the Pollakkada Local recorded desirable significant *gca* effect for yield and vulnerability index (Table 11). In addition to this Pollakkada Local also showed significant *gca* effect for other seven traits *viz.*, number of primary branches, number of fruits per plant, green fruit weight, fruit length, number of seeds per fruit, plant height and harvest index. Likewise, Koothali Local and Mangalapuram Local displayed significant desirable *gca* effect for five traits each. Koothali Local showed good performance for days to first flowering, days to 50 per cent flowering, number of fruits per plant, harvest index and duration of the crop. Mangalapuram Local showed significant performance for fruit girth, number of seeds per fruit, hundred seed weight and duration of the crop. The lines Jwalamukhi and Kottikulam Local expressed desirable *gca* effect only for three characters.

Among testers, Neyyattinkara Local expressed excellent performance with significant *gca* effects for 11 traits including yield and resistance to leaf curl. The other traits are days to first flowering, number of primary branches, number of secondary branches, green fruit weight, fruit girth, number of seeds per fruit, plant height, capsaicin content and oleoresin content.

Similarly Alampady Local displayed desirable significant *gca* effect for six traits *viz.* days to first flowering, days to 50 per cent flowering, green fruit weight, fruit length, fruit girth, and duration of the crop. Haripuram Local showed the least performance with significant *gca* effect for three traits only.

5.2.1.3 Choice of superior parents

Considering the overall performance among lines, Jwalamukhi expressed good *per se* performance along with significant desirable *gca* effect for three traits *viz.* green fruit weight, fruit length, and hundred seed weight whereas Mangalapuram Local showed good performance for number of seeds, oleoresin content and duration of the crop. The line Koothali Local and Pollakkada Local showed good *per se* and *gca* for number of fruits and number of primary branches respectively.

Neyyattinkara Local could be designated as the best tester owing to its grand display of the highest mean values as well as *gca* effects for fruit yield, number of primary branches, number of secondary branches, green fruit weight, fruit girth and capsaicin content. Alampady Local could be selected for earliness as it exhibited desirable performance for days to first flowering, days to 50 per cent flowering and duration of the crop.

5.2.2 Evaluation and selection of hybrids

The factors that must be considered for exploitation of hybrid vigour are the per se performance, heterosis values and *sca* effects of the hybrids. The *sca* effect solely may not be the criterion for assessing hybrid performance because hybrids with high *sca* effects may sometimes posses low heterosis estimate and *vice versa*.

Hence mean performance, standard heterosis and *sca* effects should be considered for choosing appropriate and desirable cross combinations.

5.2.2.1 Per se performance of hybrids

Among the hybrids, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local alone showed good performance for yield (Table 5). The hybrid Pollakkada Local x Alampady local exhibited desirable performance for nine traits *viz*., fruit yield, green fruit weight, fruit length, fruit girth, harvest index, capsaicin content, leaf curl virus resistance, number of primary branches and days to first flowering.

Similarly Pollakkada Local x Neyyattinkara Local displayed superiority for eight traits *viz*., fruit yield, number of fruits, fruit girth, harvest index, plant height, number of primary and secondary branches and days to first flowering.

The hybrids Mangalapuram Local x Haripuram Local, Mangalapuram Local x Neyyattinkara Local and Koothali Local x Neyyattinkara Local showed good performance for four characters each. All the three hybrids showed superiority for fruit girth. The hybrid Mangalapuram Local x Haripuram Local expressed best performance for number of seeds and hundred seed weight. The best performance for oleoresin content and days to first flowering was exhibited by Mangalapuram Local x Neyyattinkara Local and Koothali Local x Neyyattinkara Local respectively. The hybrids Mangalapuram Local x Alampady Local and Koothali Local x Alampady Local displayed good performance for only three and two traits respectively.

Considering the *per se* performance Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local could be selected for crop improvement programme.

5.2.2.2 Standard heterosis of hybrids

The variety Jwalamukhi was taken as check for evaluating standard heterosis. Only three hybrids *viz*. Jwalamukhi x Neyyattinkara Local, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local exhibited significant standard heterosis for yield (Table 16). Of these Pollakkada Local X Alampady Local ranked first expressing significant standard heterosis for 13 characters *viz*., fruit yield, number of fruits, green fruit weight, fruit length, number of seeds, harvest index, capsaicin content, leaf curl virus resistance, plant height, number of primary and secondary branches, days to first flowering and days to 50 per cent flowering. The cross Pollakkada Local x Neyyattinkara Local displayed significant desirable standard heterosis for ten traits *viz*., yield, number of fruits, number of seeds per fruit, capsaicin content, vulnerability index, plant height, number of primary and secondary branches, days to first flowering and days to 50 per cent flowering.

The hybrid Jwalamukhi x Neyyattinkara Local showed superiority for nine traits, *viz*., fruit yield, number of fruits per plant, capsaicin content, oleoresin content, vulnerability index, plant height, number of primary branches, days to first flowering and days to 50 per cent flowering.

Among the remaining hybrids, the hybrids Jwalamukhi x Haripuram Local, Kottikulam Local x Haripuram Local and Kottikulam Local x Neyyattinkara Local displayed significant desirable standard heterosis for vulnerability index.

