BREEDING FOR YIELD AND RESISTANCE TO CHILLI THRIPS (*Scirtothrips dorsalis* Hood) AND YELLOW MITE (*Polyphagotarsonemus latus* Banks) IN CHILLI (*Capsicum annuum* L.)

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DECLARATION

I hereby declare that this thesis entitled "**Breeding for yield and resistance to chilli thrips (*Scirtothrips dorsalis* Hood) and yellow mite (*Polyphagotarsonemus latus* Banks) 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled "**Breeding for yield and resistance to chilli thrips (*Scirtothrips dorsalis* Hood) and yellow mite (*Polyphagotarsonemus latus* Banks) in chilli (*Capsicum annuum* L.)**" is a record of research work done independently by Mr. Jayaramegowda, R. (2007-11-115) 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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Dedicated to

My Ever Loving Appa,

Amma,

And Brother M.K.Gowda

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%- Percent
^{0}C-Degree Celsius
ANOVA –Analysis of variance
CD – Critical Difference
cm- centimeter
d.f – degrees of freedom
et.al – And others
Fig. – figure
G – Gram
Gca- General combining ability
i.e – That is
KAU – Kerala Agricultural University
G – gram
Min – minute
ml-mili leter
Mse- error mean square
No. – number
NS- Not significant
Rpm – Rotation per minute
Sca- specific combining ability
SE- Standard error
SS – Sum of squares
Viz – namely
σ^2a-Additive variance
σ^2d-Dominance variance

INTRODUCTION

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the important commercial crop of India. It is a widely cultivated vegetable cum spice crop and plays an important role as a constituent in many of the world food industries (Bosland and Votava, 2000). It is a crop of tropical and subtropical regions and requires warm humid climate. The chillies are believed to be originated in the tropical America (Raju and Lukose, 1991) and known from pre-historic times in Peru. Columbus carried chilli seed to Spain in1493. The cultivation of chilli and capsicum spread rapidly from Spain to Europe. The crop was introduced to India by the Portuguese in the 16^{th} century AD and by the 19^{th} century its cultivation spread throughout the country.

Chilli is an indispensable condiment of every Indian household. It is used in the daily diet in one form or the other. It is a rich source of vitamin A and C with good medicinal properties. Among the spice consumed per head, dry chilli fruits constitute a major share. The pungency in chilli is due to the alkaloid 'capsaicinoid'. It occurs in the cores or septa walls and placenta.

India is the largest producer, consumer and exporter of chillies in the world. The total production in the country is around 8.46 lakh tonnes from 8.31 lakh ha (Rajur et al., 2008). The productivity is rather low at 1.11 tonnes per ha compared to the world average of 2 tonnes per ha. In India, chillies are grown in almost all states of the country. The important states growing chilli in terms of production are Andhra Pradesh (49%), Karnataka (15%), Orissa (8%), Maharashtra (6%), West Bengal (5%), Rajasthan (4%) and Tamil Nadu (3%).

The production and productivity of the crop are comparatively low in Kerala where only 465 ha area is under chilli cultivation.

The major reasons for the low productivity of chilli are the paucity of varieties adapted to different agro-climatic situations and growing conditions and the incidence of pest and diseases. Among the pests, chili thrips (*Scirtothrips dorsalis* Hood) and yellow mite (*Polyphagotarsonemus latus* Banks) are important not only as damaging pests but also as vectors of viral diseases. Use of resistant varieties is the simplest and more convenient method of pest control. Hence development of high yielding varieties resistant to major pests is of paramount importance.

Selection of parents on the basis of combining ability effects is a worthwhile approach in crop improvement. Application of biometrical technique; line x tester analysis appeared to be the best and vastly useful breeding tool, which gives generalized picture of genetics of the characters under study. Studies on combining ability help to identify the best parents and provide sufficient information on the inheritance of yield component characters and stress resistance. To develop varieties with high yield potential and resistance to chilli thrips and yellow mite, knowledge of the gene action involved in the inheritance of these characters and related traits is a prerequisite. Choice of breeding method depends upon the knowledge of the gene action involved in the characters under consideration.

Keeping in view the above mentioned aspects, the present investigation was undertaken with the following objectives:

- To study the combining ability variances and nature of gene action involved in inheritance of various yield related characters and resistance to thrips and yellow mites.
- To study the magnitude of heterosis of crosses for various yield related characters and resistance to thrips and yellow mite.
- To identify high yielding chilli hybrids resistant to chilli thrips and yellow mite.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study aimed at investigating the genetic basis of inheritance of yield related characters and resistance to chilli thrips and yellow mite in chilli through line × tester analysis and to identify high yielding hybrids tolerant to these pests.

Line × tester analysis is an important mating system enjoying universal application in Plant Breeding, because of its simplicity in both experiment and analysis. It provides useful information on components of variance, general combining ability (*gca*) and specific combining ability (*sca*) variances and their effects. Such studies are also useful in assessing heterosis for identifying promising crosses that can give transgressive segregants in later segregating generations. The literature pertinent to the study are reviewed under different headings.

2.1 Combining ability

Combining ability studies provide useful information for the selection of high order parents for effective breeding, besides elucidating the nature and magnitude of gene action involved in the inheritance of the character. Such informations are required to design efficient breeding programmes for rapid crop improvement. Sprague and Tatum (1942) recognized the combining ability in two classes viz., general and specific combining ability. General combining ability (*gca*) is the average performance of a genotype in a series of hybrid combinations and specific combining ability (*sca*) refers to those effects in specific combination which significantly departed from what would have been expected on the basis of average performance of the genotype involved. General combining ability is a measure of additive gene action and specific combining ability measures dominant gene action. The literature available on various aspects of chilli relating to the present investigation is reviewed here under.

Out of the 11 traits studied in a 11 × 11 half diallel cross by Khadi and Goud (1986), *gca* variances were found to be higher than *sca* variances for ten traits.

Joshi and Singh (1987) were of the opinion that *gca* estimates and per se performances are to be taken together when assessing the breeding value of a cultivar. Studying the F_1 and F_2 of a 9 × 9 diallel cross, they found *gca* to be predominant in the case of yield and yield related traits and hence straight forward selection was suggested for their improvement.

Seven genotypes were crossed in all possible combinations by Gaddagimath et al. (1988) and data were recorded for plant height, primary branches per plant, fruits per plant, average fruit weight and dry fruit weight per plant. The parents Jwala and K34-35 exhibited significant *gca* effects for most of the characters. A few cross combinations showed significant *sca* effects as well as reciprocal effects for yield and its components.

Sahoo et al. (1989) noticed predominant *gca* effects for plant height and hundred seed weight in combining ability evaluation of 45 F_2 hybrids from a diallel set of crosses involving 10 varieties. Variety BR Red had the highest *gca* for yield traits.

In a half diallel crosses of six chilli cultivars, Bhagyalakshmi et al. (1991) observed *gca* and *sca* effects with the latter predominating for days to 50 per cent flowering, fruit length, fruit girth, fresh fruit weight and 100 seed weight.

Mishra et al. (1991) crossed 10 chilli genotypes in diallel fashion without reciprocals and studied 45 F_1 hybrids along with parents. The best general combiners for most of the qualitative characters were J218 and BR Red. Pusa Jwala and Lam-x-235 were good general combiners for number of fruits per plant. Pusa Jwala × Sindhur exhibited significant *sca* effect for yield per plant.

Mulge (1992) from a study involving 18 × 3 line × tester cross, reported significant *sca* variances for number of branches. Pandian and Shanmugavelu (1992) crossed 15 chilli lines and six testers in a line × tester fashion and found close agreement between *gca* and per se performance for 10 agronomic traits and suggested that per se performance was a more reliable parameter than *sca* effect for hybrid selection.

In a line × tester analysis involving 20 lines and three testers, Jagadeesh (1995) observed high *gca* effects for number of branches and plant height while high *sca* effects was recorded for days to flower initiation, number of fruits per plant, fruit length, fruit width and fruit yield per plant.

Patil (1997) crossed 20 lines and three testers in a line × tester fashion and observed significant *gca* and *sca* effects for number of fruits per plant, average fruit weight, fruit width and number of seeds per fruit and later alone significant for number of branches, yield per plant, fruit length and capsaicin content.

Ahmed et al. (1997) studied six diverse sweet pepper lines viz., California Wonder, KSPS3, KSPA2, Arka Gaurav, World Peater and KSPS1 and their F_1 hybrids and reported that *gca* effects were more than *sca* effects for fruit length, fruit girth, seed number, fruit number and average fruit weight and hence these traits would respond favourably to direct selection. For plant height and fruit yield per plant *sca* effects were more than *gca* effects and heterosis breeding was suggested for their improvement.

Ahmed (1999) crossed six hot pepper cultivars in all possible combinations without reciprocals. Variances due to *gca* and *sca* were significant indicating the involvement of both additive and non additive gene effects in the expression of plant height, fruit girth, fruit length, average fruit weight, number of fruits and total yield per plant. Shalimar long and Elephant trunk recorded high *gca* effects for most of the characters, while Punjab Lal, G_4 and Pusa Jwala exhibited high *gca* effects for number of fruits per plant. Estimates of *sca* effects showed that Shalimar Long x Punjab Lal, Elephant trunk x Shalimar Long, Elephant trunk x Pusa Jwala and Shalimar Long x SPE-1 were promising cross combinations for yield and earliness.

Devi and Arumugam (1999) observed the role of additive and non additive gene action in the control of 23 agronomic and quality characters. Among the parents, the pungent chilli K2 was found to be good general combiner for three economic traits. In F_1 crosses, the hybrids with low × low, high × high, low × medium and high × medium *gca* parents exhibited high *sca* effects for nine characters indicating the role of additive and non additive gene actions.

Shukla et al. (1999) observed significant *sca* effects for number of branches, average fruit weight, fruit yield and plant height in a 3 × 8 line × tester analysis.

Yield and plant height were found to possess significant *sca* effects in a 6 × 6 diallel analysis by Ghandi et al. (2000).

A 10 x 10 diallel analysis by Lohithaswa et al. (2000) indicated that *gca* and *sca* effects were significant for days to flower initiation, fruit width and plant height while only *sca* effect was significant for yield per plant.

Jadhav et al. (2001) in a 6 × 2 line × tester analysis found significant *gca* and *sca* effects for number of fruits per plant, average green fruit weight, yield per plant and plant height.

Following a 6 × 6 diallel analysis, Nandadevi and Hosamani (2003) reported high *gca* and *sca* effects for days to 50 per cent flowering, number of fruits per plant, average fruit weight, seeds per fruit and yield per plant.

In a line × tester analysis involving five lines and three testers, Ajith (2004) observed high *gca* effects for fruit yield, number of seeds per fruit and number of fruits per plant while high *sca* effect was recorded for yield, number of seeds per fruit and percentage of disease incidence. High *gca* effects were observed for fruit yield, number of fruits per plant, average green fruit weight, fruit length, fruit girth, harvest index, capsaicin content and also for leaf curl incidence in chilli (Muthuswamy, 2004).

In a line × tester analysis involving five lines and nine testers, Saritha et al. (2005) observed high *sca* for all the characters which include plant height, number of primary branches, fruit length, number of fruits per plant, fresh and dry fruit yield per plant, number of seeds per fruit, ascorbic acid, capsanthin, oleoresin content and susceptibility to virus complex. High *gca* was also observed for all the characters except primary branches and number of seeds per fruit.

Srivastava et al. (2005) in 15 × 3 line × tester analysis found that among the three testers (Pusa Jwala, Pant Chilli-1 and Chanchal), Pant Chilli-1 exhibited high general combining ability effects for red ripe fruit yield per plant and several other characters, whereas Chanchal was identified as the best general combiner for capsaicin percentage. Among the 15 lines, 8803 Sel-12, Sel-7 and 399-5-2 were identified as good general combiners for red ripe fruit yield per plant and many other characters. The crosses Sel-7 × Pant Chilli-1 and Sel-12 × Pant Chilli-1 showed high specific combining ability effects for red ripe fruit yield per plant and several yield contributing traits.

Anand and Subbraman (2006) reported higher *sca* variances than *gca* variances for all the characters studied. Evaluation of 8 × 8 diallel full set comprising of 56 F_1 hybrids, Venkataramana et al. (2006) observed highly significant differences due to *gca*, *sca* and *rca* (reciprocal combining ability) effects for all the characters studied and suggested the choice of maternal parent for exploitation of appropriate gene effects.

Gondane et al. (2007) in a line × tester analysis found significant variation for *gca* for days to 50 per cent flowering, plant height, number of fruits per plant, ascorbic acid and wet red chilli yield per plant in female parents [CA-960, Jwala and AKC-86-25] and for ascorbic acid content and wet red chilli yield in male parents [GP-313, GP-22, GP-90]. Four hybrids viz., Jwala × GP-90, Jwala × GP-22, CA-960 × GP-22 and AKC-86-25 × GP-313 were found to have significant *sca* effects.

In a 6 × 6 diallel analysis, Haridass (2007) noticed high values of *gca* effects for fruit yield per plant, number of fruits per plant and incidence of anthracnose at 45 DAT and 60 DAT. High *sca* effects were recorded for fruit yield per plant, number of fruits per plant and vitamin C content.

In a line × tester analysis with 9 lines and 2 testers, Shekhawat et al. (2007) found that the lines Sel-54, 7722-1 and Sel. 16 were good general combiners for red ripe and dry fruit yield per plant whereas, cross combinations, viz., 2003 × 7950, Sel. 54-7950, Sel 16 × Sel. A-4 were best specific combiners for red-ripe yield and Sel. 54 × 7950, A-28 × Sel. A-4 and 7722-1 × 7950 were best specific combinations for dry fruit yield per plant and other yield contributing traits.

Kamble and Mulge (2008a) following a 18 × 3 line × tester analysis found that lines KCP04, KCP11, KCP13, KCP15 and testers were adjudged as superior performers for total yield per plant and fruit yield per hectare based on *gca* effects. The cross KCP01 × BL was found to be superior performer for total yield per plant and fruit yield per hectare based on *sca* effect.

In a line × tester analysis, Reddy et al. (2008) found that the parents Arka Lohit, SKAU-SC-965-5, GPC-82, SKAU-SC-1003 and SKAU-SC-304-1 were good general combiners for fruit yield per plant and GPC-82, SKAU-SC-618-2 and SKAU-SC-1005 for days to 50 per cent flowering. The hybrids SKAU-SC-1005 × Kiran, SKAU-SC-1003 × Arka Lohit, SKAU-SC-65-5 × Kiran, SKAU-SC-618-2 × GPC-82 and SKAU-SC-814-2 × GPC-82 were identified as good specific combiners for fruit yield per plant.

Chadchan (2008) found both *gca* and *sca* effects were significant for primary branches, fruit width, stalk length, stalk width, ascorbic acid content and per cent capsaicin from diallel analysis. Among six parents VN-2 and X-235 were good general combiners and Raichur local × VN-2, Raichur local ×

LAM-334, VN-2 × LAM-334 and X-235 × VN-2 were found to be having good *sca*.

In a diallel mating design involving six parental lines, Prasath and Ponnuswami (2008) found Byadagi Kaddi, MDUY and Arka Abir to be good general combiners for yield and quality characters. The cross MDU × CO4 had desirable significant *sca* effect for yield and quality characters like fresh yield, dry yield, total extractable colour and capsaicin.

In a line × tester analysis, Khereba et al. (2008) reported that the *gca* estimates for the parent PI 166988 indicated it as the best parent for early yield and *sca* estimates for the cross PI 166988 × PI 159236 showed that it was the best cross for plant height, number of days to flowering, average fruit weight, fruit length, fruit diameter and total yield.

Combining ability analysis by Jagadeesha and Wali (2008) indicated that the parents VN-2, B-Kaddi, Arka Lohit, Phule-5 and LCA-312 were good general combiners for fruit and seed characters.

2.2 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 influences the phenotypic expression of characters. Therefore the effect of individual genes must be considered using suitable statistical procedures to obtain genetic information.

Salazar and Vallejo (1990) observed significant difference between *gca* and *sca* effects and prominence of non-additive gene action in relation to yield per plant, fruit number and mean fruit weight in a diallel analysis consisting of seven parents. Ahmed et al. (1997) reported predominance of additive gene action for days to fruit set, fruit length, seed number, fruit number and fruit weight while non additive gene action was reported for plant height and fruit yield per plant.

Bhagyalakshmi et al. (1991) conducted a half diallel analysis using six chilli cultivars and inferred preponderance of non-additive gene action for days to 50 per cent flowering, fruit length, fruit girth and 100 seed weight among 13 characters studied.

Tavares et al. (1997) found that fruit number is controlled by non-additive gene action. Murthy and Desphande (1997) evaluated six generations of four F_1s for fruit number, fruit length and dry chilli yield and observed additive x dominance interaction but their degree differed with crosses.

Sundaram and Irulappan (1998) reported additive gene action for fruit length, fruit girth and number of fruits. Shukla et al. (1999) evaluated 24 F_1s from L × T design and observed non-additive gene action for fruit length and fruit girth. Non-additive gene action for yield and days to flowering was reported by Echevervi et al. (1999).

In a 6 × 6 diallel analysis, Devi and Arumugam (1999) found that additive gene action was more important than non additive gene action for all yield components except for fruit length. Lohithaswa et al. (1999) reported both additive and dominance for all characters except days to initiation of flowering and yield per plant. Ghandi et al. (2000) detected the involvement of both additive and non-additive gene action for expression of all characters.

Lohithaswa et al. (2001) from his diallel analysis excluding parents revealed preponderance of non-additive gene action for all the characters except fruit length and fruit diameter. Non-additive gene action was dominant over additive gene action for plant height, fruit number, fruit weight and fruit yield. Rajender et al. (2001) observed additive gene action for capsaicin content.

From a 10 × 10 half diallel analysis, Pandey et al. (2002) inferred non additive gene action for fruit yield and number of fruits. Rathod et al. (2002) indicated the presence of additive gene action for the number of fruits pr plant, fresh red chilli yield per plant and plant height.