The hybrids Jwalamukhi x Haripuram Local showed significant desirable standard heterosis for vulnerability index and other seven traits *viz*., number of fruits per plant, hundred seed weight, oleoresin content, plant height, number of primary branches, number of secondary branches and days to 50 per cent flowering. The hybrids Kottikulam Local x Haripuram Local and Kottikulam Local x Neyyattinkara Local displayed superiority for six and seven traits respectively.

The hybrid Pollakkada Local x Alampady Local alone had significant desirable standard heterosis for vulnerability index of leaf curl virus disease when Pant C1 was used as check.

Based on standard heterosis three hybrids Pollakkada Local x Alampady Local, Pollakkada Local x Neyyattinkara Local and Jwalamukhi x Neyyattinkara Local could be identified as desirable for yield attributes.

5.2.2.3 Sca effect of hybrids

Eight hybrids *viz*., Jwalamukhi x Haripuram Local, Jwalamukhi x Neyyattinkara Local, Kottikulam Local x Alampady Local, Mangalapuram Local x Haripuram Local, Koothali Local x Haripuram Local, Koothali Local x Alampady Local, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local expressed significant *sca* effects for fruit yield (Table 12). Of these Pollakkada Local x Alampady Local is the best combination displaying desirable significant *sca* effect for 13 traits *viz*., fruit yield, green fruit weight, fruit length, fruit girth, number of seeds, hundred seed weight, harvest index, capsaicin content, oleoresin content, vulnerability index, plant height, number of primary and secondary branches.

Likewise, Jwalamukhi x Haripuram Local and Mangalapuram Local x Haripuram Local expressed desirable *sca* effect for 11 traits. These hybrids, displayed significant desirable *sca* effect for yield, fruit length, number of seeds, hundred seed weight, harvest index and plant height. Besides, Jwalamukhi x Haripuram Local showed significant desirable *sca* effect for number of fruits, oleoresin content, vulnerability index and number of primary and secondary branches, whereas Mangalapuram Local x Haripuram Local expressed superiority for green fruit weight, fruit girth, capsaicin content, days to 50 per cent flowering and duration of the crop.

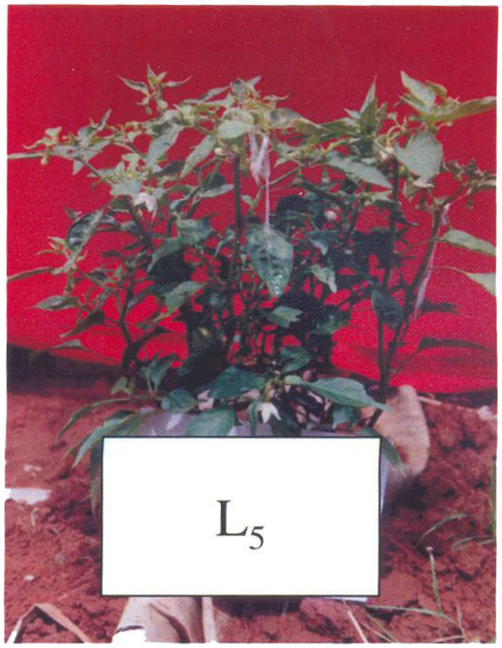
The hybrids Jwalamukhi x Neyyattinkara Local and Pollakkada Local x Neyyattinkara Local expressed significant *sca* effect for seven traits. Jwalamukhi x Neyyattinkara Local expressed significant desirable *sca* effect for yield, green fruit weight, hundred seed weight, harvest index, capsaicin content, vulnerability index and plant height. Pollakkada local x Neyyattinkara Local recorded significant desirable *sca* effect for yield, number of fruits per plant, fruit length, plant height, number of secondary branches, days to first flowering and days to 50 per cent flowering.

Besides yield the hybrids Kottikulam Local x Alampady Local, Koothali Local x Haripuram Local and Koothali Local x Alampady Local showed superiority in *sca* effects for four, three and five other characters respectively.

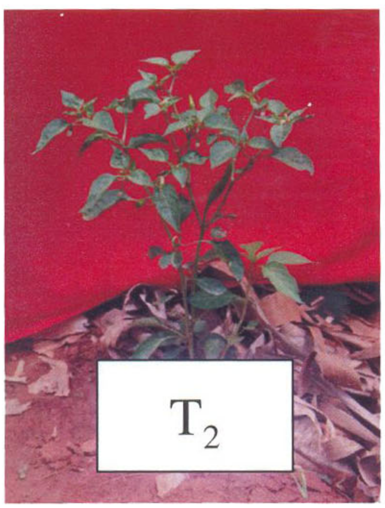
Considering the *sca* effects, five hybrids *viz*., Pollakkada Local x Alampady Local, Jwalamukhi x Haripuram Local, Mangalapuram Local x Haripuram Local, Pollakkada Local x Neyyattinkara Local and Jwalamukhi x Neyyattinkara Local could be identified as desirable single crosses.

5.2.2.4 Selection of best hybrids

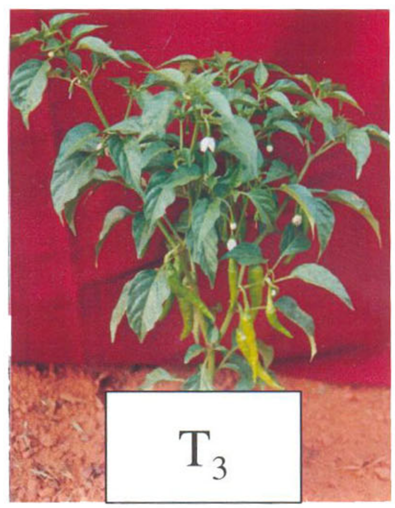
Based on all the criteria *viz*., *per se* performance, standard heterosis and *sca* effects the cross Pollakkada Local x Alampady Local was found to be superior with respect to fruit yield per plant, fruit length, harvest index, capsaicin content, vulnerability index and number of primary branches (Plate 3 and 4). Likewise, Pollakkada Local x Neyyattinkara Local was superior in fruit yield, number of fruits per plant, number of primary and secondary branches and days to first flowering



Pollakkada Local

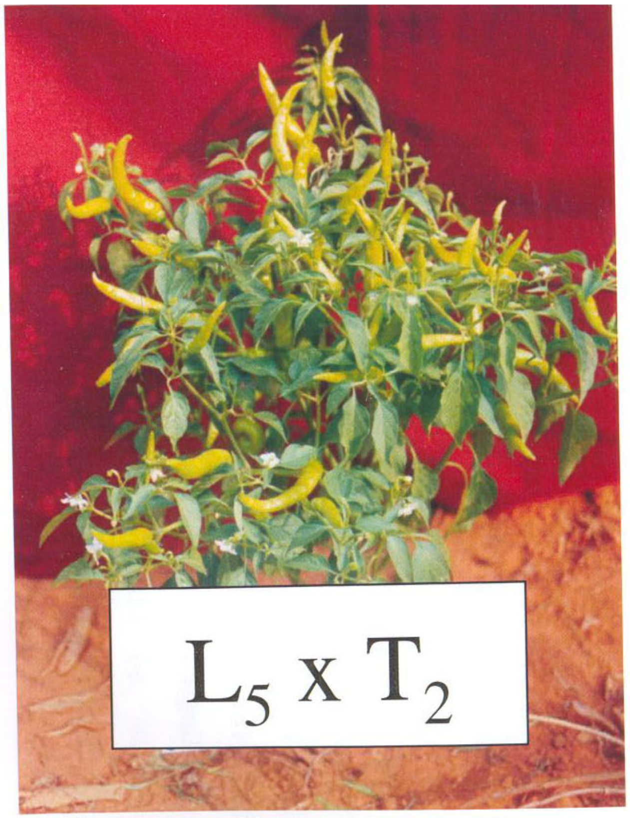


Alampady Local

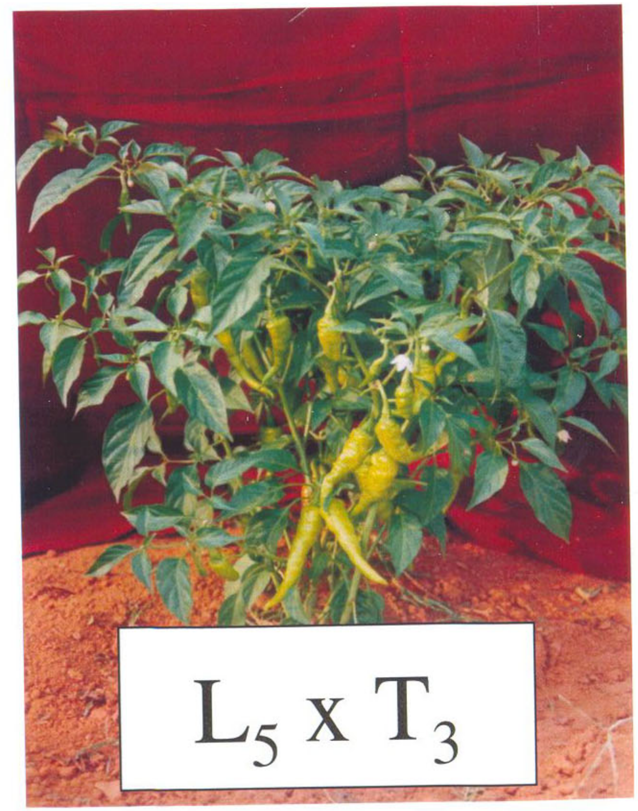


Neyyattinkara Local

Plate 3. Parents of the two selected hybrids



Pollakkada Local x Alampady Local



Pollakkada Local x Neyyattinkara Local

Plate 4. Selected hybrids

(Plate 3 and 4). Thus these two hybrids could be identified as good hybrid *to be included in the crop improvement programme.*

Besides the desirable crosses with respect to mean, standard heterosis and *sca* effect in important characters are as follows :

Character		*Crosses*
Days to first flowering	-	Kottikulam Local x Haripuram Local Koothali Local x Neyyatinkara Local Pollakkada Local x Neyyatinkara Local
Days to 50 per cent flowering	-	Koothali Local x Neyyatinkara Local
Number of fruits per plant	-	Pollakkada Local x Neyyatinkara Local
Green fruit weight	-	Pollakkada Local x Alampady Local
Fruit yield per plant	-	Pollakkada Local x Neyyatinkara Local Pollakkada Local x Alampady Local
Duration of the crop	-	Jwalamukhi x Alampady Local Mangalapuram Local x Haripuram Local Koothali Local x Neyyatinkara Local
Vulnerability index	-	Pollakkada Local x Alampady Local

Parents involved in the following hybrids had high *gea* effects for several *characters (days to first flowering, days to 50 per cent* flowering, green fruit weight, fruit girth, number of seeds per fruit, duration of the crop, oleoresin content and vulnerability index) (Table 11). *But the sca effects in the characters were not significant* (Table 12). This indicated that the characters could be improved through recombination breeding programme like pedigree method.