Patel et al. (2002) observed the additive gene action in the inheritance of days to flower, plant height, fruit length, fruit girth and average fruit weight. Additive gene action was noticed for traits plant height, fruit length, fruit girth, individual green fruit weight, dry fruit weight and capsaicin content (Sathiyamurthy, 2002). Ahmed et al. (2003) indicated that fruit length and pericarp thickness were influenced by both additive and non-additive gene actions while plant height, number of branches, fruit girth, fruits per plant, fruit weight and yield per plant were influenced by non-additive gene action.

Doshi (2003) reported additive gene effects for plant height, fruit weight and capsaicin content and overdominance for days to flowering, number of primary branches, fruits per plant, fruit length, fruit girth and yield per plant.

Nandadevi and Hosamani (2003) observed preponderance of additive gene action for fruit length and seeds per fruit while predominance of non additive gene action for days to 50 per cent flowering, fruit diameter, green fruit weight, number of fruits and green fruit yield per plant.

Sousa and Maluf (2003), in diallel cross of hot pepper lines observed non-additive gene action for yield, capsaicin content and seeds per fruit.

Pandey et al. (2003) noticed preponderance of non additive gene action for the traits plant height, number of primary branches, secondary branches per plant, number of fruits per plant, fruit length, fruit width and yield per plant.

Gouda (2003) observed both additive and non additive components of genetic variance for plant height, number of secondary branches, plant spread and number of primary branches while high *gca* and *sca* was recorded for stem girth and height at first branching revealing the non additive type of gene action.

In a line × tester analysis of crosses involving four male sterile and twelve male parents, Patel et al. (2004) reported the existence of non additive gene action for the characters days to flowering, plant height, primary branches per plant, fruits per plant, fruit length, fruit weight, fruit girth and green fruit yield per plant.

In a generation mean analysis, Ajith (2004) observed additive and dominance × dominance interaction for number of fruits per plant, average green fruit weight, fruit weight per plant, fruit length and fruit girth.

Jagadeesha et al. (2004) estimated gene action using six generation mean analysis and found that dry fruit yield had higher magnitude of dominant gene action with duplicate epistasis compared to additive gene effects. Fruit quality traits like fruit length, fruit width, fruit weight, pericarp weight, ascorbic acid content and capsaicin content were under the control of additive type of gene action. While thrips and mite resistance was under the control of dominance, additive × additive and additive × dominance gene effects.

In a 7 × 7 half diallel cross, Philip (2004) observed the predominance of non additive gene action for days to 50 per cent flowering, plant height, primary branches per plant, secondary branches per plant, fruits per plant, yield per plant and capsaicin content. The study also indicated the equal importance of additive and non additive gene action for crop duration. Muthuswamy (2004) following generation mean analysis reported predominant contribution of dominance and epistatic interaction for yield and major yield contributing characters.

Srivastava et al. (2005), found that the non-additive gene action had greater role in the inheritance of most of the characters studied. For fruit length and red ripe fruit yield per plant, additive gene action played an important role.

Ajith and Manju (2006) reported predominance of additive gene action for fruits per plant, average green fruit weight, fruit weight per plant, fruit length and fruit girth while evaluating the 76 genotypes of *Capsicum annum*. Duntode et al. (2006) reported additive gene effects for green fruit yield, marketable yield of green fruits per plant, fruit length, ascorbic acid content, plant spread, diameter of the fruit and green fruits per plant.

In a line × tester analysis involving 14 parents and 45 F_1 hybrids, Anand and Subbaraman (2006) found the non additive gene effects for yield and its component characters. Sood et al. (2007) observed additive effect for capsaicin and marketable fruit yield per plant while evaluating 25 genotypes of bell pepper.

In a generation mean analysis, Jagadeesha and Wali (2006) found that Leaf Curl Index (LCI) for thrips was found to be predominantly under the control of non additive gene action with duplicate type of gene interaction whereas non additive gene interaction for LCI mites. In generation mean analysis, Kamboj et al. (2006) found that the additive gene action was involved predominantly in the inheritance of fruit length, fruit and seed weight of ten fruits, seeds per fruit and test weight.

A triallel analysis by Haridass (2007) revealed the predominance of dominance × dominance gene effect for fruit yield per plant, number of branches per plant, number of fruits per plant, average fruit weight, fruit length, fruit girth, harvest index and capsaicin while the traits viz., days to first flowering, plant height, number of seeds per fruit and incidence of anthracnose had additive × dominance type of epistatic effect.

In a generation mean analysis, Somashekar et al. (2008) reported for VN-2 × Arka Lohit, Byadagi Kaddi × Arka Lohit and Byadagi Dabbi × LCA-312 that the magnitude of dominance gene effect was greater than the magnitude of additive gene effect for dry fruit yield per plant.

Line × tester analysis by Reddy et al. (2008) indicated that *sca* variance was higher than *gca* variance for yield and yield contributing characters indicating the predominance of non additive gene action. In 6 × 6 diallel analysis, Prasath and Ponnuswami (2008) revealed the preponderance of additive gene action for all yield and quality characters except dry fruit yield per hectare and capsaicin.

From a diallel analysis, Chadchan (2008) found predominance of additive gene action for days to 50 per cent flowering, fruit length, fruit width, stalk length, stalk width, number of fruits per plant, green fruit yield per plant and ratio of fruit length to width.

Khereba et al. (2008) found that non-additive gene effect played major role in the inheritance of plant height, average fruit weight, fruit length, fruit diameter and total yield.

Jagadeesha and Wali (2008) observed higher proportion of additive gene effect for fruit related traits, while seed related traits were under the control of non-additive gene action.

2.3 Heterosis

Heterosis may be defined as the increase or decrease in vigour of F_1 population over mid parent (relative heterosis), better parent (heterobeltiosis) or a standard parent (standard heterosis) with respect to any character in the direction of breeders desire (Mandal, 1991). Heterosis breeding is a potential tool for achieving quantum jump in production and productivity. Hybrid vigour can be used as a guide for selecting promising recombinants in the subsequent generations to release the best variety when it attains homozygosity. To know the potential of hybrids, studies on the magnitude and direction of heterosis are very important. The first report on heterosis in chilli came from Deshpande (1933) who observed it for earliness, plant height, fruit girth, fruits per plant and yield per plant.

Bhagyalakshmi et al. (1991) observed negative heterosis in fourteen hybrids among fifteen for days to first flowering, relative heterosis for number of fruits and reported that LCA 208 × LCA 960, LCA 206 × LCA 1079, LCA 960 × X 235 and X 235 × G_4 exhibited greater heterosis value for fruit yield.

Singh et al. (1992) reported the highest of 122.86 per cent heterobeltiosis in the cross Tiwari × Jawahar-218 for number of fruits per plant and observed heterosis ranging from -36.85 per cent (Jull × Pusa Jwala) to 40.40 per cent (Jull × IC-851201) for fruit length.

Saraladevi (1994) recorded negative relative and standard heterosis for days to first flowering and recorded heterosis for plant height, number of primary branches, fruit length, fruit girth and fruit yield per plant.

Joshi et al. (1995) observed that only one hybrid showed significant difference for plant height in a diallel cross involving 12 × 12 purelines and reported heterosis of 75 and 68.60 per cent over the check and best variety respectively for fruit yield per plant.

Heterosis was high for total yield and average fruit weight during an evaluation of sweet pepper cross Fimentao × Pip and their F_1, F_2 and backcross generations (Mohamed et al., 1995).

Significant negative heterosis over better parent and the best parent was observed for plant height in the hybrid RHRC Clustered Pendent × CA59, while the other hybrids in the study exhibited significant positive heterosis (Anandanayaki, 1997).

Ahmed et al. (1999) crossed six hot pepper cultivars viz., Elephant trunk, Pusa Jwala, Shalimar long, SPE-1, Punjab Lal and G-4 in all possible combinations without reciprocals and found that the high heterosis over better parent for yield and earliness were for the crosses Shalimar long × Punjab Lal, Elephant trunk × Shalimar long and Shalimar long × SPE-1.

Doshi and Shukla (2000) observed negative heterosis for capsaicin in 43 hybrids whereas only one hybrid exhibited positive heterosis.

Out of 15 hybrids obtained from 6 × 6 diallel, four exhibited significant heterobeltiosis and 11 exhibited standard heterosis for dry fruit yield per plant (Ghandi et al., 2000). Hemavathy (2000) observed the highest positive relative heterosis of 245.65 per cent for number of fruits per plant in CA 133 × CA 100.

Malathi (2001) observed highly significant positive heterosis over the mid, better and best parents for number of fruits per plant, plant height and revealed a significant heterosis over mid, better and best parents in CA86-1 × CA84 for dry fruit weight and CA 86-2 × CA 84 for number of branches per plant.

Singh and Hundal (2001) found both positive and negative heterosis over the better parent for fruit yield per plant with the highest estimate of 108.17 per cent.

Sathiyamurthy (2002) reported significant negative heterosis in seven hybrids for plant height and relative heterosis in 13 crosses for number of branches per plant.

Muthuvel (2003) reported that the relative heterosis for plant height was highest in Arka Lohit × CHD8 (14.67 per cent) and the lowest in Ujwala × CHD (-12.14 per cent) in summer season. The heterobeltiosis estimates ranged from -15.32 per cent in Arka Lohit × CHD8 to 32.46 per cent in the Puhjab Lal × CC3 for fresh fruit weight. He found that the hybrid Ujwala × CHD8 exhibited positive heterosis over standard parent (75.66 per cent) for dry fruit yield. Relative heterosis for capsaicin was high (34.36 per cent).

Muthuswamy (2004) reported positive standard heterosis for number of branches per plant, fruit length, fruit girth, fruit yield per plant and recorded heterobeltiosis, relative and standard heterosis for capsaicin content.

In a line × tester analysis, Ajith (2004) reported positive heterosis for fruit girth and negative heterobeltiosis and standard heterosis for duration of the crop.

Philip (2004) reported significant positive heterosis for fruits per plant and fruit yield per plant while Shankaranag et al. (2005) reported negative heterosis for number of fruits per plant.

Kumar et al. (2005) crossed six inbreds in a 6 × 6 diallel fashion and observed that for capsaicin content relative heterosis ranged from -46.15 to 89.16 per cent and heterobeltiosis from -55.30 to 72.52 per cent.

In a line × tester analysis involving ten lines and three testers, Adpawar et al. (2006) reported among the 30 hybrids, three (CA-960 × GP-172, AK-8625 × GP-196 and AK-8625 × GP-198) consistently exhibited high heterosis for yield and yield component characters.

Shankarnag et al. (2006), following line × tester analysis involving three cytoplasmic genetic male sterile (CGMS) lines and seven testers reported that the cross L_5 × T_{14} was the most heterotic over check hybrids for early green fruit yield followed by L_3 × T_{14}.

Haridass (2007) studied 15 hybrids and their possible three way cross hybrids by triallel analysis and reported that the cross Jwalamukhi × Ujwala showed highest standard heterosis for number of fruits per plant, fruits yield per plant and capsaicin content. The three way cross hybrid, Vellayani Athulya × Ujwala × Jwalamukhi had high relative heterosis and heterobeltiosis for fruit yield per plant.

Kamble and Mulge (2008b) studied heterosis for 45 hybrids from line × tester mating design and found that the crosses KCPO2 × CW and KCPO9 × BL were superior over the commercial check with respect to total yield per plant and number of fruits per plant respectively.

Patel et al. (2008) studied heterosis for fruit yield and quality in crosses made using five cyloplasmic male sterile (CMS) lines and eight testers and found that hybrid ACMS-2 × LCA-206 exhibited the greatest significant positive heterosis over mid parent and better parent values; while ACMS-4 × GVC-101 and ACMS-2 × GVC-101 exhibited the highest significant positive heterosis and heterobeltiosis for chlorophyll and capsaicin content, respectively.

In a line × tester analysis involving 10 lines and four testers, Reddy et al. (2008) observed standard heterosis for total yield per plant, seed weight per fruit and growth parameters in the cross SKAU-SC-1003 × Arka Lohit, while the hybrid SKAU-SC-965-5 × GPC-82 showed significant standard heterosis for plant spread, number of fruits per plant, fruit length, fruit width, average fruit weight, pedicel length, pericarp thickness and number of seeds per fruit. Standard heterosis in desirable direction was recorded in twenty crosses for number of fruits per plant (Chadchan, 2008).

Prasath and Ponnuswami (2008) found that heterosis over best parent ranged from 40.35 to 126.32 per cent for dry yield per hectare. The hybrids Byadagi Kaddi × Arka Abir and MDUY × CO4 were superior with respect to total extractable colour, dry yield and yield contributing characters.

2.4 Chilli thrips and yellow mite

Chilli thrips, *Scirtothrips dorsalis* (Hood) and yellow mite, *Polyphagotarsonemus latus* (Banks) are two serious pests of chilli (Ananthakrishnan, 1973; Amin, 1979) both in the nursery and main field. Adults and nymphs suck the sap from tender leaves and growing shoot. Affected leaves curl either upward due to thrips or downward due to mite feeding resulting in damage called ‘chilli leaf curl’. The overall reduction of in yield of dry chilli ranges from 40 to 70 per cent due to the incidence of thrips and mites (Jagadesha et al. 2000). Chemical protection is not advisable on account of likely health hazards and environmental pollution. Application of chemical pesticides aggravate the problem of resurgence of chilli mite (David, 1991). So identification of sources of resistance has assumed great importance recently. Population count and damage intensity are the criteria usually adopted for evaluation of genotypes for resistance to these pests.

2.4.1 Description and biology of the pests and damage symptoms in chilli

Scirtothrips dorsalis is a polyphagous species with more than 100 recorded hosts from about 40 different families. This includes many crop plants such as amaranthus, cashew, groundnut, tea, chilli, citrus, soybean, tomato, tobacco, brinjal, mung bean and grapes. Field identification of chilli thrips is not easy due to its similarity with other thrips and often difficult to differentiate from other thrips in the field. Adult chilli thrips have a pale body with dark wings and are less than 2 mm in length. Nymphs of chilli thrips are pale in colour similar many other thrips species. Some of the distinguishing characteristics of chilli thrips are as follows: antennae are 8-segmented with segments 1-11 pale, III-VIII dark, head is pale in colour with three pairs of ocellar setae, fore wings are brown and paler distally (www.doacs.state.fl.us/pi/enpp/ento/chillithrips).

According to Amin and Palmer (1985) the duration of each life stage of chilli thrips is a follows: eggs 6-8 days, larval stage 6-7 days, pupal stage 2-3 days, adults up to 22 days with an average of 11 days. Reproduction is both sexually and parthenogenetically. It is mainly a foliage feeder. It spreads virus diseases in many crop plants (Rao et al., 2003; Campbell et al., 2005).

Scirtothrips dorsalis infestation results in upward curling of young top leaves in boat shaped manner and leaf lamina on both sides of the mid-rib becomes corrugated. Leaves become smaller, thickened and brittle. Stunting of plants occur due to severe infestation (Karmakar, 1995).

Yellow mites are much smaller in size compared to thrips. Adult female mites are about 0.2 mm long and oval in outline. Their bodies are swollen in profile and are light yellow to amber or green in colour with an indistinct median stripe that fork near the back end of the body. Males are similar in colour but lack the stripe. The two hind legs of the adult females are reduced to whip-like appendages. The male is smaller (0.11 mm) and faster moving than the female. Yellow mite has a wide host range. Food crops listed as hosts include: apple, avocado, cantaloupe, castor, chilli, citrus, coffee, cotton, eggplant, grapes, guava, jute, papaya, passion fruit, pear, potato, sesame, string or pole beans, mango, tea, tomato (Penna and Campbell, 2005).

The yellow mite has four stages in its life cycle: egg, larva, nymph and adult. Adult females lay 30 to 76 eggs (averaging five per day) on the underside of leaf and in the depressions of small fruit over an eight to 13-day period and then die. Adult males may live five to nine days. While unmated females lay male eggs, mated females usually lay four female eggs for every male egg. The egg hatch in two or three days and the larvae emerge from the egg shell to feed. Larvae are slow moving and do not disperse far. After two or three days, the larvae develop into a quiescent larval (nymph) stage. Quiescent female larvae become attractive to the males which pick them up and carry them to the new foliage. Males and females are very active, but the males apparently account for much of the dispersal of mite population in their frenzy to carry the quiescent female larvae to new leaves. When females emerge from the quiescent stage, males immediately mate with them.

Feeding by the mites cause downward rolling of leaves, elongation of the petiole of older leaves and clustering of tender leaves at the tip of the branches. The growth of the plant is arrested (Desai et al., 2006).

2.4.2 Sources of resistance to chilli thrips and yellow mite

Sanap and Nawale (1987) observed the number of *Scirothrips dorsalis* nymphs and *Polyphagotarsonemus latus* on 40 *Capsicum annuum* varieties and reported LIC 8 as resistant and Pant C1 and LEC 7 as moderately resistant to these pests.

In a field trial with several chilli varieties, Naitam et al. (1990) observed low leaf curl incidence by thrips and mites in chilli varieties Jwala and Pant CI. They also found that yield of these varieties were higher than the other varieties in the field trial.

Mallapur (2000) while evaluating 62 chilli genotypes for resistance to *Scirtothrips dorsalis* and yellow mite observed that 13 varieties showed lower percentage leaf curl due to these pests than local checks.

Tatagar et al. (2001) screened the 24 genotypes of chilli against chilli thrips and mites to identify sources of resistance in chilli. Cultivars Pant C1, LCA-304 and LCA-312 were found to be promising sources of resistance against thrips and mites.

Khalid et al. (2001) screened 77 chilli cultivars to identify yellow mite resistance sources. Based on population count, injury grade and damage index, these varieties were grouped into three categories (resistant, susceptible and highly susceptible). Nine cultivars namely, LCA235, LCA330, EC128946, cluster mutant, LIC19, LCA312, yellow anther mutant, LIC13 and LIC45 were considered as resistant.

Babu et al. (2002) screened 308 chilli varieties for resistance to chilli thrips and yellow mites and identified 17 promising types based on visual rating of leaf curl caused by thrips and mites. Most of the germplasm accessions reacted independently to leaf curl caused by thrips and mites. They found that one exotic entry (EC-391082, a paprika type) as resistant to leaf curl caused by both thrips and mites.

Echer et al. (2002) evaluated fifteen Capsicum accessions, one hybrid and four pepper cultivars in greenhouse for resistance to the broad mite and ranked the accession BGH/UFV 1774 (*C. annuum*) and BGH/UFV 5086 (*C. frutescens*) as resistant and highly resistant respectively to *Polyphagotarsonemus latus* under severe testing conditions.

Kalaiyarasan et al. (2002) showed that accession PS 64 recorded lower thrips population (0.47 and 0.81 thrips/leaf) in the field and in pot culture, respectively. Thrips infestation was lower in accessions PS 64, PS 69, PS 177, PS 166, PS 4, PS 171 and PS 173 in the range 12.9-17.4 per cent) compared to the other accessions.

Desai et al. (2006) screened 21 chilli genotypes against yellow mite and found ACG 77 to be promising on account of low pest population count and leaf curl intensity.

Ambika et al. (2008), screened sixteen cultivars in field condition for yellow mite resistance. Based on mean population count, intensity of leaf curling and grading index, cultivars Pusa Sadabahar and Pusa Jwala were identified as resistant to yellow mite.

Reddy et al. (2008), screened 50 genotypes to identify resistance source against chilli thris and mites. Based on population count and damage intensity, genotype HS-HP154 and DCL-352 were found tolerant to chilli thrips and mite respectively whereas the genotype Poonkulam local was resistant to both chilli thrips and yellow mite.

Chilli varieties Bhagyalakshmi (G_4), Kiran and Bhaskar were found to be tolerant to chilli thrips and yellow mite (www.ikisan.com).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken to estimate the combining ability and gene action for yield and resistance to chilli thrips and yellow mites by line x tester analysis and to identify high yielding hybrids resistant to these pests. The research work was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2008-09. The field study was conducted in two experiments viz.,

Experiment I – Crossing programme

Experiment II (a) – Evaluation parents and hybrids for yield

II (b) – Evaluation of parents and hybrids for resistance to chilli thrips (Plate 1) and yellow mite (Plate 2).

The details of the experiments conducted and the statistical analysis carried out are as follows.

3.1 EXPERIMENT I : CROSSING PROGRAMME

3.1.1 MATERIALS

The material for the study included five susceptible high yielding chilli genotypes and three chilli thrips and mite tolerant chilli genotypes selected as lines and testers respectively. The lists of the genotypes used as lines and testers are given in the Table 1.

3.1.2 METHODS

The five lines and three testers were raised in a crossing block. The seedlings were raised in pots. One month old seedlings were transplanted to the main field adopting a spacing of 45 x 45 cm. The parents were crossed in line x tester pattern to get fifteen hybrid combinations by adopting hand emasculation and pollination.

Table 1. Genotypes used as lines and testers and their important features

	Genotypes	Features
Lines	Anugraha (L_1)	• Plants are medium sized • Fruits are medium long, medium pungent, pendulous and light green in colour • Suitable for green chilli purpose
	Jwalamukhi (L_2)	• Plants are dwarf with moderate branching • Fruits are long, pendulous, succulent, dark green, wrinkled and with less pungency • Suitable for green chilli purpose
	Jwalasakhi (L_3)	• Plants are dwarf with moderate branching • Fruits are long, pendulous, succulent, sulphury green and low pungent. • Suitable for green chilli purpose.
	Ujwala (L_4)	• Plants are non spreading but highly branching acropetally centered on the primary branch. • Fruits are medium long, dark green and glossy at the immature stage, highly pungent and borne in clusters of 9-10. • Suitable for green chilli purpose
	Vellayani Athulya (L_5)	• Plants are medium sized with highly branching • Fruit are very long, pendulous, sulphury green and medium pungent • Mainly suitable for green chilli purpose

Table 1 Continued

	Genotypes	Features
Testers	Bhagyalakshmi (T_1)	• Plants are tall and dense • Fruits are olive green, calyx deeply shaped, medium pungent and turning dark red on ripening and • Suitable for both dry and green chilli purpose
	Bhaskar (T_2)	• Plants are compact type • Flowers with yellow anthers • Fruits are medium long, tip pointed, calyx deeply cup shaped and highly pungent • Suitable for dry chilli purpose
	Kiran (T_3)	• Plants are tall and dense • Fruits are light green and turning to light red on ripening, calyx is deeply cup shaped and highly pungent. • Suitable for dry chilli purpose.

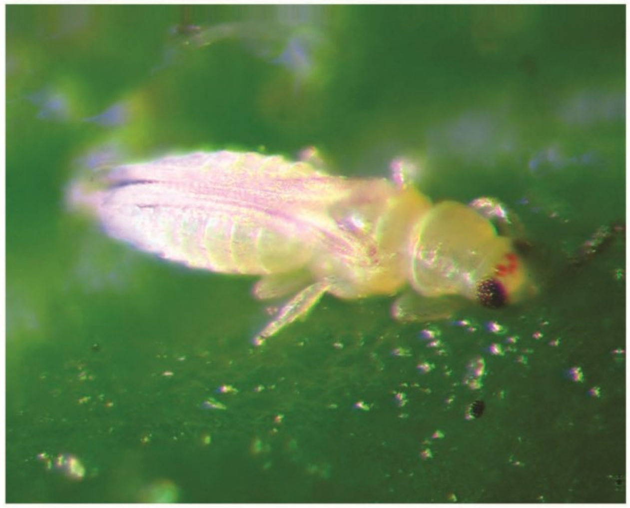


Plate 1. Chilli thrips (*Scirtothrips dorsalis* Hood)

Plate 2. Yellow mite (*Polyphagotarsonemus latus* Banks)

For crossing mature flower buds of female parents, flower which would open on the following day were selected and emasculated in the evening. Emasculation was done by opening the corolla and removing the anthers by holding the filaments with the help of forceps. The emasculated flower buds were covered with butter paper covers. The next day morning pollen from undehisced anthers of selected male parents were scooped out through the lateral sutures of anthers with a needle and transferred to the stigma of emasculated flowers of female parents. After pollination the flowers were covered with small butter paper covers and properly labeled indicating the crosses. The labels were retained till the fruits ripened. The labeled and ripe fruits were harvested and F_1 seeds were extracted.

3.2 EXPERIMENT II (a) – Evaluation of parents and hybrids for yield

3.2.1 Materials

The material for this experiment consisted of eight parents (5 lines and 3 testers) and the fifteen hybrids.

3.2.2 Methods

3.2.2.1 Layout and conduct of the experiment

The crop was raised in randomized block design with three replications during November 2008 to April 2009. The entire field was divided into three blocks of twenty three plots each and treatments (15 hybrids + 5 lines + 3 testers) were allotted to plots in each block at random. Plot size was 2.43 m^2. Spacing was 45 x 45 cm. Seedlings were raised in nursery beds and one month old seedlings were transplanted in the experimental plots at the rate of one seedling per pit. The crop was managed as per the package of practices recommendations of the Kerala Agricultural University (2007).

3.2.2.2 Observations

Data on the following characters were obtained from observations recorded on five randomly selected observation plants from each plot and working out the mean values.

a. Days to 50 % flowering

Number of days from sowing to flowering of 50 per cent of the plants were recorded.

b. Plant height (cm)

Height was measured from the base of the plant to the tip of the longest branch immediately before the last harvest of fruits.

c. Number of primary branches

The branches originating from the main stem were counted and recorded at the full maturity of the plant.

d. Number of secondary branches

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

e. Plant canopy width (cm)

Measured immediately after first harvest at the widest point.

f. Fruit bearing period

Number of days from first fruit set to last fruit formation.

g. Number of fruits per plant

Number of fruits harvested from each observation plant at each harvest was counted.

h. Green fruit yield per plant (g)

The weight of fresh fruits collected from the observation plants was recorded at each harvest. Total yield was obtained by adding the weight of fruits at each harvest.

i. Duration (days)

Number of days from sowing to the last harvest.

j. Fruit characters

The fruit characters, viz., fruit length (cm), fruit girth (cm) and fruit weight (g) were recorded from 10 randomly selected fruits at vegetable maturity stage collected at the second harvest from the five observation plants. Fruit length was measured from the point of attachment to the pedicel to the tip of the fruit. The circumference at the broadest part of the fruits selected for recording length was measured to obtain fruit girth. Fruit weight was the average weight of the ten fruits taken at random from the five observation plants.

k. Capsaicin content (%)

The capsaicin content of fruits was estimated by colorimetric method.

Procedure

Fruits harvested at red ripe stage were dried in a hot air oven at 50°C and powdered finely. A quantity of 0.5 g dry chilli powder was transferred to a volumetric flask into which 10 ml acetone was added and shaken it for 3 hours in a mechanical shaker. The contents were allowed to settle down. From this, 1 ml of the clear supernatant was pipetted into a test tube and kept in a hot water bath for evaporate to dryness. The residue was dissolved by adding 5 ml of 0.4 per cent sodium hybroxide solution and 3 ml of 3 per cent phosphomolybdic acid was added. The content was shaken and allowed to stand for 1 hour. The solution was filtered into centrifuge tubes and centrifuged at about 5000 rpm for 10-15 min. The clear blue coloured solution was transferred into the cuvette and the absorbance was recorded at 650 nm using spectrophotometer.

To determine the per cent value of pure capsaicin a stock solution of standard capsaicin was prepared by dissolving 50 mg capsaicin in 50 ml of 0.4 per cent sodium hydroxide solution (1000 μg/ml). From this stock solution a series of solutions of different concentrations were prepared and their absorbance read at 650 nm using spectrophotometer. A standard graph was prepared from which capsaicin content in the samples was found out.

3.2.2.3 Statistical Analysis

3.2.2.3.1 Combining ability analysis

Combining ability analysis of the Line x Tester was done through ANOVA technique (Dabholkar, 1992) as follows (Table 2).

Table 2. Analysis of variance for line x tester design

Source	df	SS	MS	Expected mean square
Replication	r – 1	SSR	MSR	
Genotypes	n – 1	SSG	MSG	
Parents	(l + t) – 1	SSP	MSP	
Parents vs. crosses	1	SSO	MSO	
Crosses	l x t – 1	SSC	MSC	
a. Lines	l – 1	SSL	M_L	$\sigma^2 e + r\sigma^2 sca + rt\sigma^2 gca$
b. Testers	t – 1	SST	M_T	$\sigma^2 e + r\sigma^2 sca + rl\, \sigma^2 gca$
c. Line x Tester	(l – 1) (t – 1)	SSLT	M_{LT}	$\sigma^2 e + r\sigma^2_{sca}$
Error	(n – 1) (r – 1)	SSE	M_e	σ^2_e
Total	nr – 1			

Where, n = number of treatment materials l + t + l x t

r = number of replications

l = number of lines

t = number of testers

3.2.2.3.1.1 Estimation of General and Specific Combining Ability Effects

General combining ability effect (*gca*) of parents and specific combining ability effect (*sca*) 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} hybrid.

i = 1, 2, …, l

j = 1, 2, …, t

k = 1, 2, …, r

The individual effects were estimated as follows:

(i) Mean = $\dfrac{X\ldots}{rlt}$

(ii) *gca* effect of lines = $\dfrac{X_{i\ldots}}{rt} - \dfrac{X\ldots}{rlt}$

(iii) *gca* effect of testers = $\dfrac{X_{.j.}}{rl} - \dfrac{X\ldots}{rlt}$

(iv) *sca* effect of hybrids = $\dfrac{X_{ij.}}{r} - \dfrac{X_{i..}}{rt} - \dfrac{X_{.j.}}{rl} + \dfrac{X\ldots}{rlt}$

where,

$X_{...}$ = sum of all hybrids over 'r' replications.

$X_{i..}$ = sum of all hybrids involving i^{th} line over 't' tester and 'r' replications

$X_{.j.}$ = sum of all hybrids involving j^{th} tester over 'l' lines and 'r' replications

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

The significance of combining ability effects was tested by computing values as effects/SE of the effect and were compared with table 't' values at error degree of freedom at five per cent level of significance.

(i) SE of gca (lines) $= \sqrt{\dfrac{M_e}{rt}}$

(ii) SE of gca (testers) $= \sqrt{\dfrac{M_e}{rl}}$

(iii) SE of sca (hybrids) $= \sqrt{\dfrac{M_e}{r}}$

3.2.2.3.1.2 Combining Ability Analysis

The GCA variance for lines and testers and SCA variance for the hybrids were calculated as follows:

$$\sigma^2 \text{ GCA (lines)} = \frac{M_L - M_{LT}}{rt} = \text{Cov. H.S. (lines)}$$

$$\sigma^2 \text{ GCA (testers)} = \frac{M_T - M_{LT}}{r \times l} = \text{Cov. H.S. (testers)}$$

$$\sigma^2 \text{ SCA (hybrids)} = \frac{M_{LT} - M_e}{r}$$

3.2.2.3.1.3 Gene Action

After estimating the variances due to gca (σ^2 GCA) and sca (σ^2 SCA) the gene action was worked out as:

When F = 1

σ^2 GCA = ½ σ^2 A

σ^2 SCA = 2 σ^2 D

So, σ^2 A = 2 σ^2 GCA

σ^2 D = ½ σ^2 SCA

3.2.2.3.1.4 Proportional Contribution of Lines, Testers and Line x Tester interaction to the Total Sum of Squares of the Hybrids

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

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

$$\text{Contribution of lines} \times \text{testers} = \frac{\text{S.S. (line x tester)}}{\text{S.S. (hybrids)}} \times 100$$

3.2.2.3.2 Estimation of Heterosis

Heterosis (expressed in percentage) was estimated for all the characters over mid parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis) as suggested by Rai (1979).

3.2.2.3.2.1 Relative Heterosis

Relative heterosis was estimated as the percentage deviation of the mean performance of F_1 ($\overline{F_1}$) over the mean performance of the parents ($\overline{MP}$).

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

where, $\overline{MP}$ mid parental mean value

$\overline{F_1}$ = average of performance of F_1

3.2.2.3.2.2 Heterobeltiosis

Heterobeltiosis was estimated in comparison to the better parent as

$$\text{Heterobeltiosis (HB)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\overline{BP}$ = better parental mean of a particular cross.

3.2.2.3.2.3 Standard Heterosis

Standard heterosis was estimated in comparison to the standard variety (Jwalasakhi) as

$$\text{Standard heterosis (HB)} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

Where, $\overline{SP}$ mean of the standard variety.

The significance of different types of heterosis was tested by 't' test with (n – 1) (r – 1) degrees of freedom. The critical difference (CD) for comparison of differences of F_1 is

$$F_1 \text{ with } \overline{MP} \text{ is } = t_{\alpha}\sqrt{\frac{3\,M_e}{2r}}$$

$$F_1 \text{ with } \overline{BP} \text{ is } = t_{\alpha}\sqrt{\frac{2\,M_e}{r}}$$

$$F_1 \text{ with } \overline{SP} \text{ is } = t_\alpha \sqrt{\frac{2 M_e}{r}}$$

where t_α is table value of student's 't' distribution at five per cent level for (n – l) (r – l) df.

3.3. EXPERIMENT II (b) – Evaluation of parents and hybrids for resistance to chilli thrips and yellow mite

3.3.1 Materials

The material for this experiment consisted of eight parents (5 lines and 3 testers) and fifteen line x tester hybrids.

3.3.2 Methods

3.3.2.1 Layout and conduct of experiment

The crop was raised in randomized block design with three replications during November 2008 to April 2009. The entire field was divided into three blocks of twenty three plots each and treatments were allotted to plots in each block at random. Plot size was 2.43 m^2 with spacing of 45 x 45 cm. The crop was managed as per the package of practices recommendations of the Kerala Agricultural University, 2007. However, application of insecticides in the field was avoided taking into consideration of the possible interference with the population build up of the target pests in the experimental plots.

3.3.2.2 Observations

3.3.2.2.1 Evaluation for resistance to thrips

a. Number of thrips per leaf

Number of thrips from three leaves per plant, one each from top, middle and bottom regions of five plants selected at random was counted using stereobinocular microscope in laboratory. Adults are swift in movement and fly away while counting. Therefore to avoid errors in thrips count only nymphs were considered for recording observations. The first observation was taken at 30 days after transplanting (DAT) and thereafter at 45 and 60 DAT.

b. Intensity of damage by thrips infestation:

Five plants were selected at random from each plot and scored on the basis of intensity of damage to leaves on 0-4 scale as given below (Plate 3). The first observation was recorded at 30 days after transplanting and thereafter at 45 and 60 DAT.

Damage score	Symptoms
0	No leaf curl incidence (Healthy plant)
1	<25 % leaves showing upward curling in a plant
2	26-50 % leaves showing upward curling in a plant
3	51 to 75 % leaves showing upward curling in a plant
4	>75 % leaves showing upward curling in a plant

The damage intensity of thrips was calculated taking the sum of the product of number of plants and concerned category score and dividing the sum by the total number of plants scored.

3.3.2.2.2 Evaluation of resistance to mite

a. Number of mites per leaf:

Number of mites on six terminal leaves of five randomly selected plants in each plot was counted using stereobinocular microscope in laboratory. The first observation was taken at 30 days after transplanting and thereafter twice at fortnightly intervals (45 and 60 DAT).

b. Intensity of damage by mite infestation

Five plants were selected from each plot and scored for leaf curl symptoms following a 0-4 scale proposed by Desai et al. (2006) described below.