Character	Crosses
Days to first flowering	Koothali Local x Alampad Local
Days to 50 per cent flowering	Koothali Local x Alampad Local
Green fruit weight	Pollakkada Local x Neyyatinkara Local
Fruit girth	Mangalapuram Local x Alampady Local
Number of seeds per fruit	Mangalapuram Local x Neyyatinkara Local
Duration of the crop	Mangalapuram Local x Alampady Local
	Koothali Local x Alampady Local
Oleoresin content	Kottikulam Local x Neyyatinkara Local
Vulnerability index	Pollakkada Local x Neyyatinkara Local

5.2.3 Proportional contribution of parents and hybrids

In the present study, lines contributed maximum variability (Table 13) towards majority of the traits studied *viz.*, number of primary branches, number of secondary branches, green fruit weight, fruit yield per plant, fruit length, number of seeds per fruit, duration of the crop and vulnerability index. The variability was high for line x tester hybrids for traits *viz.*, days to first flowering, number of fruits per plant, plant height, harvest index, capsaicin and oleoresin content.

However, the testers contributed maximum for three traits only *viz.*, days to 50 per cent flowering, fruit girth and hundred seed weight.

5.2.4 Genetic component of variance

When F = 0, the additive to dominance variation ratio ranges from 0.004 for harvest index to 0.27 for number of secondary branches (Table 14). When F = 1, the values ranged from 0.008 to 0.54 for the characters respectively (Table 15). The dominance variance was greater than additive variance for all characters indicating that non-additive gene action was predominant than additive gene action. Hence, recombination breeding and heterosis breeding programme has to be followed for the improvement of yield and other economically important characters.

5.3 GENERATION MEAN ANALYSIS

The concept of generation mean analysis was formulated by Hayman (1958). The merit of generation mean analysis is that it helps in the estimation of epistatic gene effects namely additive x additive (i), additive x dominance (j) and dominance x dominance (l). Of the varying models available, six-parameter model was utilized for the current study in which six generations (P_1, P_2, F_1, F_2, B_1 and B_2) were utilized and information on six parameters were derived. The two superior cross combinations *viz.* Pollakkada Local x Alampady local (Cross 1) and Pollakkada local x Neyyattinkara local (Cross 2) identified from the evaluation of line x tester analysis were utilized for generation mean analysis and the results are discussed.

The scaling tests (A, B, C and D) indicated that one or more of the tests were significant in both the crosses indicating the presence of non allelic interaction (epitasis) (Table 17).

5.3.1 Days to first flowering

Pollakkada Local x Alampady Local exhibited significant dominance (h) effect and all the three type of epistatic interaction. But among the interaction components, only additive x additive alone was in the desirable negative direction. Significant and negative values for dominance and additive x additive components in Pollakkada Local x

Alampady Local indicated that heterosis breeding and recombination breeding approaches are beneficial for improving this character.

The high and negative significance of dominance effect in Pollakkada Local x Neyyattinkara Local expressed the relevance of heterosis breeding in improving the trait. The dominant gene action for days to flower initiation was also observed by Anandanayaki and Natarajan (2000) and overdominance effect by Lazic (1997).

Opposite signs of 'h' and 'l' in both the crosses indicated the duplicate nature of epistasis.

5.3.2 Days to 50 per cent flowering

Inheritance for days to 50 per cent flowering was found to be controlled by dominance (h) and additive x additive (i) components of gene action in Pollakkada Local x Alampady Local. Though dominance x dominance effect (l) was significant, its direction was positive. Heterosis breeding and selection of superior recombinants in the advanced generations are useful for improving the trait.

Among the significant dominance (h), additive x dominance (j) and dominance x dominance (l) effects in Pollakkada Local x Neyyattinkara Local only dominance effect was in a desirable negative direction. Heterosis breeding could be advocated to be followed here.

Opposite signs of 'h' and 'l' in both the crosses indicated duplicate nature of gene action. Predominance of both additive and non-additive gene action was earlier reported by Singh and Singh (1977a), Gopalakrishnan *et al.* (1987b), Bhagyalakshmi *et al.* (1991), Echeverri *et al.* (1998) and Lohithaswa *et al.* (2000).

5.3.3 Number of primary branches

Dominance (h), additive x dominance (j) and dominance x dominance (l) components were significant in Pollakkada Local x Alampady Local and epitasis existed was of complementary type. The highest magnitude noticed for the dominance x dominance (l) effect implies heterosis breeding would be more suitable. The predominant *dominance x dominance component was noticed earlier* by Joshi (1990).