Plate 3. Damage score for chilli thrips

Damage score	Symptoms
0	No leaf curl incidence
1	<25 % leaves showing downward curling in a plant
2	26-50 % leaves showing downward curling in a plant
3	51 to 75 % leaves showing downward curling in a plant
4	>75 % leaves showing downward curling in a plant

The damage intensity of mite was calculated taking the sum of the product of number of plants and concerned category score and dividing the sum by the total number of plants scored (Thania and Giraddi, 2005).

Further data on plant height, primary branches, fruits per plant and yield were also collected as descended in section 3.2.2.2. Observation on the incidence of other pests and diseases in the field was also recorded.

3.3.2.3 Statistical analysis

The data on population count and damage intensity were subjected to the following statistical analyses.

3.3.2.3.1 Analysis of variance

The data on population count and damage intensity of thrips and mites at periodical observations were subjected to analysis of variance. Data on population count and damage intensity were subjected to $\sqrt{x + 1}$ transformation to satisfy the basic assumptions in ANOVA (Panse and Sukhatme, 1985).

3.3.2.3.2 Combining ability and gene action

Combining ability and gene action for resistance to chilli thrips and mite was worked out as like in experiment II (a).

RESULTS

4.RESULTS

Fifteen hybrids derived from crosses between five lines and three testers were evaluated along with their parents for combining ability and heterosis for yield and resistance to chilli thrips and yellow mite. The results of the experiment are presented under two headings:

(i) Evaluation of genotypes for yield and yield components

(ii) Evaluation of genotypes for resistance to chilli thrips and yellow mite.

4.1 Evaluation of genotypes for yield and yield components

The data on morphological and yield characters were collected from the field experiment and were subjected to line x tester analysis. The abstract of ANOVA of all the characters are represented in Table 3. Analysis of variance showed that the genotypes are significantly different for all the characters viz., days to 50 per cent flowering, plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period, number of fruits per plant, fruit length, fruit girth, fruit weight, green fruit yield per plant, duration and capsaicin content. The lines were significantly different for fruit length, fruit girth, fruit weight and green fruit yield per plant, while testers were significantly different for number of secondary branches. Line x tester interaction was significant for all the characters. ANOVA revealed significant differences among parents for all the characters whereas the hybrids differed significantly except for fruit girth.

4.1.1 Mean performance

The mean performance of lines, testers and their hybrids for different characters are presented in Table 4 and 5.

Table 3 Abstract of ANOVA of the characters (MSE)

Source	df	Days to 50 % flowering	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant canopy width (cm)	Fruit bearing period (days)	Number of fruits per plant
Genotypes	22	65.36**	122.20**	7.01**	70.28**	69.98**	189.55**	2296.44**
Lines	4	19.88	89.19	7.83	118.64	7.86	95.74	3347.14
Testers	2	7.35	187.50	2.06	13.72	0.66	80.80	158.72
L x T	8	47.05**	58.14**	6.19**	52.22**	51.21**	76.73**	1880.32**
Parents	7	114.00**	213.04**	5.30**	31.01**	57.43**	392.72**	1409.87**
Crosses	14	33.61**	85.49**	6.07**	65.70**	31.60**	82.75**	2053.47**
Parent Vs Crosses	1	169.33**	0.23	32.12**	409.35**	695.18**	262.56**	11904.13**
Error	44	15.72	8.87	0.11	1.73	4.53	9.74	66.64

**Significant at 1 per cent level, * Significant at 5 per cent level

Table 3 continued

Source	df	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green fruit yield per plant (g)	Duration (days)	Capsaicin content (%)
Genotypes	22	9.05**	2.02*	19.50**	46061.82**	235.24**	0.033**
Lines	4	18.51**	5.30*	48.51**	67932.00*	138.78	0.010
Testers	2	0.16	0.39	0.72	6382.50	84.00	0.031
L x T	8	2.11**	0.27**	1.58**	12322.63**	140.67**	0.019**
Parents	7	11.18**	2.90*	31.53**	45972.22**	468.32**	0.061**
Crosses	14	6.52**	1.73	14.86**	27362.43**	132.04**	0.018**
Parent Vs Crosses	1	29.63**	0.02	0.15	308480.50**	48.63**	0.031
Error	44	0.09	0.01	0.14	1029.82	14.51	0.0001

**Significant at 1 per cent level, * Significant at 5 per cent level

4.1.1.1 Days to 50 per cent flowering

All the lines and testers were not significantly different. Among crosses, L_1 x T_3 (69.00) was earliest to flower which was on par with L_1 x T_1 (71.00), L_2 x T_3 (71.00), L_3 x T_2 (70.67), L_3 x T_3 (74.00), L_4 x T_1 (72.00), L_5 x T_2 (71.00) and L_5 x T_3 (75.00).

4.1.1.2 Plant height (cm)

There was no significant difference between the lines as well as testers with respect to plant height. However, the crosses were significantly different. The cross L_2 x T_1 was the tallest (67.52) which was significantly different from other crosses. The minimum plant height was noted for L_2 x T_2 (47.12) which was on par with L_1 x T_1, L_1 x T_2, L_1 x T_3 and L_5 x T_2.

4.1.1.3 Number of primary branches

Number of primary branches was not significantly different for lines as well as testers. Among the crosses, L_1 x T_3 (8.12) had maximum number of primary branches which was on par with L_4 x T_2 (7.93) and the hybrids L_3 x T_2 (3.53) and L_3 x T_3 (3.92) were showed lowest value.

4.1.1.4 Number of secondary branches

The lines and testers were not significantly different for number of secondary branches. The hybrid L_1 x T_3 (28.92) recorded maximum number and was significantly different from other hybrids. The minimum value was recorded for L_4 x T_3 (14.47) which was on par with L_2 x T_1, L_2 x T_2, L_3 x T_2 and L_4 x T_1.

4.1.1.5 Plant canopy width (cm)

There was no significant difference between the lines and testers for plant canopy width. The cross L_4 x T_2 had maximum canopy width (57.93) which was on par with L_2 x T_3 and the minimum value was noted for L_4 x T_3 (46.61) and was on par with L_1 x T_1, L_4 x T_1, L_5 x T_2 and L_5 x T_3.

Table 4 Mean performance of lines and testers for various characters

Treatments \ Characters	Days to 50 % flowering	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant canopy width (cm)	Fruit bearing period (days)	Number of fruits per plant
Line							
Anugraha (L_1)	77.67	44.62	3.44	11.88	43.75	60.53	91.16
Jwalamukhi (L_2)	72.33	47.67	3.89	16.26	42.81	65.08	108.67
Jwalasakhi (L_3)	79.00	47.04	3.60	14.81	38.47	64.00	109.22
Ujwala (L_4)	87.00	50.25	5.27	20.30	38.66	56.33	132.11
Vellayani Athulya (L_5)	66.33	51.32	6.19	20.49	43.29	74.42	69.22
Tester							
Bhagyalakshmi (T_1)	77.33	64.37	3.46	12.84	47.89	71.85	99.25
Bhaskar (T_2)	81.00	63.72	6.10	15.06	49.94	91.87	137.07
Kiran (T_3)	80.67	63.88	2.70	13.71	48.78	78.92	103.28
SE±	2.29	1.72	0.19	0.76	1.23	1.80	4.71
CD	-	-	-	2.16	-	-	-

Table 4 continued

Characters / Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green fruit yield per plant (g)	Duration (days)	Capsaicin content (%)
Line Anugraha (L_1)	8.65	3.25	3.13	226.53	144.72	0.239
Jwalamukhi (L_2)	8.31	4.64	5.85	502.70	160.92	0.129
Jwalasakhi (L_3)	8.41	4.87	6.31	506.86	162.67	0.143
Ujwala (L_4)	5.34	3.16	2.86	224.94	150.59	0.345
Vellayani Athulya (L_5)	12.48	6.26	13.46	442.08	168.58	0.220
Tester Bhagyalakshmi (T_1)	9.06	4.71	6.02	402.76	167.81	0.248
Bhaskar (T_2)	8.26	4.43	5.96	552.56	185.08	0.511
Kiran (T_3)	8.58	4.14	6.53	406.89	171.08	0.472
SE±	0.17	0.07	0.21	18.53	2.20	0.002
CD	0.49	0.19	0.61	52.67	-	-

Plate 4. Fruits of parents

4.1.1.6 Fruit bearing period (days)

The lines and testers were not significantly different for fruit bearing period. The cross L_3 x T_2 (74.08) had long fruit bearing which was on par with L_1 x T_1, L_2 x T_1, L_2 x T_2, L_3 x T_1 and L_5 x T_1. The cross L_5 x T_2 had short fruit bearing period (57.71) which was on par with L_1 x T_2, L_2 x T_3, L_4 x T_1 and L_4 x T_3.

4.1.1.7 Number of fruits per plant

There was no significant difference among the lines and testers for number of fruits per plant. The hybrid L_1 x T_3 (190.56) was outstanding with respect to number of fruits per plant followed by L_4 x T_2 (174.42) and L_4 x T_1 (162.72). The cross L_3 x T_3 (108.28) gave the lowest number of fruits which was on par with L_2 x T_1, L_2 x T_2, L_3 x T_2, L_4 x T_3, L_5 x T_1, L_5 x T_2 and L_5 x T_3.

4.1.1.8 Fruit length (cm)

Fruit length was maximum for Vellayani Athulya (12.48) and minimum for Ujwala (5.34) among the lines. The testers were not significantly different with respect to fruit length (Plate 4). The cross L_5 x T_2 (12.58) had longest fruit followed by L_5 x T_3 and the lowest value was recorded for L_2 x T_1 (7.90) which was on par with L_4 x T_2 (Plate 5).

4.1.1.9 Fruit girth (cm)

The highest fruit girth was recorded for Vellayani Athulya (6.26) and lowest for Ujwala (3.16) which was on par with Anugraha among lines. The testers were not significantly different for fruit girth (Plate 4). The hybrid L_5 x T_2 (5.74) had highest fruit girth and L_1 x T_2 (3.40) had lowest value followed by L_1 x T_1 (Plate 5).

4.1.1.10 Fruit weight (g)

While considering lines, Vellayani Athulya (13.46) had significantly high fruit weight and Ujwala (2.86) had low fruit weight which was on par

Table 5 Mean performance of hybrids for various characters

Characters / Treatments	Days to 50 % flowering	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant canopy width (cm)	Fruit bearing period (days)	Number of fruits per plant
$L_1 \times T_1$	71.00	50.53	5.24	20.02	50.12	69.57	122.42
$L_1 \times T_2$	76.67	50.26	5.75	24.94	50.32	62.03	157.89
$L_1 \times T_3$	69.00	47.76	8.12	28.92	52.60	64.61	190.56
$L_2 \times T_1$	78.67	67.52	5.36	15.67	52.97	72.89	110.45
$L_2 \times T_2$	77.67	47.12	4.24	16.29	47.86	70.83	116.00
$L_2 \times T_3$	71.00	58.64	4.42	21.27	55.01	61.30	139.42
$L_3 \times T_1$	77.00	55.94	7.03	22.38	51.92	70.69	142.67
$L_3 \times T_2$	70.67	47.38	3.53	15.23	49.93	74.08	113.80
$L_3 \times T_3$	74.00	53.82	3.92	18.85	52.16	67.75	108.28
$L_4 \times T_1$	72.00	54.44	6.20	14.57	47.17	58.50	162.72
$L_4 \times T_2$	76.00	54.64	7.93	24.37	57.93	68.78	174.42
$L_4 \times T_3$	79.33	55.83	4.88	14.47	46.61	62.17	120.36
$L_5 \times T_1$	76.67	56.96	7.12	25.90	53.24	70.18	112.44
$L_5 \times T_2$	71.00	51.30	6.32	24.41	47.31	57.71	119.39
$L_5 \times T_3$	75.00	57.84	6.38	24.17	47.81	63.07	116.56
SE±	2.29	1.72	0.19	0.76	1.23	1.80	4.71
CD	6.51	4.89	0.54	2.16	3.49	5.12	13.40

Table 5 Continued

Characters / Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green fruit yield per plant (g)	Duration (days)	Capsaicin content (%)
$L_1 \times T_1$	9.79	3.50	4.07	514.39	160.11	0.118
$L_1 \times T_2$	10.67	3.40	4.24	511.34	154.11	0.325
$L_1 \times T_3$	11.17	3.67	4.76	572.44	155.94	0.263
$L_2 \times T_1$	7.90	4.11	4.82	437.08	168.89	0.161
$L_2 \times T_2$	9.34	5.00	6.36	501.94	165.25	0.408
$L_2 \times T_3$	8.12	4.29	5.29	501.92	155.01	0.150
$L_3 \times T_1$	11.19	4.88	7.13	599.56	165.19	0.163
$L_3 \times T_2$	9.84	4.81	6.20	503.75	165.92	0.211
$L_3 \times T_3$	9.71	5.34	6.33	576.67	169.11	0.250
$L_4 \times T_1$	9.60	3.95	4.37	483.14	152.11	0.276
$L_4 \times T_2$	8.19	3.80	4.12	536.75	168.00	0.364
$L_4 \times T_3$	8.62	4.12	4.82	416.39	159.56	0.308
$L_5 \times T_1$	11.14	4.96	9.81	628.19	175.17	0.222
$L_5 \times T_2$	12.58	5.74	11.18	805.28	159.66	0.212
$L_5 \times T_3$	12.32	5.51	9.01	639.45	158.47	0.275
SE±	0.17	0.07	0.21	18.53	2.20	0.002
CD	0.49	0.19	0.61	52.67	6.25	0.005

Plate 5. Fruits of hybrids

with Anugraha. No significant difference was observed for testers, the value ranged from 5.96 (Bhaskar) to 6.53 (Kiran).

Among crosses, L_5 x T_2 (11.18) exhibited maximum value whereas minimum value was shown by L_1 x T_1 (4.07) which was on par with L_1 x T_2, L_4 x T_1 and L_4 x T_2.

4.1.1.11 Green fruit yield per plant (g)

The lines, Jwalasakhi (506.86) and Jwalamukhi (502.70) were high yielding and Ujwala (224.94) and Anugraha (226.53) were low yielding genotypes. There was no significant differences among testers for green fruit yield per plant. Among hybrids L_5 x T_2 (805.28) and L_4 x T_3 (416.39) were the highest and lowest yielders respectively.

4.1.1.12 Duration (days)

No significant difference was observed for both lines and testers. Among crosses, short duration was noted for L_4 x T_1, L_1 x T_2, L_1 x T_3 and L_2 x T_3. The maximum value was noted for L_5 x T_1 (175.17).

4.1.1.13 Capsaicin content (%)

Capsaicin content was not significant among lines and testers. Among hybrids, L_2 x T_2 (0.408) and L_1 x T_1 (0.118) recorded maximum and minimum value.

4.1.2 Combining ability and gene action

The data on different characters were subjected to line x tester analysis to study the gene action in terms of general combining ability and specific combining ability effects.

4.1.2.1 General combining ability effects

The general combining ability effects calculated for each parent are presented in Table 6 and Fig. (1 & 2).

Table 6 General combining ability of lines and testers

Treatments \ Characters	Days to 50 % flowering	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant canopy width (cm)	Fruit bearing period (days)	Number of fruits per plant
Line							
Anugraha (L_1)	-2.16	-4.48**	0.61**	3.85**	0.15	-0.87	23.13**
Jwalamukhi (L_2)	1.40	3.76**	-1.09**	-3.04**	1.08	2.06	-11.87**
Jwalasakhi (L_3)	-0.49	-1.62	-0.94**	-1.87**	0.47	4.56**	-12.24**
Ujwala (L_4)	1.40	0.97	0.56**	-2.98**	-0.29	-3.13**	18.68**
Vellayani Athulya (L_5)	-0.16	1.37	0.84**	4.04**	-1.41	-2.63*	-17.69**
SE±	1.32	0.99	0.11	0.44	0.71	1.04	2.72
Tester							
Bhagyalakshmi (T_1)	0.69	3.08**	0.43**	-1.08**	0.22	2.09*	-3.68
Bhaskar (T_2)	0.02	-3.86**	-0.21*	0.32	-0.19	0.41	2.48
Kiran (T_3)	-0.71	0.78	-0.22*	0.75*	-0.03	-2.50**	1.21
SE±	1.02	0.77	0.08	0.34	0.55	0.81	2.11

**Significant at 1 per cent level, * Significant at 5 per cent level

4.1.2.1.1 Days to 50 per cent flowering

General combing ability effects of lines varied from -2.16 (Anugraha) to 1.40 (Jwalamukhi and Ujwala) and for testers it varied from -0.71 (Kiran) to 0.69 (Bhagyalakshmi). None of the lines or testers exhibited significant *gca* effects.

4.1.2.1.2 Plant height (cm)

General combining ability effects of lines varied from -4.48 (Anugraha) to 3.76 (Jwalamukhi). Jwalamukhi (3.76) showed significant positive *gca* effect whereas Anugraha (-4.48) showed significant negative *gca* effect. Among the testers, Bhagyalakshmi (3.08) showed significant positive *gca* effects whereas Bhaskar (-3.86) showed significant negative *gca* effect.

4.1.2.1.3 Number of primary branches

Significant *gca* effects were observed for all the lines. The *gca* effect was positive for Vellayani Athulya (0.84) which was on par with Anugraha (0.61) and Ujwala (0.56) while *gca* effects were negative direction for Jwalamukhi (-1.09) and Jwalasakhi (-0.94). Among the testers Bhagyalakshmi (0.43) showed significant positive *gca* effect whereas Bhaskar (-0.21) and Kiran (-0.22) showed significant negative *gca* effects.

4.1.2.1.4 Number of secondary branches

Among lines Anugraha (3.85) and Vellayani Athulya (4.04) had significant positive *gca* effects while Jwalamukhi (-3.04), Jwalasakhi (-1.87) and Ujwala (-2.98) had significant negative *gca* effects. In the tester group, Kiran (0.75) exhibited significant positive *gca* effect whereas Bhagyalakshmi (-1.08) exhibited significant negative *gca* effect.

4.1.2.1.5 Plant canopy width (cm)

None of the lines and testers showed significant *gca* effects for plant canopy width.

Table 6 Continued

Characters / Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green fruit yield per plant (g)	Duration (days)	Capsaicin content (%)
Line						
Anugraha (L_1)	0.53**	-0.94**	-1.81**	-15.83	-5.45**	-0.009**
Jwalamukhi (L_2)	-1.56**	0.02	-0.67**	-68.24**	0.88	-0.004**
Jwalasakhi (L_3)	0.23*	0.54**	0.39	11.44	4.57**	-0.036**
Ujwala (L_4)	-1.21**	-0.54**	-1.73**	-69.79**	-2.28	0.056**
Vellayani Athulya (L_5)	2.00**	0.94**	3.83**	142.42**	2.27	-0.007**
SE±	0.10	0.04	0.12	10.70	1.27	0.0011
Tester						
Bhagyalakshmi (T_1)	-0.09	-0.19**	-0.13	-16.08	2.13*	-0.048**
Bhaskar (T_2)	0.11	0.09**	0.25*	23.26**	0.42	0.043**
Kiran (T_3)	-0.02	0.10**	-0.13	-7.18	-2.55*	0.006**
SE±	0.08	0.03	0.10	8.29	0.98	0.0009

**Significant at 1 per cent level, * Significant at 5 per cent level

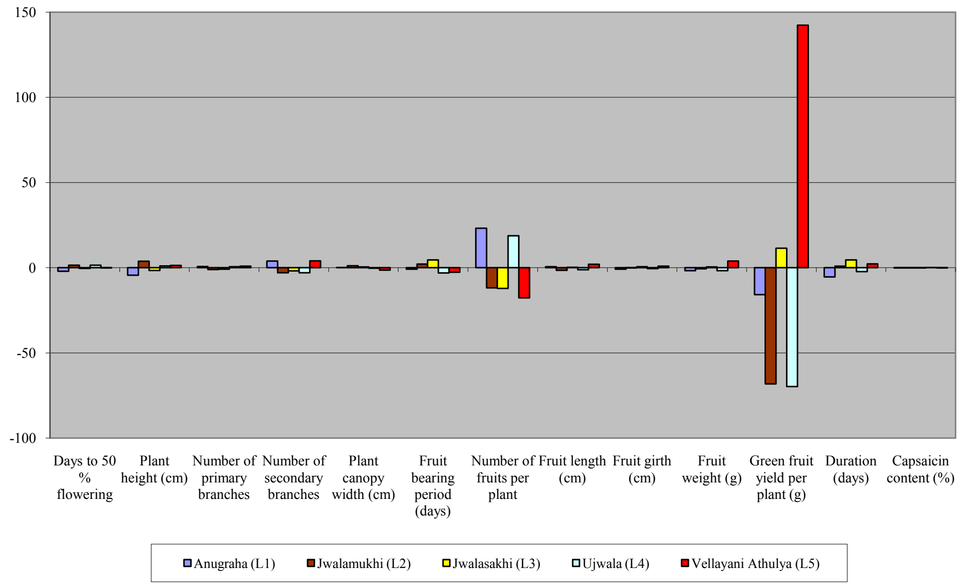


Fig. 1 General combining ability effects of lines

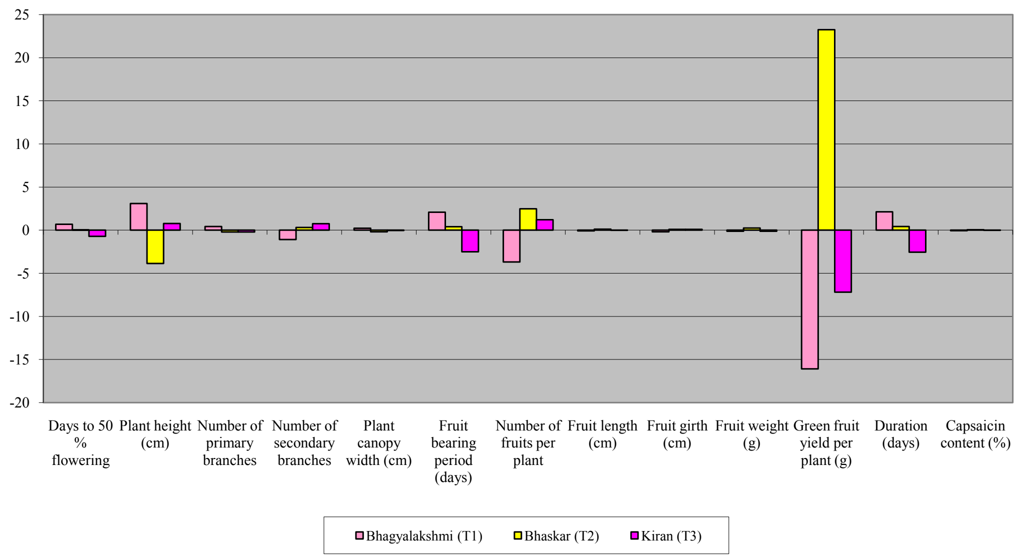


Fig. 2 General combining ability effects of testers

4.1.2.1.6 Fruit bearing period (days)

While considering lines, Jwalasakhi (4.56) had significant positive *gca* effect whereas Ujwala (-3.13) and Vellayani Athulya (-2.63) exhibited significant negative *gca* effects. Among testers, Bhagyalakshmi (2.09) and Kiran (-2.50) had significant positive and negative *gca* effects respectively.

4.1.2.1.7 Number of fruits per plant

Significant positive *gca* effects were observed for the lines Anugraha (23.13) and Ujwala (18.68) while significant negative *gca* effect was observed for Vellayani Athulya (-17.69) which was on par with Jwalasakhi (-12.24) and Jwalamukhi (-11.87). None of the testers showed significant *gca* effect.

4.1.2.1.8 Fruit length (cm)

Significant *gca* effects were observed for all the lines, the effects being positive for Vellayani Athulya (2.00), Anugraha (0.53) and Jwalasakhi (0.23) and negative for Jwalamukhi (-1.56) and Ujwala (-1.21). None of the testers exhibited significant *gca* effect.

4.1.2.1.9 Fruit girth (cm)

The *gca* effects were significant and positive for Vellayani Athulya (0.94), Jwalasakhi (0.54) and Jwalamukhi (0.02) among lines, while Anugraha (-0.94) and Ujwala (-0.54) showed significant negative *gca* effects. Among testers, Bhaskar (0.09) and Kiran (0.10) had significant positive *gca* effects while Bhagyalakshmi (-0.19) had significant negative *gca* effect.

4.1.2.1.10 Fruit weight (g)

The *gca* effects of the lines were significant for fruit weight wherein Jwalasakhi (0.39) and Vellayani Athulya (3.83) exhibited positive values and Anugraha (-1.81), Jwalamukhi (-0.67) and Ujwala (-1.73) exhibited negative values. Among the testers only Bhaskar (0.25) showed significant *gca* effect.

Table 7 Specific combining ability effects of hybrids

Characters / Treatments	Days to 50 % flowering	Plant height (cm)	Number of primary branches	Number of secondary branches	Plant canopy width (cm)	Fruit bearing period (days)	Number of fruits per plant
$L_1 \times T_1$	-1.91	-2.06	-1.56**	-3.53**	-1.12	2.08	-30.85**
$L_1 \times T_2$	4.42	4.60*	-0.41*	-0.01	-0.50	-3.78*	-1.54
$L_1 \times T_3$	-2.51	-2.53	1.97**	3.54**	1.62	1.70	32.39**
$L_2 \times T_1$	2.20	6.68**	0.26	-0.99	0.80	2.46	-7.82
$L_2 \times T_2$	1.87	-6.78**	-0.22	-1.78*	-3.89**	2.08	-8.43**
$L_2 \times T_3$	-4.07	0.10	-0.04	2.77**	3.09*	-4.54*	16.25**
$L_3 \times T_1$	2.42	0.48	1.78**	4.53**	0.36	-2.24	24.77*
$L_3 \times T_2$	-3.24	-1.14	-1.09**	-3.72**	-1.21	2.83	-10.26**
$L_3 \times T_3$	0.82	0.66	-0.69**	-0.82	0.85	-0.59	-14.51**
$L_4 \times T_1$	-4.47	-3.61*	-0.57**	-2.16**	-3.62**	-6.74**	13.91**
$L_4 \times T_2$	0.20	3.53*	1.80**	6.24**	7.56**	5.22**	19.44**
$L_4 \times T_3$	4.27	0.08	-1.24**	-4.08**	-3.94**	1.52	-33.35
$L_5 \times T_1$	1.76	-1.49	0.09	2.15**	3.57**	4.43*	0.00
$L_5 \times T_2$	-3.24	-0.21	-0.08	-0.74	-1.95	-6.35**	0.78
$L_5 \times T_3$	1.49	1.70	-0.01	-1.41	-1.61	1.92	-0.78
SE±	2.29	1.72	0.19	0.76	1.23	1.80	4.71

**Significant at 1 per cent level, * Significant at 5 per cent level

4.1.2.1.11 Green fruit yield per plant

Significant positive *gca* effect was observed for the Vellayani Athulya (142.42) and significant negative *gca* effects were observed for Jwalamukhi (-68.24) and Ujwala (-69.79) among lines. The tester Bhaskar (23.26) had significant positive *gca* effect.

4.1.2.1.12 Duration (days)

Among lines Jwalasakhi (4.57) and Anugraha (-5.45) showed significant positive and negative *gca* effects respectively. Among testers Bhagyalakshmi (2.13) had significant positive and Kiran (-2.55) had significant negative *gca* effect.

4.1.2.1.13 Capsaicin content (%)

Among lines, Ujwala (0.056) showed significant positive *gca* effect while other lines showed significant negative *gca* effects. Among testers, Bhaskar (0.043) and Kiran (0.006) exhibited significant positive *gca* effects while Bhagyalakshmi (-0.048) exhibited significant negative *gca* effect.

4.1.2.2 Specific combining ability

The specific combining ability effects of hybrids for the characters studied are given in Table 7 and Fig. 3.

4.1.2.2.1 Days to 50 per cent flowering

None of the hybrids exhibited significant *sca* effect. The *sca* effect varied from -4.47 (L_4 x T_1) to 4.42 (L_1 x T_2).

4.1.2.2.2 Plant height (cm)

Significant positive *sca* effects were shown by hybrids L_1 x T_2 (4.60), L_2 x T_1 (6.68) and L_4 x T_2 (3.53). Hybrids L_2 x T_2 (-6.78) and L_4 x T_1 (-3.61) exhibited significant negative *sca* effects.

Table 7 Continued

Characters / Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green fruit yield per plant (g)	Duration (days)	Capsaicin content (%)
$L_1 \times T_1$	-0.67**	0.16*	-0.16	-2.26	1.26	-0.069**
$L_1 \times T_2$	0.02	-0.21**	-0.37	-44.64*	-3.03	0.047**
$L_1 \times T_3$	0.65**	0.05	0.53*	46.90*	1.77	0.022**
$L_2 \times T_1$	-0.46*	-0.17*	-0.55**	-27.15	3.71	-0.031**
$L_2 \times T_2$	0.77**	0.44**	0.62**	-1.63	1.78	0.126**
$L_2 \times T_3$	-0.31	-0.27**	-0.07	28.78	-5.49*	-0.095**
$L_3 \times T_1$	1.03**	0.05	0.71**	55.65**	-3.67	0.003
$L_3 \times T_2$	-0.52**	-0.28**	-0.61**	-79.50**	-1.24	-0.040**
$L_3 \times T_3$	-0.51**	0.23**	-0.10	23.85	4.92*	0.037**
$L_4 \times T_1$	0.88**	0.21**	0.06	20.46	-9.90**	0.063**
$L_4 \times T_2$	-0.73**	-0.21**	-0.57*	34.73	7.69**	-0.066**
$L_4 \times T_3$	-0.16	-0.01	0.51*	-55.19**	2.21	0.003
$L_5 \times T_1$	-0.78**	-0.26**	-0.06	-46.70*	8.61**	0.034**
$L_5 \times T_2$	0.45*	0.25**	0.93**	91.05**	-5.20	-0.067**
$L_5 \times T_3$	0.33	0.01	-0.86**	-44.35*	-3.41	0.033**
SE±	0.17	0.07	0.21	18.53	2.20	0.002

**Significant at 1 per cent level, * Significant at 5 per cent level

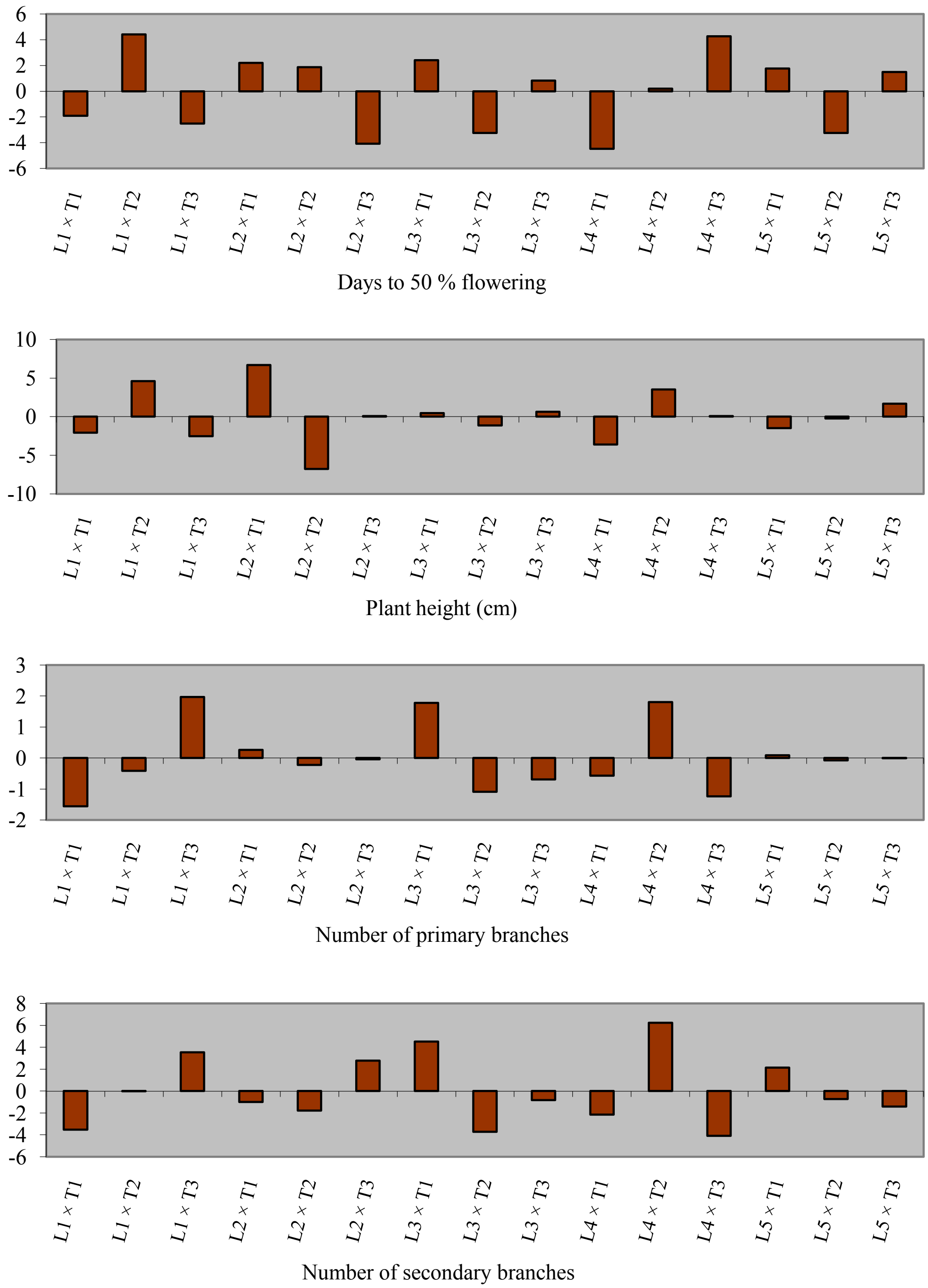
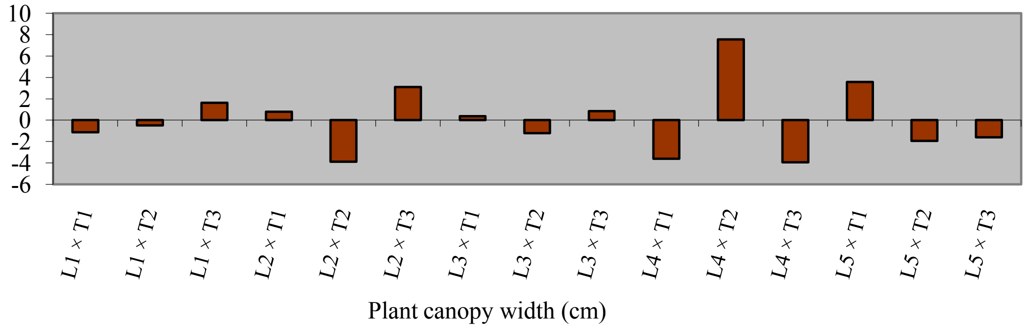
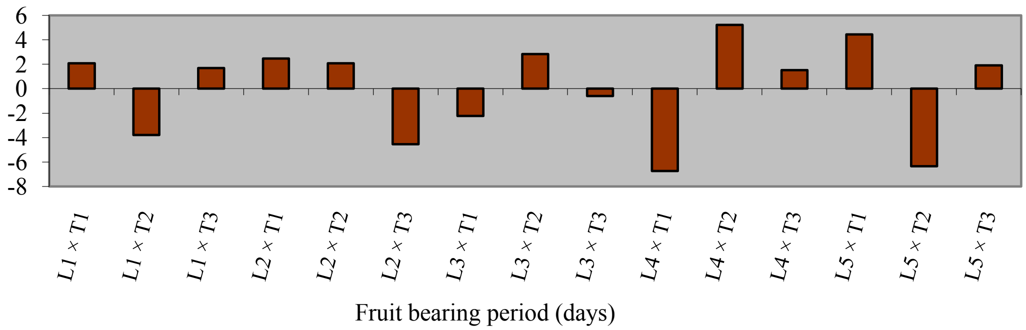
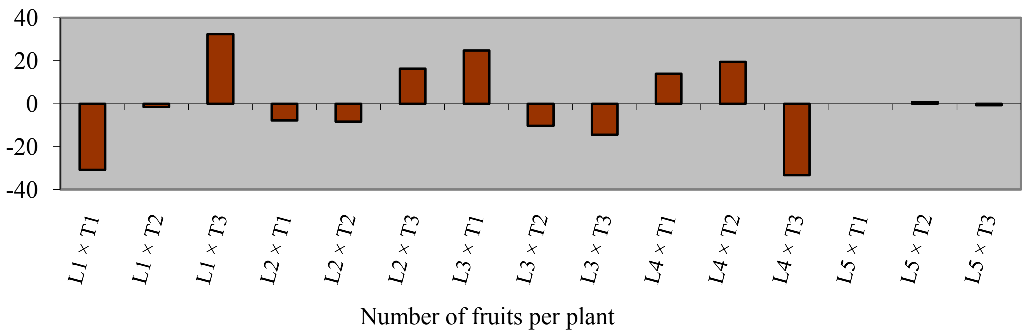