Pollakkada Local x Neyyattinkara Local recorded significance for all the genetic components. But dominance x dominance effect is in negative *direction. Opposite signs of 'h' and 'l' in* Pollakkada Local x Neyyattinkara Local indicated duplicate nature of epistasis. Hence direct selection, heterosis breeding, recombination breeding would be useful for *improvement of this trait. The presence of both* additive and non-additive gene action for number of branches per plant was earlier reported by Milkova (1984), Joshi (1988), Cao and Su (1988), Bhagyalakshmi *et al. (1991) and Doshi and Shukla (2000).*

5.3.4 Number of secondary branches

In Pollakkada *Local x Alampady Local, all the genetic* component additive (d), dominance (h), additive x additive (i), additive x dominance (j), dominance x dominance (l) components were positive and significant. *Hence direct selection, heterosis breeding and* recombination breeding could be resorted to for improving the number of secondary branches.

Significant and positive values of dominance and dominance x dominance effects in Pollakkada Local x Neyyattinkara Local denoted that heterosis breeding would be helpful.

Similar signs of 'h' and 'l' indicated complementary nature of epistasis in both the crosses.

5.3.5 Number of fruits per plant

Significant *and positive* values for dominance (h), additive x additive (i) and additive x dominance (j) components were noticed in Pollakkada Local x Alampady Local indicating heterosis breeding and recombination *breeding programmes as beneficial for improving* the number of fruits per plant.

Significant and positive dominance, additive x additive, additive x *dominance and dominance* x *dominance effects in* Pollakkada Local x Neyyattinkara Local indicated that heterosis breeding and recombination breeding might be the appropriate methods to improve the number of fruits.

Similar signs of 'h' and 'l' indicated the presence of complementary nature of epistasis.

Importance of *dominance and all the interaction* components was pointed out earlier by Murthy and Deshpande (1997). Contradictory to the observations in the present study, predominance of additive gene action was reported by Lippert (1975), Pandey *et al.* (1981b), Gaddagimath *et al.* (1988), Nowaczyle *et al.* (1993), Pitchaimuthu and Pappiah (1995), Devi and Arumugam (1999b) and Rathod *et al.* (2002).

5.3.6 Green fruit weight

Among the significant genetic components in Pollakkada Local x Alampady Local only dominance and dominance x dominance components acted in positive direction. Hence heterosis breeding would be recommended. The importance of over dominance for this trait was earlier reported by Todorova (2000).

All the three kinds of interaction along with dominance effect were significant in Pollakkada Local x Neyyattinkara Local. However, only the dominance and additive x additive effects were positive indicating heterosis and recombination breeding could be utilized for improving the average weight of fruits.

Pollakkada Local x Alampady Local displayed complementary epistasis while duplicate epistasis was expressed in Pollakkada Local x Neyyattinkara Local.

Contradictory to the present finding; additive gene action for fruit weight was observed by Dolgikh and Sviridova (1983), Miranda and

Coasta (1988), Gopalakrishnan *et al.* (1987b), Gaddagimath (1992), Nowaczyk *et al.* (1993) and Devi and Arumugam (1999b).

5.3.7 Fruit yield per plant

Significant and positive values for dominance (h), additive x additive (i) and dominance x dominance (l) effects were noticed in Pollakkada Local x Alampady Local. Recombination breeding would be the appropriate method for the improvement of the trait.

Significance of additive, dominance and all the three interaction components for fruit yield was earlier reported by Ahmed *et al* (1994) and Murthy and Deshpande (1997).

Only dominance effect was found to be significant in Pollakkada Local x Neyyattinkara Local indicating the suitability of heterosis breeding to improve the character. The results are in agreement with those of Jadhav and Dhumal (1994).

Complementary epistasis was prevalent in both the crosses.

5.3.8 Fruit length

All the genetic components except additive x additive effect were significant in Pollakkada Local x Alampady Local. However, only dominance and dominance x dominance were positive indicating heterosis breeding could be exploited for the improvement of the trait. The dominance effect for fruit length was earlier reported by Joshi (1988) whereas Krishnamurthy and Deshpande (1997) observed partial dominance for the trait.

Though additive (d) and dominance x dominance (l) effects were significant in Pollakkada Local x Neyyattinkara Local only the latter one acted in positive direction thereby suggesting heterosis breeding as suitable for improving fruit length.

Complementary epistasis was noticed in both the crosses.

5.3.9 Fruit girth

Significant and positive values for dominance (h) and additive x additive (i) components were noticed in Pollakkada Local x Alampady Local indicating heterosis and recombination breeding could be utilized for the improvement of the trait.

Additive and dominance effect and all the interactions except additive x dominance were significant in the cross Pollakkada Local x Neyyattinkara Local. However dominance x dominance effect had negative value. This indicated that hybridization followed by selection of genotype with higher fruit girth might be beneficial. Recurrent selection can also be exploited. Similar report was observed for the cross California wonder x Elephant Trunk by Joshi (1990). Doshi and Shukla (2000) reported additive and over dominance effects for the trait.

Duplicate epistasis was noted in both the crosses.