Fig. 3. Specific combining ability effects of hybrids







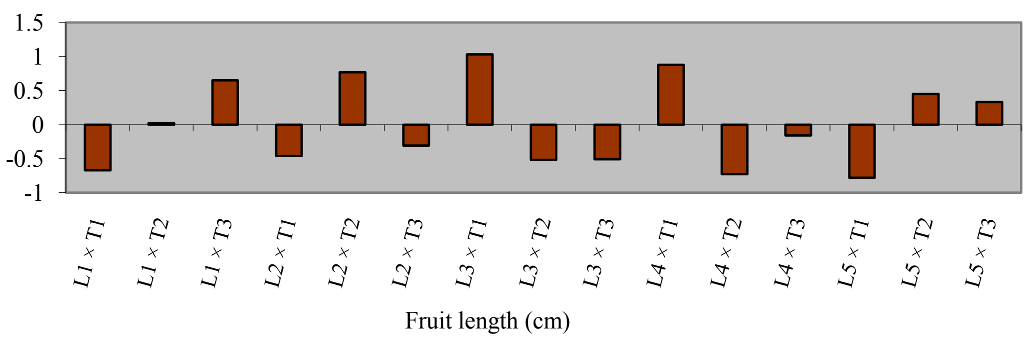


Fig. 3. Continued

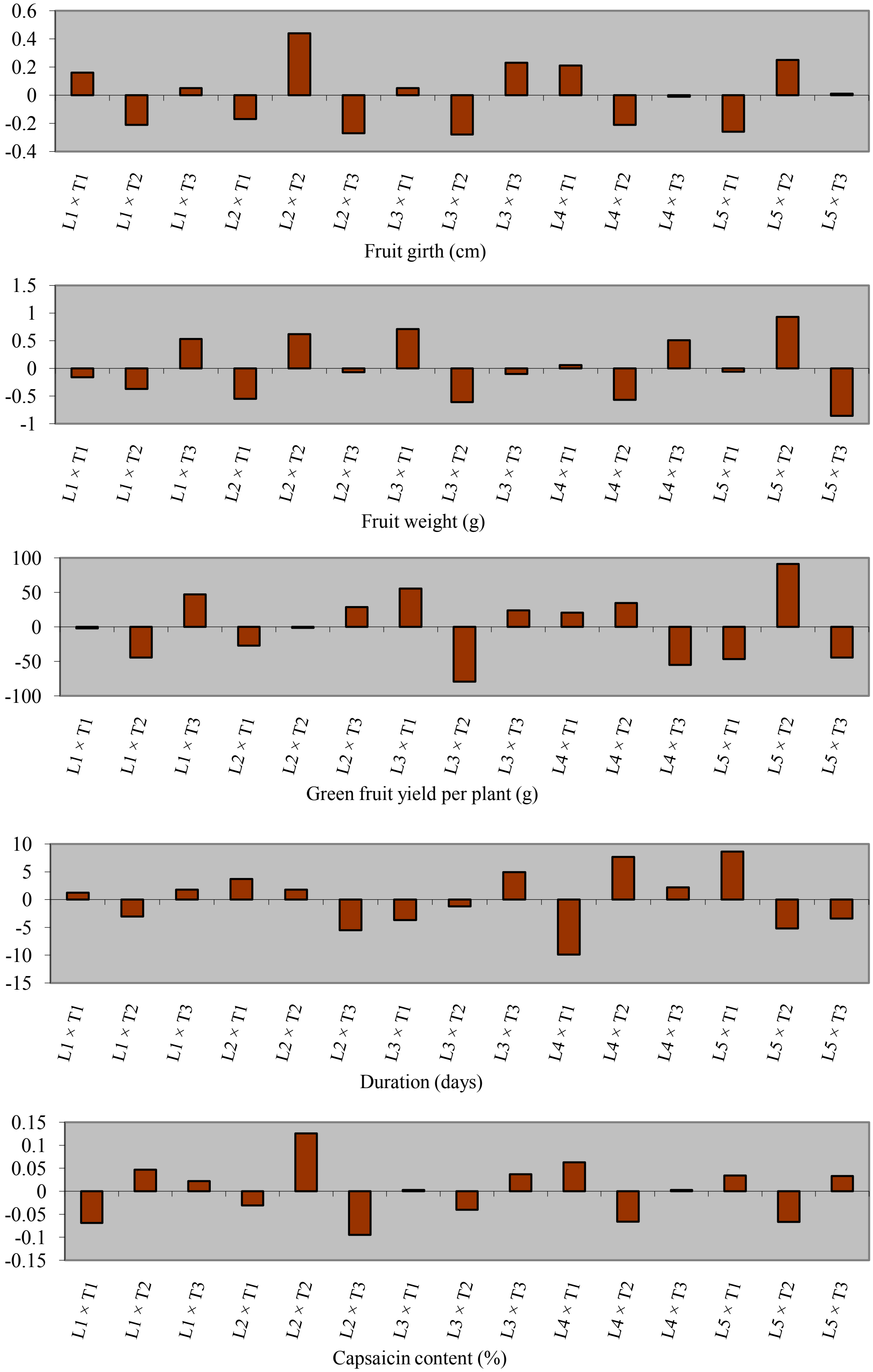


Fig. 3. Continued

1.

2.2.3 Number of primary branches

The *sca* effect was positive and significant in L_1 x T_3 (1.97), L_3 x T_1 (1.78) and L_4 x T_2 (1.80) while significant negative *sca* effects were observed in L_1 x T_1 (-1.56), L_1 x T_2 (-0.41), L_3 x T_2 (-1.09), L_3 x T_3 (-0.69), L_4 x T_1 (-0.57) and L_4 x T_3 (-1.24).

4.1.2.2.4 Number of secondary branches

Ten out of the fifteen hybrids showed significant *sca* effects. Hybrids L_1 x T_3 (3.54), L_2 x T_3 (2.77), L_3 x T_1 (4.53), L_4 x T_2 (6.24) and L_5 x T_1 (2.15) had positive effect whereas L_1 x T_1 (-3.53), L_2 x T_2 (-1.78), L_3 x T_2 (-3.72), L_4 x T_1 (-2.16) and L_4 x T_3 (-4.08) had negative *sca* effects.

4.1.2.2.5 Plant canopy width (cm)

Significant positive *sca* effect was shown by crosses, L_2 x T_3 (3.09), L_4 x T_2 (7.56) and L_5 x T_1 (3.57). While the hybrids L_2 x T_2 (-3.89), L_4 x T_1 (-3.62) and L_4 x T_3 (-3.94) showed significant negative *sca* effects.

4.1.2.2.6 Fruit bearing period (days)

The crosses, L_4 x T_2 (5.22) and L_5 x T_1 (4.43) exhibited positive *sca* effects whereas L_1 x T_2 (-3.78), L_2 x T_3 (-4.54), L_4 x T_1 (-6.74) and L_5 x T_2 (-6.35) exhibited negative *sca* effects.

4.1.2.2.7 Number of fruits per plant

The *sca* effects were significant and positive for L_1 x T_3 (32.39), L_2 x T_3 (16.25), L_3 x T_1 (24.71), L_4 x T_1 (13.91) and L_4 x T_2 (19.44) whereas *sca* effects were negative and significant in L_1 x T_1 (-30.85), L_2 x T_2 (-8.43), L_3 x T_2 (-10.26) and L_3 x T_3 (-14.51).

4.1.2.2.8 Fruit length (cm)

Five hybrids viz., L_1 x T_3 (0.65), L_2 x T_2 (0.77), L_3 x T_1 (1.03), L_4 x T_1 (0.88) and L_5 x T_2 (0.45) exhibited significant positive *sca* effects, while significant negative *sca* effects were exhibited by the hybrids L_1 x T_1 (-0.67),

L_2 x T_1 (-0.46), L_3 x T_2 (-0.52), L_3 x T_3 (-0.51), L_4 x T_2 (-0.73) and L_5 x T_1 (-0.78).

4.1.2.2.9 Fruit girth (cm)

L_1 x T_1 (0.16), L_2 x T_2 (0.44), L_3 x T_3 (0.23), L_4 x T_1 (0.21) and L_5 x T_2 (0.25) had significant positive *sca* effects while L_1 x T_2 (-0.21), L_2 x T_1 (-0.17), L_2 x T_3 (-0.27), L_3 x T_2 (-0.28), L_4 x T_2 (-0.21) and L_5 x T_1 (-0.26) had significant negative *sca* effects.

4.1.2.2.10 Fruit weight (g)

Significant positive *sca* effects were recorded for L_1 x T_3 (0.53), L_2 x T_2 (0.62), L_3 x T_1 (0.71), L_4 x T_3 (0.51) and L_5 x T_2 (0.93). The hybrids L_2 x T_1 (-0.55), L_3 x T_2 (-0.61), L_4 x T_2 (-0.57), L_4 x T_2 (-0.57) and L_5 x T_3 (-0.86) showed significant negative *sca* effects.

4.1.2.2.11 Green fruit yield per plant (g)

Three hybrids exhibited significant positive *sca* effects. The maximum value was for L_5 x T_2 (91.05) followed by L_3 x T_1 (55.65) and L_1 x T_3 (46.90). Five hybrids viz., L_1 x T_2 (-44.64), L_3 x T_2 (-79.50), L_4 x T_3 (-55.19), L_5 x T_1 (-46.70) and L_5 x T_3 (-44.35) exhibited significant negative *sca* effects.

4.1.2.2.12 Duration (days)

Three hybrids each showed significant positive and negative *sca* effects. The maximum positive value was for L_5 x T_1 (8.16) followed by L_4 x T_2 (7.69) and L_3 x T_3 (4.92). The maximum negative value was for L_4 x T_1 (-9.90) followed by L_2 x T_3 (-5.49) and L_5 x T_2 (-5.20).

4.1.2.2.13 Capsaicin content (%)

Seven hybrids showed significant positive *sca* effects. The maximum positive value was for L_2 x T_2 (0.126) followed by L_4 x T_1 (0.063). Six hybrids showed significant negative *sca* effects. The maximum value was noticed for L_2 x T_3 (-0.095).

Table 8 Components of genetic variance (F=1)

Sl. No.	Characters	Additive variance (σ^2A)	Dominance variance (σ^2D)	σ^2A/σ^2D
1	Days to 50 per cent flowering	0.00	10.44	-
2	Plant height (cm)	1.93	16.43	0.12
3	Number of primary branches	0.00	2.03	-
4	Number of secondary branches	0.95	16.83	0.06
5	Plant canopy width (cm)	0.00	15.56	-
6	Fruit bearing period (days)	0.43	22.33	0.02
7	Number of fruits per plant	12.24	604.56	0.02
8	Fruit length (cm)	0.31	0.67	0.46
9	Fruit girth (cm)	0.10	0.09	1.11
10	Fruit weight (g)	0.94	0.48	1.96
11	Green fruit yield per plant (g)	1063.42	3764.27	0.28
12	Crop duration (days)	0.00	42.05	-
13	Capsaicin content (%)	0.00	0.003	-

Table 9 Proportional contribution of lines, testers and L x T to total variance

Sl. No.	Characters	Lines (%)	Testers (%)	Line x Tester (%)
1	Days to 50 per cent flowering	16.89	3.12	79.99
2	Plant height (cm)	29.81	31.33	38.86
3	Number of primary branches	36.84	4.86	58.30
4	Number of secondary branches	51.60	2.98	45.42
5	Plant canopy width (cm)	7.10	0.30	92.60
6	Fruit bearing period (days)	33.06	13.95	52.99
7	Number of fruits per plant	46.57	1.10	52.32
8	Fruit length (cm)	81.16	0.35	18.49
9	Fruit girth (cm)	87.76	3.21	9.02
10	Fruit weight (g)	93.24	0.69	6.07
11	Green fruit yield per plant (g)	70.93	3.33	25.73
12	Crop duration (days)	30.03	9.09	60.88
13	Capsaicin content (%)	15.74	24.44	59.82

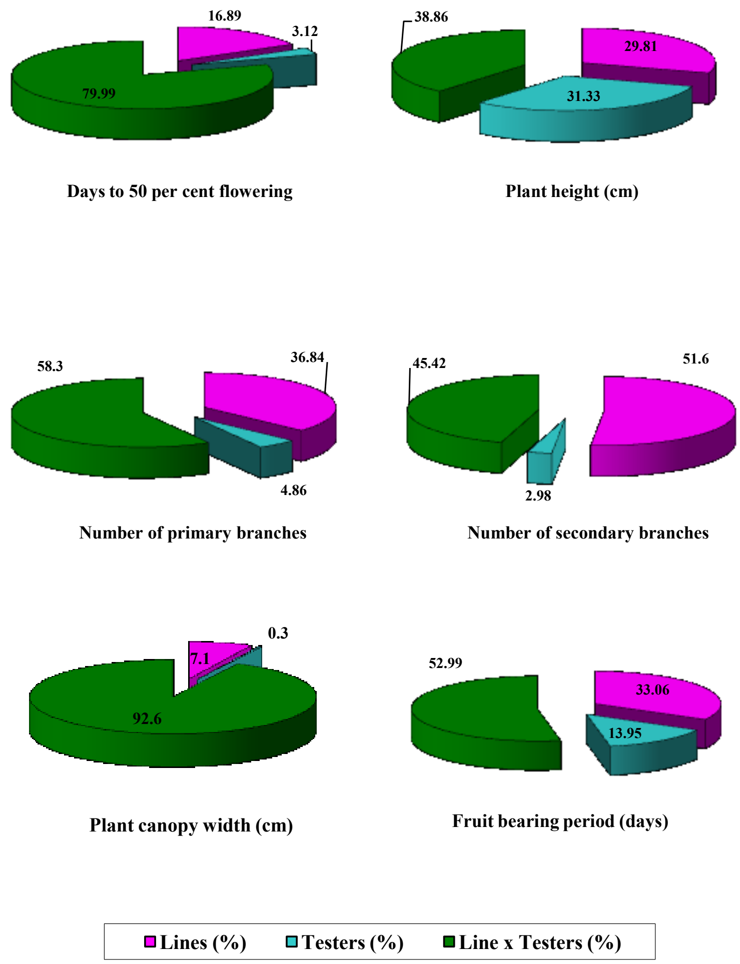


Fig.4. Proportional contribution of lines, testers and line x testers to the total variance

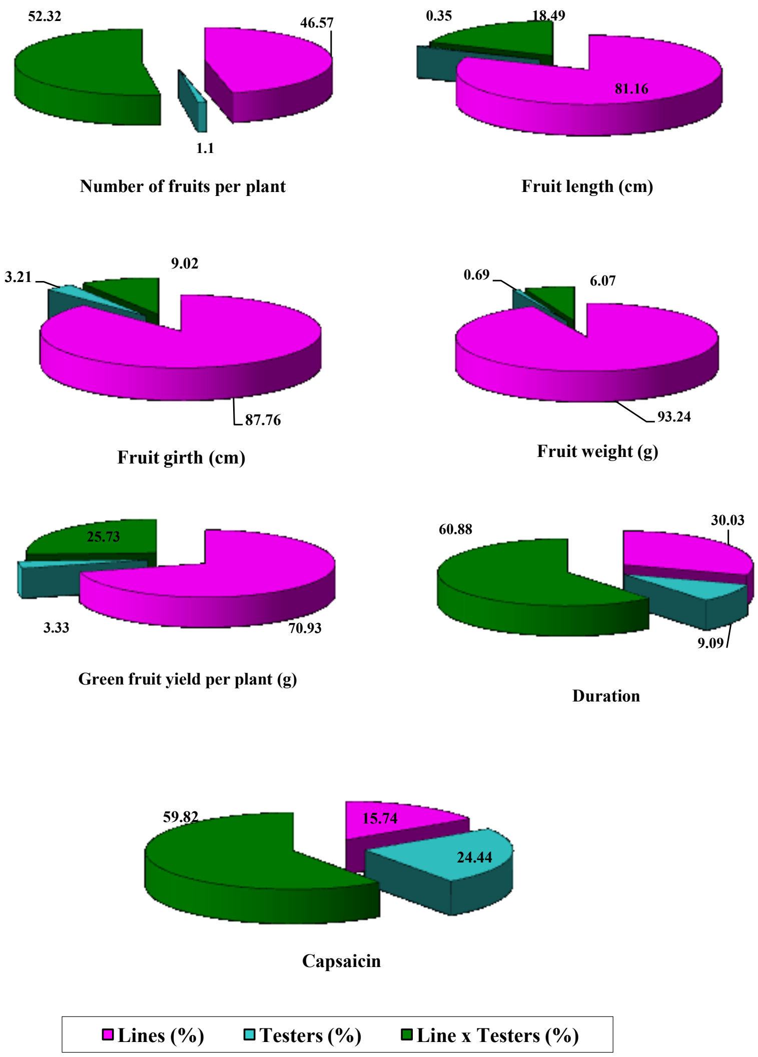


Fig. 4. Continued

4.1.3 Components of genetic variance

Components of genetic variance are given in Table 8. The dominance variance was higher than the additive variance for all the characters except for fruit girth and fruit weight. The additive to dominance variance ratio was very low for number of secondary branches (0.06), fruit bearing period (0.02) and number of fruits per plant (0.02) and the ratio was medium for plant height (0.12), green fruit yield per plant (0.28) and fruit length (0.46). The ratio was higher and more than one for fruit girth (1.11) and fruit weight (1.96).

4.1.4 Proportional contribution

Proportional contribution of lines, testers and hybrids to the total variation for the thirteen characters under study are presented in Table 9 and Fig. 4. Among the different characters contribution of lines, ranged widely from a minimum of 7.10 per cent for plant canopy width to a maximum of 93.24 per cent for fruit weight. In the testers the range was from 0.30 per cent for plant canopy width to 31.33 per cent for plant height. The contribution of hybrids also ranged widely from 6.07 per cent for fruit weight to 92.60 per cent for plant canopy width.

Contribution of lines to the total variance was high for the characters viz., number of secondary branches (51.60 %), fruit length (81.16 %), fruit girth (87.76 %), fruit weight (93.24 %) and green fruit yield per plant (70.93 %). While it was medium for days to 50 per cent flowering (16.89 %), Plant height (29.81%) number of primary branches (36.84 %), plant canopy width (7.10 %), fruit bearing period (33.06 %), number of fruits per plant (46.57 %) and duration (30.03).

The relative contribution of testers was very low for all the characters except plant height (31.33 %), while it was medium for capsaicin content (24.44 %).

Table 10 Heterosis (%) for days to 50 per cent flowering

Genotypes	SH	HB	RH
$L_1 \times T_1$	-10.13*	-8.58*	-8.39*
$L_1 \times T_2$	-2.95	-5.35	-3.36
$L_1 \times T_3$	-12.66**	-14.46**	-12.84**
$L_2 \times T_1$	-0.42	1.72	5.12
$L_2 \times T_2$	-1.69	-4.11	1.30
$L_2 \times T_3$	-10.13*	-11.98**	-7.19
$L_3 \times T_1$	-2.53	-2.53	-1.49
$L_3 \times T_2$	-10.55*	-12.76**	-11.67**
$L_3 \times T_3$	-6.33	-8.26*	-7.31*
$L_4 \times T_1$	-8.86*	-17.24**	-12.37**
$L_4 \times T_2$	-3.80	-12.64**	-9.52**
$L_4 \times T_3$	0.42	-8.81*	-5.37
$L_5 \times T_1$	-2.95	-0.86	6.73
$L_5 \times T_2$	-10.13*	-12.35**	-3.62
$L_5 \times T_3$	-5.06	-7.02	2.04
CD	6.51	6.51	5.63

**Significant at 1 per cent level, * Significant at 5 per cent level
SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 11 Heterosis (%) for plant height (cm)

Genotypes	SH	HB	RH
$L_1 \times T_1$	7.42	-21.49**	-7.27
$L_1 \times T_2$	6.83	-21.12**	-7.22
$L_1 \times T_3$	1.53	-25.23**	-11.96
$L_2 \times T_1$	43.52**	4.89	20.52**
$L_2 \times T_2$	0.16	-26.05**	-15.40**
$L_2 \times T_3$	24.65**	-8.21*	5.13
$L_3 \times T_1$	18.92**	-13.09**	0.43
$L_3 \times T_2$	0.72	-25.64**	-14.45**
$L_3 \times T_3$	14.41**	-15.75**	-2.96
$L_4 \times T_1$	15.73**	-15.42**	-5.00
$L_4 \times T_2$	16.16**	-14.24**	-4.11
$L_4 \times T_3$	18.67**	-12.61**	-2.18
$L_5 \times T_1$	21.08**	-11.51**	-1.53
$L_5 \times T_2$	9.04	-19.49**	-10.82*
$L_5 \times T_3$	22.96**	-9.45*	0.42
CD	4.89	4.89	4.23

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Crosses contributed maximum for days to 50 per cent flowering (79.99 %), plant height (38.86), number of primary branches (58.30 %), plant canopy width (92.60 %), fruit bearing period (52.99 %), number of fruits per plant (52.32 %), duration (60.88 %) and capsaicin content (59.82 %). But it was medium for the remaining characters.

4.1.5 Heterosis

Standard heterosis, heterobeltiosis and relative heterosis for the 15 hybrids with respect to 13 characters under study were estimated and the results are furnished in Tables 10 to 22 and Fig. 5. Heterosis for each character ranged widely among the different crosses (Table 23). The standard heterosis was estimated using Jwalasakhi as the check variety.

4.1.5.1 Days to 50 per cent flowering

Significant negative standard heterosis was shown by six crosses. Among these, the high negative heterosis was noticed for L_1 x T_3 (-12.66) followed by L_3 x T_2 (-10.55) and L_4 x T_1 (-8.86). Nine crosses showed significant negative heterobeltiosis which ranged from -17.24 for L_4 x T_1 to -8.28 for L_3 x T_3. The crosses L_1 x T_1 (-8.39), L_1 x T_3 (-12.84), L_3 x T_2 (-11.67), L_3 x T_3 (-7.31), L_4 x T_1 (-12.37) and L_4 x T_2 (-9.52) showed significant negative relative heterosis.

4.1.5.2 Plant height (cm)

All the hybrids showed positive standard heterosis of which nine were significant with maximum value 43.52 (L_2 x T_1) and minimum value 14.41 (L_3 x T_3). None of the hybrids showed significant positive heterobeltiosis. The value ranged from -26.05 (L_2 x T_2) to 4.89 (L_2 x T_1). Only L_2 x T_1 (20.52) showed significant positive relative heterosis while three hybrids, L_2 x T_2 (-15.40), L_3 x T_2 (-14.45) and L_5 x T_2 (-10.82) have shown significant negative relative heterosis

Table 12 Heterosis (%) for number of primary branches

Genotypes	SH	HB	RH
$L_1 \times T_1$	45.51**	51.54**	51.91**
$L_1 \times T_2$	59.76**	-5.58	20.68**
$L_1 \times T_3$	125.35**	135.82**	164.35**
$L_2 \times T_1$	48.75**	37.67**	45.78**
$L_2 \times T_2$	17.76*	-30.40**	-15.05**
$L_2 \times T_3$	22.57**	13.44	33.97**
$L_3 \times T_1$	95.19**	95.19**	99.15**
$L_3 \times T_2$	-2.13	-42.15**	-27.29**
$L_3 \times T_3$	8.79	8.79	24.38**
$L_4 \times T_1$	72.06**	17.72**	42.09**
$L_4 \times T_2$	120.17**	30.13**	39.63**
$L_4 \times T_3$	35.52**	-7.28	22.59**
$L_5 \times T_1$	97.69**	15.14**	47.68**
$L_5 \times T_2$	75.30**	2.10	2.85
$L_5 \times T_3$	77.06	3.12	43.59**
CD	0.54	0.54	0.46

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 13 Heterosis (%) for number of secondary branches

Genotypes	SH	HB	RH
$L_1 \times T_1$	35.17*	55.90**	61.96**
$L_1 \times T_2$	68.38**	65.63**	85.15**
$L_1 \times T_3$	95.25**	110.97**	126.02**
$L_2 \times T_1$	5.81	-3.59	7.72
$L_2 \times T_2$	9.99	0.23	4.06
$L_2 \times T_3$	43.56**	30.82**	41.94**
$L_3 \times T_1$	51.06**	51.06**	61.82**
$L_3 \times T_2$	4.86	3.10	3.95
$L_3 \times T_3$	27.27**	27.27**	32.20**
$L_4 \times T_1$	-1.64	-28.24**	-12.09*
$L_4 \times T_2$	64.49**	20.01**	37.81**
$L_4 \times T_3$	-2.30	-28.71**	-14.90**
$L_5 \times T_1$	74.82**	26.37**	55.36**
$L_5 \times T_2$	64.81**	19.13**	37.33**
$L_5 \times T_3$	63.14**	17.92**	41.31**
CD	2.16	2.16	1.87

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

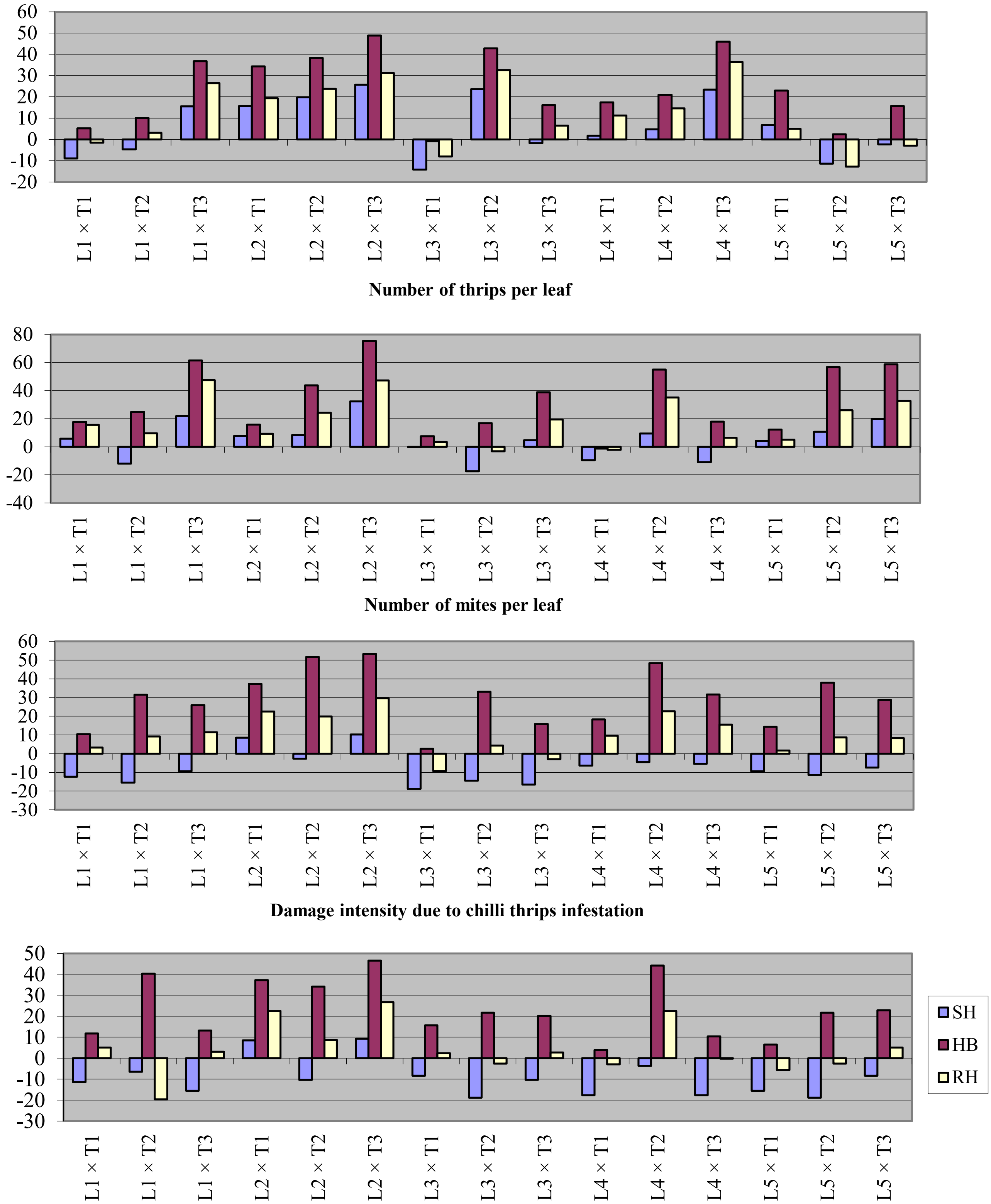


Fig. 9 Heterosis for resistance parameters

. Table 14 Heterosis (%) plant canopy width (cm)

Genotypes	SH	HB	RH
$L_1 \times T_1$	30.26**	4.66	9.38**
$L_1 \times T_2$	30.79**	0.76	7.42*
$L_1 \times T_3$	36.73**	7.83*	13.70**
$L_2 \times T_1$	37.68**	10.62**	16.81**
$L_2 \times T_2$	24.41**	-4.16	3.21
$L_2 \times T_3$	42.97**	12.76**	20.11**
$L_3 \times T_1$	34.94**	8.42*	20.23**
$L_3 \times T_2$	29.77**	-0.03	12.94**
$L_3 \times T_3$	35.57**	6.91	19.55**
$L_4 \times T_1$	22.60**	-1.50	9.00*
$L_4 \times T_2$	50.58**	16.00**	30.76**
$L_4 \times T_3$	21.15**	-4.46	6.61
$L_5 \times T_1$	38.38**	11.18**	16.78**
$L_5 \times T_2$	22.96**	-5.27	1.48
$L_5 \times T_3$	24.28**	-1.99	3.86
CD	3.49	3.49	3.03

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

4.1.5.3 Number of primary branches

All the hybrids showed significant standard heterosis except L_3 x T_2 (-2.13) and L_3 x T_3 (8.79). The maximum standard heterosis was noticed for L_1 x T_3 (125.35) and minimum for L_3 x T_2 (-2.13).

Heterobeltiosis was positive and significant for the hybrids, L_1 x T_1 (51.54), L_1 x T_3 (135.82), L_2 x T_1 (37.67), L_3 x T_1 (95.19), L_4 x T_1 (17.72), L_4 x T_2 (30.13) and L_5 x T_1 (15.14) while it was significant and negative for hybrids L_2 x T_2 (-30.40) and L_3 x T_2 (-42.15). Significant positive relative heterosis was observed for twelve hybrids while the hybrids L_2 x T_2 (-15.05) and L_3 x T_2 (-29.29) showed negative and significant values. In all three cases, the maximum heterosis was shown by L_1 x T_3 (125.35, 135.82 and 164.35 respectively).

4.1.5.4 Number of secondary branches

Standard heterosis was positive and significant for ten hybrids with maximum value for L_1 x T_3 (95.25). While considering heterobeltiosis, ten hybrids exhibited significant positive heterosis while the hybrids L_4 x T_1 (-28.24) and L_4 x T_3 (-28.71) showed significant negative heterosis. Significant relative heterosis was noticed for twelve hybrids of which two were in the negative direction. L_1 x T_3 exhibited maximum heterosis irrespective of the parameters employed in its calculation.

4.1.5.5 Plant canopy width (cm)

Significant positive standard heterosis was exhibited by all the hybrids with maximum for L_4 x T_2 (50.58) and minimum for L_4 x T_3 (21.15). Significant positive heterobeltiosis was shown by six hybrids, none of the hybrids exhibited significant negative heterosis. The maximum heterobeltiosis was recorded for L_4 x T_2 (16.00). Relative heterosis was positive and significant in eleven hybrids. L_4 x T_2 (30.76) and L_1 x T_2 (7.42) showed maximum and minimum relative heterosis. L_4 x T_2 was the most heterotic among the crosses irrespective of the basis adopted for its estimation.