5.3.10 Number of seeds per fruit

Both additive and dominance effects were significant and positive in Pollakkada Local x Alampady Local. Among interactions only additive x additive interaction was significant which was also positive. Heterosis and recombination breeding could be exploited for the improvement of the trait. Involvement of both additive and non-additive gene action was observed earlier by Milkova (1984), Bhagyalakshmi *et al.* (1991) and Lohithaswa (1997). In the cross Pollakkada Local x Neyyattinkara Local only dominance x dominance (l) interaction alone was found to be significant. But the direction is negative. Duplicate epistasis was prevalent in both crosses.

5.3.11 Hundred seed weight

Only the interaction effects were significant in Pollakkada Local x Alampady Local. However, only dominance x dominance (l) effect had positive value. Hence heterosis breeding would be effective in improving the trait. Contradictory to the present study, Lippert (1975) and Gaddagimath (1992) observed additive gene action for seed weight. None of the genetic components were significant in Pollakkada Local x Neyyattinkara Local.

Duplicate epistasis was noticed in both crosses

5.3.12 Plant height

All the genetic components were significant in Pollakkada Local x Alampady Local. But additive gene effect (d) had negative value. Heterosis and recombination breeding could be utilized for the improvement of the trait. Joshi (1990) observed dominance and all the three interaction effects for plant height. But predominance of both additive and non additive gene action was reported by Cao and Su (1988), Patil (1997), Echeverri *et al.* (1998), Gandhi and Navale (2000), and Lohithaswa *et al.* (2000).

Significant and positive additive (d), dominance (h) and additive x additive (i) effects in Pollakkada Local x Neyyattinkara Local indicated heterosis breeding and recombination breeding will be effective Pollakkada Local x Alampady Local displayed complementary epistasis while duplicate epistasis was expressed in Pollakkada Local x Neyyattinkara Local.

5.3.13 Duration of the crop

Although additive, dominance and all the interaction effects were significant in Pollakkada Local x Alampady Local, dominance x dominance (l) effect alone in negative direction. Hence heterosis breeding might be helpful in improving the trait (short duration types).

Dominance (h) and additive x dominance (j) effects were significant in Pollakkada Local x Neyyattinkara Local. But additive x dominance (j) was positive. Hence heterosis breeding could be exploited to develop short duration genotypes.

Pollakkada Local x Alampady Local displayed duplicate epistasis while complementary epistasis was noted in Pollakkada Local x Neyyattinkara Local.

5.3.14 Harvest index

Significant and positive dominance (h) and additive x additive (i) effects in Pollakkada Local x Alampady Local indicated that recurrent selection could be effective to improve the character.

Dominance and all the interaction effects were significant in Pollakkada Local x Neyyattinkara Local. But additive x dominance (j) was in negative direction. Improvement of this trait could be through recombination breeding programmes.

Pollakkada Local x Alampady Local displayed duplicate epistasis while complementary epistasis was noted in Pollakkada Local x Neyyattinkara Local.

5.3.15 Capsaicin content

Dominance and all the interaction effects were positive and significant in Pollakkada Local x Alampady Local and epistasis also was recorded. Presence of non-additive gene action for capsaicin content was earlier reported by Patil (1997). The highest magnitude for dominance x dominance (l) effect implies that heterosis breeding could be exploited for the improvement of the character.

Pollakkada Local x Neyyattinkara Local recorded significant additive x additive (i) and additive x dominance (j) effect. However, only additive x dominance (j) had positive value. Hence recombination breeding could be recommended. The epistasis is of duplicate type.

5.3.16 Oleoresin content

Significant and positive values for dominance and additive x additive (i) effect in Pollakkada Local x Alampady Local indicated that hybridization and selection in the segregating generations could be followed for improvement of the trait. Presence of non-additive gene action for oleoresin content was noted by Singh and Hundal (2001a).

Additive (d) and additive x dominance (j) effect were significant and negative in Pollakkada Local x Neyyattinkara Local.

Pollakkada Local x Alampady Local displayed duplicate epistasis while complementary epistasis was noted for Pollakkada Local x Neyyattinkara Local.

5.3.17 Leaf curl incidence (VI)

Though dominance and all the interaction components were significant in Pollakkada Local x Alampady Local, only additive x additive (i) and additive x dominance (j) were in desirable negative direction. The predominance of non-additive gene effects was reported earlier by Nandadevi and Hosamani (2003b). Improvement of this trait could be through recombination breeding or recurrent selection programmes.

Significant and negative additive x dominance (j) effect in Pollakkada Local x Neyyattinkara Local indicated that recombination breeding or recurrent selection could be effected in programmes for improvement of the trait.

5.4 TRANSGRESSIVE SEGREGANTS

In Pollakkada Local x Alampady Local transgressive seggregants was observed (Table 18) for all the characters studied excluding number of secondary branches, number of fruits per plant, harvest index, capsaicin content and oleoresin content. In Pollakkada Local x Neyyattinkara Local it was noticed for all the characters. This indicated the possibility of identifying desirable recombinants, which could be further utilized for developing superior variety.

Estimates of trasnsgressive segregants (%) in F_2 were the highest for number of fruits per plant and average green fruit weight followed by fruit yield per plant in Pollakkada Local x Neyyattinkara Local.

In Pollakkada Local x Alampady Local the highest value was exhibited for duration of the crop (95.56) followed by fruit length (32.22).

Pollakkada Local x Neyyattinkara Local expressed more number transgressive segregants than that of Pollakkada Local x Alampady Local, for all the characters except fruit length, hundred seed weight and duration of the crop.

SUMMARY

6. SUMMARY

The present study entitled "Genetic analysis of yield and leaf curl virus resistance in Chilli (*Capsicum annuum* L.)" was undertaken at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2003 as three major experiments with a view to study the genetic diversity and inheritance pattern of important quantitative and qualitative characters including yield and leaf curl virus resistance in chilli (*Capsicum annum* L.).

In Experiment I, five susceptible high yielding types lines (Jwalamukhi, Kottikulam Local, Mangalapuram Local, Koothali Local and Pollakkada Local) and three resistant types-testers (Haripuram Local, Alampady Local and Neyyattinkara Local) identified from a previous experiment conducted (Jose, 2001) in the Department were crossed in L x T pattern and 15 F_1s were produced.

In experiment II, the parents and F_1 hybrids were evaluated for yield and its component characters in randomized block design with three replications. Leaf curl virus disease incidence was ensured artificially by growing susceptible plants and releasing viruliferrous white flies in the experimental field. Observations were recorded on 17 characters *viz.*, days to first flowering, days to 50 per cent flowering, number of primary branches, number of secondary branches, number of fruits per plant, average green fruit weight (g), fruit yield per plant, fruit length, fruit girth, number of seeds per fruit, hundred seed weight, plant height, duration of the crop, harvest index, capsaicin content, oleoresin content and vulnerability index calculated on the basis of virus disease scoring.

The salient conclusions from the Experiment II are summarized under.

1. Analysis of variance revealed highly significant differences among the genotypes for all the characters.

2. Higher estimates of phenotypic and genotypic coefficient of variation (PCV and GCV) were recorded for capsaicin content, fruit yield per plant and vulnerability index. Moderate values of PCV and GCV were observed for number of primary branches, number of secondary branches, number of fruits per plant, average green fruit weight, fruit length, fruit girth, number of seeds per fruit, hundred seed weight, plant height, harvest index and oleoresin content.
3. High heritability coupled with high genetic advance were exhibited for number of primary branches, number of secondary branches, number of fruits per plant, average green fruit weight, fruit yield per plant, fruit length, fruit girth, number of seeds per fruit, hundred seed weight, plant height, harvest index, capsaicin content, oleoresin content and vulnerability index. The character days to 50 per cent flowering showed high heritability with moderate genetic advance.
4. Number of branches (both primary and secondary), number of fruits per plant, green fruit weight, fruit length, fruit girth, number of seeds per fruit, plant height, harvest index, duration of the crop and capsaicin content were found to be significantly correlated to fruit yield. High and negative association of yield with vulnerability index indicated that susceptibility to the leaf curl virus disease leads to reduction in yield.
5. Combining ability analysis revealed significant differences for all the characters studied among parents and crosses. In parents vs. hybrids significant difference was observed for all characters except number of secondary branches and average green fruit weight.
6. The *sca* variance was greater than *gca* variance for all the characters indicating that non-additive gene action is predominant than additive gene action.

7. The line Pollakkada Local and the tester Neyyattinkara Local were good general combiners for fruit yield along with resistance to leaf curl virus disease.
8. Eight hybrids *viz.*, Jwalamukhi x Haripuram Local, Jwalamukhi x Neyyattinkara Local, Kottikulam Local x Alampady Local, Mangalapuram Local x Haripuram Local, Koothali Local x Haripuram Local, Koothali Local x Alampady Local, Pollakkada Local x Alampady Local, Pollakkada Local x Neyyattinkara Local exhibited significant *sca* effect for fruit yield. The cross combinations, Jwalamukhi x Haripuram Local, Jwalamukhi x Neyyattinkara Local, Kottikulam Local x Haripuram Local and Pollakkada Local x Alampady Local recorded significant desirable *sca* effect for vulnerability index.
9. Only three hybrids *viz.* Jwalamukhi x Neyyattinkara Local, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local exhibited significant standard heterosis for yield. Significant desirable standard heterosis for vulnerability index was expressed by six hybrids *viz.*, Jwalamukhi x Haripuram Local, Jwalamukhi x Neyyattinkara Local, Kottikulam Local x Haripuram Local, Kottikulam Local x Neyyattinkara Local, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local.
10. Considering *per se* performance, standard heterosis and *sca* effect of hybrids together, two hybrids Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local were chosen as the best hybrids.

In experiment III, generation mean analysis was done using two superior F_1 hybrids Pollakkada Local x Alampady Local (cross 1) and Pollakkada Local x Neyyattinkara Local (cross 2), their respective parents (P_1 and P_2) and the backcrosses (B_1 and B_2) and F_2 generations. These six populations were evaluated in randomized block design with three replications during summer 2003. Leaf curl virus incidence was ensured artificially by growing susceptible plants and releasing viruliferrous white flies in the experimental field. Through generation mean analysis additive, dominance and epistatic gene effects were estimated for 17 traits. The salient findings of generation mean analysis are summarized here under.

1. Significance of scaling tests indicated the presence of epistasis (non allelic interaction) for all the traits under study.
2. Major contribution of dominance, additive x additive and dominance x dominance in desirable direction was noted in Pollakkada Local x Alampady Local whereas only dominance effect was found to be significant in Pollakkada Local x Neyyattinkara Local for fruit yield per plant.
3. Significant and positive values for dominance, additive x additive, additive x dominance components were noticed in both the crosses for number of fruits per plant. In addition to that Pollakkada Local x Neyyattinkara Local exhibited significant and positive dominance x dominance effect for this trait.
4. Significant and positive dominance effect was noted in both the crosses for average green fruit weight. Among the interaction effects significant desirable dominance x dominance effect and additive x additive effect was observed for Pollakkada Local and Alampady Local respectively for this trait.
5. Dominance and dominance x dominance effect were significant and positive in Pollakkada Local x Alampady Local for fruit length whereas Pollakkada Local x Neyyattinkara Local had significant positive dominance x dominance effect for this trait.
6. Dominance and all the epistatic interactions were positive and significant in Pollakkada Local x Alampady Local for capsaicin content whereas only additive x dominance effect alone was significant and positive in Pollakkada Local x Neyyattinkara Local for this trait.

7. Significant and positive dominance and additive x additive effects were noted in Pollakkada Local x Alampady Local for oleoresin content. None of the genetic component was significant in the desirable direction in Pollakkada Local x Neyyattinkara Local for this trait.
8. Negative and significant additive x additive and additive x dominance effects were noticed in Pollakkada Local x Alampady Local for vulnerability index. Pollakkada Local x Neyyattinkara Local exhibited significant and negative additive x dominance effect for vulnerability index. This suggested that recurrent selection programme could be applied for improving leaf curl virus resistance.
9. Since predominant contribution of dominance and epistatic interaction components was noted for yield and major yield contributing characters recurrent selection or recombination breeding programme could be followed to exploit both additive and non-additive component for future breeding programmes.

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GENETIC ANALYSIS OF YIELD AND LEAF CURL VIRUS RESISTANCE IN CHILLI (*Capsicum annuum* L.)

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ABSTRACT

Chillies are the green and dried ripe fruits of *Capsicum annuum* L. or *Capsicum frutscens*. It forms an indispensable adjunct in every house in tropical world. It is specially liked for its pungency and spicy taste, besides the appealing colour it adds to the food. One of the important biotic stresses in this crop is the leaf curl disease virus caused by the chilli leaf curl virus, which causes considerable loss in yield. It is transmitted by the vector *Bemisia tabaci* and can be controlled by chemicals but harmful to health and environment. Due to this cultivation of chillies has become uneconomical particularly during summer season. There is an immediate need to develop leaf curl resistant varieties for summer cultivation. Hence the present investigation was undertaken on "Genetic analysis of yield and leaf curl virus resistance in Chilli (*Capsicum annuum* L.)" at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2003 with the objective of estimating the combining ability, heterosis and gene action involved in the inheritance of yield and leaf curl virus resistance.

Five susceptible high yielding lines Jwalamukhi, Kottikulam Local, Mangalapuram Local, Koothali Local and Pollakkada Local were crossed with three resistant testers Haripuram Local, Alampady Local and Neyyattinkara Local in L x T pattern and 15 F_1s thus produced were evaluated along with the parents in randomized block design. Analysis of variance revealed highly significant genotypic difference for all the characters studied.

The observations recorded were days to first flowering, days to 50 per cent flowering, number of primary branches, number of secondary branches, number of fruits per plant, average green fruit weight, fruit yield per plant, fruit length, fruit girth, number of seeds per fruit, hundred seed weight, plant height, duration of the crop, harvest index,

capsaicin content, oleoresin content and vulnerability index calculated on the basis of virus disease scoring. Variability studies indicated high GCV and PCV for the characters fruit yield, capsaicin content and vulnerability index.

High heritability coupled with high genetic advance were exhibited for all the characters excluding days to first flowering, days to 50 per cent flowering and duration of the crop. Fruit yield per plant showed significant positive genotypic correlation with primary and secondary branches, number of fruits per plant, green fruit weight, fruit length, fruit girth, number of seeds per fruit, plant height, harvest index, duration of the crop and capsaicin content. It had significant negative correlation with vulnerability index.

Combining ability analysis showed that the line Pollakkada Local and the tester Neyyattinkara Local were good general combiners for fruit yield along with leaf curl resistance. Significant desirable *sca* effect for fruit yield and vulnerability index was exhibited by three hybrids *viz.*, Jwalamukhi x Haripuram Local, Jwalamukhi x Neyyattinkara Local and Pollakkada Local x Alampady Local.

The hybrids Jwalamukhi x Neyyattinkara Local, Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local exhibited significant desirable standard heterosis for yield and vulnerability index.

Considering per se performance, standard heterosis and *sca* effect two hybrids Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local were chosen as the good hybrids.

Generation mean analysis was carried out using six-parameter model. Six generations *viz.* P_1, P_2, F_1, F_2, B_1, B_2 were built up among the crosses Pollakkada Local x Alampady Local and Pollakkada Local x Neyyattinkara Local. Presence of additive, dominance and epistatic interaction for all the characters indicated that recurrent selection or recombination-breeding programme can be followed for future breeding.