Table 15 Heterosis (%) for fruit bearing period (days)

Genotypes	SH	HB	RH
$L_1 \times T_1$	8.71*	-3.17	5.11
$L_1 \times T_2$	-3.08	-32.48**	-18.60
$L_1 \times T_3$	0.95	-18.13**	-7.33*
$L_2 \times T_1$	13.89**	1.45	6.46
$L_2 \times T_2$	10.68**	-22.90**	-9.74**
$L_2 \times T_3$	-4.22	-22.32**	-14.86**
$L_3 \times T_1$	10.46*	-1.61	4.08
$L_3 \times T_2$	15.76**	-19.36**	-4.94
$L_3 \times T_3$	5.86	-14.15**	-5.19
$L_4 \times T_1$	-8.59*	-18.58**	-8.72*
$L_4 \times T_2$	7.46	-25.13**	-7.18*
$L_4 \times T_3$	-2.86	-21.24**	-8.07*
$L_5 \times T_1$	9.65*	-5.70	-4.04
$L_5 \times T_2$	-9.83*	-37.18**	-30.59**
$L_5 \times T_3$	-1.45	-20.08**	-17.73**
CD	5.12	5.12	4.44

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 16 Heterosis (%) for number of fruits per plant

Genotypes	SH	HB	RH
$L_1 \times T_1$	12.08	23.34**	28.58**
$L_1 \times T_2$	44.56**	15.19**	38.36**
$L_1 \times T_3$	74.47**	84.51**	96.01**
$L_2 \times T_1$	1. 13	1.64	6.24
$L_2 \times T_2$	6.21	-15.37**	-5.59
$L_2 \times T_3$	27.65**	28.30**	31.56**
$L_3 \times T_1$	30.62**	30.62**	36.87**
$L_3 \times T_2$	4.19	-16.97**	-7.59
$L_3 \times T_3$	-0.86	-0.86	1.91
$L_4 \times T_1$	48.97**	23.17**	40.67**
$L_4 \times T_2$	59.69**	27.25**	29.59**
$L_4 \times T_3$	10.20	-8.89	2.27
$L_5 \times T_1$	2.95	13.29	33.49**
$L_5 \times T_2$	9.33	-12.90*	15.75**
$L_5 \times T_3$	6.72	12.86	35.14**
CD	13.40	13.40	11.60

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 17 Heterosis (%) for fruit length (cm)

Genotypes	SH	HB	RH
$L_1 \times T_1$	16.32**	8.06**	10.54**
$L_1 \times T_2$	26.86**	23.39**	26.24**
$L_1 \times T_3$	32.73**	29.09**	29.59**
$L_2 \times T_1$	-6.06	-12.73**	-8.97**
$L_2 \times T_2$	11.01**	12.44**	12.76**
$L_2 \times T_3$	-3.45	-5.36	-3.81
$L_3 \times T_1$	32.96**	23.52**	28.07**
$L_3 \times T_2$	17.00	17.00**	18.07**
$L_3 \times T_3$	15.37**	13.09**	14.22**
$L_4 \times T_1$	14.10**	6.00*	33.33**
$L_4 \times T_2$	-2.65	-0.85	20.41**
$L_4 \times T_3$	2.50	-0.47	23.84**
$L_5 \times T_1$	32.45**	-10.71**	3.48
$L_5 \times T_2$	49.52**	0.80	21.31**
$L_5 \times T_3$	46.43**	-1.28	16.98**
CD	0.49	0.49	0.43

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

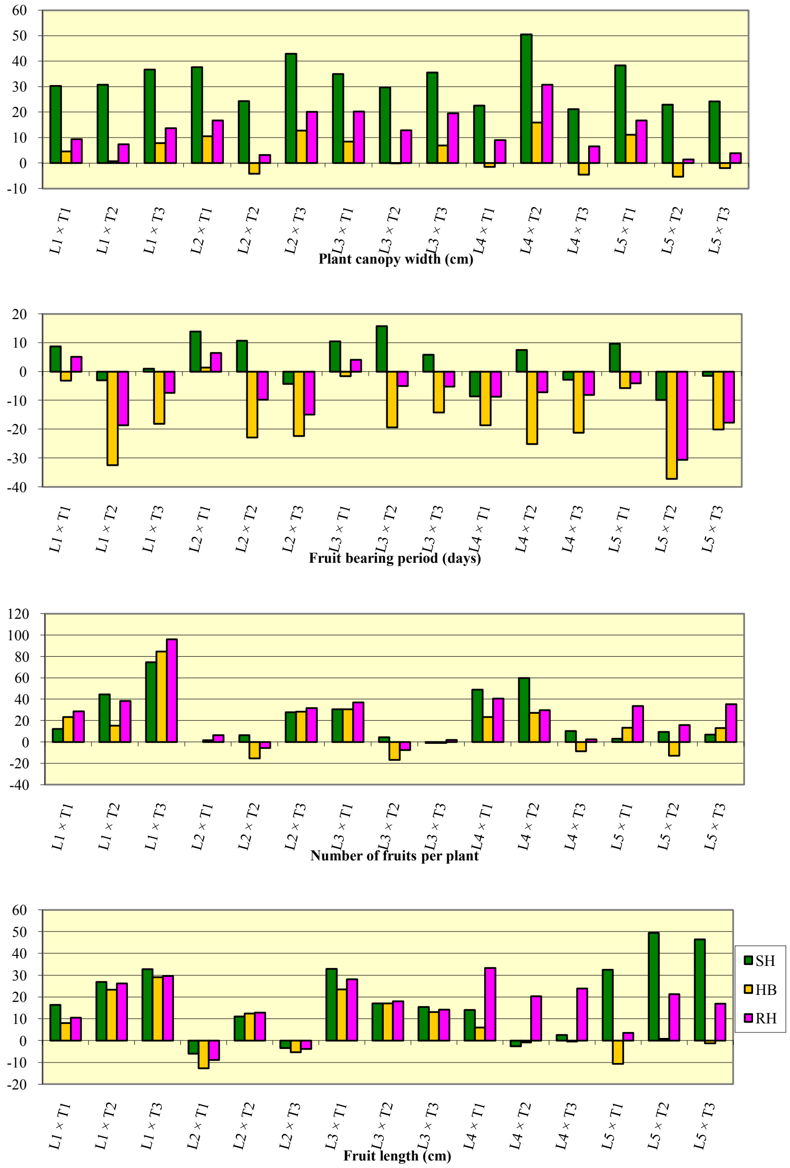


Fig. 5 Continued

4.1.5.6 Fruit bearing period (days)

The hybrids viz., L_1 x T_1 (8.71), L_2 x T_1 (13.89), L_2 x T_2 (10.68), L_3 x T_1 (10.46), L_3 x T_2 (15.76) and L_5 x T_1 (9.65) have shown significant positive standard heterosis. Whereas the hybrids L_4 x T_1 (-8.59) and L_5 x T_2 (-9.83) showed significant negative standard heterosis. None of the hybrids showed significant positive heterosis over mid and better parent. Eleven hybrids have shown significant negative heterobeltiosis and nine hybrids showed significant negative relative heterosis.

4.1.5.7 Number of fruits per plant

Out of fifteen hybrids, six expressed significant positive standard heterosis. They were L_1 x T_2 (44.56), L_1 x T_3 (74.47), L_2 x T_3 (27.65), L_3 x T_1 (30.62), L_4 x T_1 (48.97) and L_4 x T_2 (59.69). Heterobeltiosis was significant and positive for L_1 x T_1 (23.34), L_1 x T_2 (15.19), L_1 x T_3 (84.51), L_2 x T_3 (28.30), L_3 x T_1 (30.62), L_4 x T_1 (23.17) and L_4 x T_2 (27.25) while it was significant and negative for L_3 x T_2 (-16.97), L_2 x T_2 (-15.37) and L_5 x T_2 (-12.90). Ten hybrids showed significant positive relative heterosis. The maximum positive relative heterosis was shown by L_1 x T_3 (96.01) followed by L_4 x T_1 (40.67). In all the three cases the hybrid L_1 x T_3 has shown maximum heterosis.

4.1.5.8 Fruit length (cm)

For fruit length, eleven crosses showed significant positive heterosis over check variety, with the highest magnitude of heterosis by L_5 x T_2 (49.52) followed by L_5 x T_3 (46.43). For heterobeltiosis eight hybrids exhibited significant positive heterosis with the maximum vale for L_1 x T_3 (29.09). L_2 x T_1 (-12.73) and L_5 x T_1 (-10.71) exhibited significant negative heterosis over better parent. Twelve hybrids have shown significant positive relative heterosis, of which L_4 x T_1 (33.33) had the highest value.

Table 18 Heterosis (%) for fruit girth (cm)

Genotypes	SH	HB	RH
$L_1 \times T_1$	-28.25**	-25.81**	-12.14**
$L_1 \times T_2$	-30.23**	-23.31**	-11.46**
$L_1 \times T_3$	-24.69**	-11.35**	-0.63
$L_2 \times T_1$	-15.66**	-12.80**	-12.15**
$L_2 \times T_2$	2.53	7.61*	10.10**
$L_2 \times T_3$	-11.90**	-7.54**	-2.24
$L_3 \times T_1$	0.07	0.07	1.74
$L_3 \times T_2$	-1.30	-1.30	3.37
$L_3 \times T_3$	9.51**	9.51**	18.42**
$L_4 \times T_1$	-18.88**	-16.12**	0.47
$L_4 \times T_2$	-21.96**	-14.21**	0.22
$L_4 \times T_3$	-17.58**	-2.98	10.10**
$L_5 \times T_1$	1.78	-20.77**	-9.60**
$L_5 \times T_2$	17.78**	-8.31**	7.36**
$L_5 \times T_3$	13.06**	-11.98**	5.96**
CD	0.19	0.19	0.17

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 19 Heterosis (%) for fruit weight (g)

Genotypes	SH	HB	RH
$L_1 \times T_1$	-35.47**	-32.43**	-11.04
$L_1 \times T_2$	-32.82**	-28.88**	-6.72
$L_1 \times T_3$	-24.58**	-27.19**	-1.52
$L_2 \times T_1$	-23.57**	-19.98**	-18.83**
$L_2 \times T_2$	0.90	6.83	7.76*
$L_2 \times T_3$	-16.07**	-18.98**	-14.53**
$L_3 \times T_1$	13.11**	13.11**	15.71**
$L_3 \times T_2$	-1.69	-1.69	1.11
$L_3 \times T_3$	0.32	-3.16	-1.45
$L_4 \times T_1$	-30.66**	-27.39**	-1.54
$L_4 \times T_2$	-34.73**	-30.89**	-6.62
$L_4 \times T_3$	-23.57**	-26.22**	2.63
$L_5 \times T_1$	55.50**	-27.12**	0.68
$L_5 \times T_2$	77.27**	-16.92**	15.18**
$L_5 \times T_3$	42.81**	-33.07**	-9.89**
CD	0.61	0.61	0.53

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 20 Heterosis (%) for green fruit yield per plant (g)

Genotypes	SH	HB	RH
$L_1 \times T_1$	1.48	27.71**	63.48**
$L_1 \times T_2$	0.88	-7.46	31.26**
$L_1 \times T_3$	12.94	40.69**	80.75**
$L_2 \times T_1$	-13.77**	-13.05*	-3.46
$L_2 \times T_2$	-0.97	-9.16	-4.87
$L_2 \times T_3$	-0.98	-0.16	10.36*
$L_3 \times T_1$	18.29**	18.29**	31.83**
$L_3 \times T_2$	-0.61	-8.83	-4.90
$L_3 \times T_3$	13.77**	13.77**	26.22**
$L_4 \times T_1$	-4.68	19.96**	53.94**
$L_4 \times T_2$	5.90	-2.86	38.07**
$L_4 \times T_3$	-17.85**	2.33	31.80**
$L_5 \times T_1$	23.94**	42.10**	48.71**
$L_5 \times T_2$	58.88**	45.74**	61.92**
$L_5 \times T_3$	26.16**	44.64**	50.64**
CD	52.67	52.67	45.61

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

4.1.5.9 Fruit girth (cm)

Three crosses viz., L_3 x T_3 (9.51), L_5 x T_2 (17.78) and L_5 x T_3 (13.06) exhibited positive significant standard heterosis while eight crosses recorded significant negative standard heterosis. Only the hybrids L_2 x T_2 (7.61) and L_3 x T_3 (9.51) showed significant positive heterobeltiosis. Ten other hybrids recorded significant negative heterobeltiosis. Maximum significant positive relative heterosis was noticed for L_3 x T_3 (18.42) followed by L_2 x T_2 (10.10), L_4 x T_3 (10.10), L_5 x T_2 (7.36) and L_5 x T_3 (5.96). Significant negative relative heterosis was noticed for four crosses.

4.1.5.10 Fruit weight (g)

The hybrid L_5 x T_2 (77.27) showed maximum significant positive standard heterosis followed by L_5 x T_1 (55.50) and L_5 x T_3 (42.81). Eight crosses showed significant negative heterosis. Only the hybrid L_3 x T_1 exhibited significant positive heterosis over standard mid and better parent. Eleven hybrids showed significant negative heterobeltiosis and three hybrids showed significant negative relative heterosis. The crosses L_2 x T_2 (7.76), L_5 x T_2 (15.18) and L_3 x T_1 (15.71) exhibited significant positive relative heterosis.

4.1.5.11 Green fruit yield per plant (g)

Standard heterosis for green fruit yield per plant was positive and significant for five hybrids viz., L_3 x T_1 (18.29), L_3 x T_3 (13.77), L_5 x T_1 (23.94), L_5 x T_2 (58.88) and L_5 x T_3 (26.16), while L_2 x T_1 (-13.77) and L_4 x T_3 (-17.85) showed negative heterosis. Only cross exhibiting negative heterobeltiosis was L_2 x T_1 (-13.05). Crosses with high values of heterobeltiosis were L_5 x T_2 (45.74), L_5 x T_3 (44.64) and L_5 x T_1 (42.10). Highly significant positive relative heterosis was exhibited by twelve crosses. L_1 x T_3 (80.75) recorded the highest relative heterosis followed by L_1 x T_1 (63.48) and L_5 x T_2 (61.92).

Table 21 Heterosis (%) for duration (days)

Genotypes	SH	HB	RH
$L_1 \times T_1$	-1.57	-4.59*	2.46
$L_1 \times T_2$	-5.26**	-16.73**	-6.55**
$L_1 \times T_3$	-4.13*	-8.85**	-1.24
$L_2 \times T_1$	3.83	0.65	2.76
$L_2 \times T_2$	1.59	-10.72**	-4.48**
$L_2 \times T_3$	-4.71*	-9.40**	-6.62**
$L_3 \times T_1$	1.55	-1.56	-0.03
$L_3 \times T_2$	2.00	-10.36**	-4.58**
$L_3 \times T_3$	3.96*	-1.15	1.34
$L_4 \times T_1$	-6.49**	-9.35**	-4.45*
$L_4 \times T_2$	3.28	-9.23**	0.10
$L_4 \times T_3$	-1.91	-6.74**	-0.80
$L_5 \times T_1$	7.68**	3.91*	4.14*
$L_5 \times T_2$	-1.85	-13.74**	-9.71**
$L_5 \times T_3$	-2.58	-7.37**	-6.69**
CD	6.25	6.25	5.41

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 22 Heterosis (%) for capsaicin content

Genotypes	SH	HB	RH
$L_1 \times T_1$	-17.52**	-52.49**	-51.68**
$L_1 \times T_2$	127.57**	-36.51**	-13.50**
$L_1 \times T_3$	84.35**	-44.32**	-26.09**
$L_2 \times T_1$	12.62**	-35.13**	-14.62**
$L_2 \times T_2$	186.22**	-20.14**	27.60**
$L_2 \times T_3$	5.14**	-68.24**	-50.08**
$L_3 \times T_1$	14.02**	-34.32**	-16.65**
$L_3 \times T_2$	47.90**	-58.74**	-35.47**
$L_3 \times T_3$	75.23**	-47.07**	-18.70**
$L_4 \times T_1$	93.22**	-20.00**	-7.07**
$L_4 \times T_2$	154.54**	-65.80**	-24.48**
$L_4 \times T_3$	115.65**	-34.86**	-24.68**
$L_5 \times T_1$	55.37**	-10.50**	-5.20**
$L_5 \times T_2$	48.83**	-58.48**	-41.93**
$L_5 \times T_3$	92.52**	-41.85**	-20.66**
CD	0.005	0.005	0.005

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

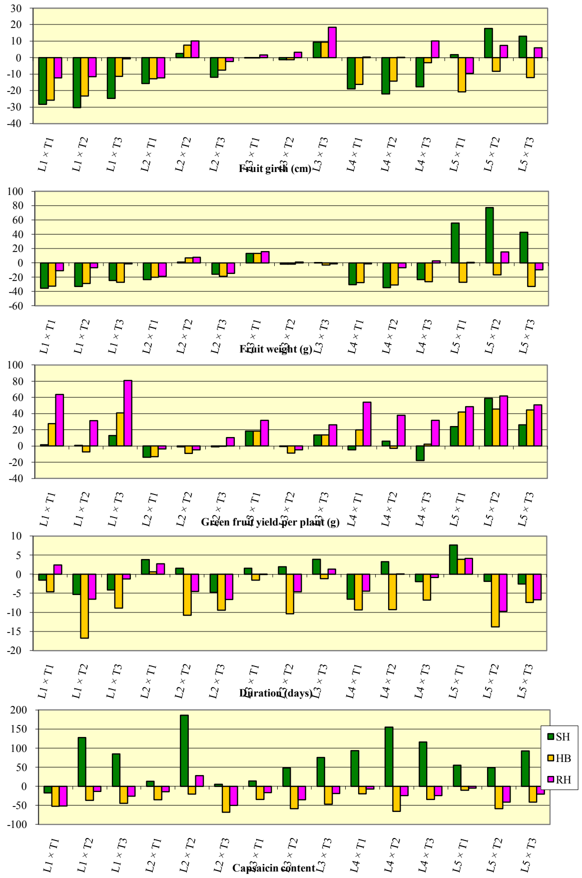


Fig. 5 Continued

Table 23 Heterosis range of the characters

Sl. No.	Characters	SH	HB	RH
1	Days to 50 per cent flowering	-12.66 to 0.42	-17.24 to 1.72	-12.84 to 6.73
2	Plant height (cm)	0.16 to 43.52	-26.05 to 4.89	-15.40 to 20.52
3	Number of primary branches	-2.13 to 125.35	-42.15 to 135.82	-27.29 to 164.35
4	Number of secondary branches	-2.3 to 95.25	-28.71 to 110.97	-14.90 to 126.02
5	Plant canopy width (cm)	21.15 to 50.58	-5.27 to 16.00	1.48 to 30.76
6	Fruit bearing period (days)	-9.83 to 15.76	-37.18 to 1.45	-30.59 to 6.46
7	Number of fruits per plant	-0.86 to 74.47	-16.97 to 84.51	-7.59 to 96.01
8	Fruit length (cm)	-6.06 to 49.52	-12.73 to 29.09	-8.97 to 33.33
9	Fruit girth (cm)	-30.23 to 17.78	-25.81 to 9.51	-12.15 to 18.42
10	Fruit weight (g)	-35.47 to 77.27	-33.07 to 13.11	-18.83 to 15.71
11	Green fruit yield per plant (g)	-17.85 to 58.88	-13.05 to 45.74	-4.90 to 80.75
12	Crop duration (days)	-6.49 to 7.68	-16.73 to 3.91	-9.71 to 4.14
13	Capsaicin content (%)	-17.52 to 186.22	-68.24 to -10.50	-51.68 to 27.60

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

4.1.5.12 Duration (days)

Significant negative standard heterosis was shown by the hybrids L_1 x T_2 (-5.26), L_1 x T_3 (-4.13), L_2 x T_3 (-4.71) and L_4 x T_1 (-6.49) whereas the hybrids L_3 x T_3 (3.96) and L_5 x T_1 (7.68) had significant positive heterosis values. Only one hybrid exhibited significant positive heterosis (L_5 x T_1) over the better parent. The highest negative value for heterobeltiosis was observed for L_1 x T_2 (-16.73) followed by L_5 x T_2 (-13.74). Out of the eight crosses which showed significant relative heterosis, only L_5 x T_1 (4.14) showed significant positive heterosis. High negative values were noted for L_5 x T_2 (-9.71), L_5 x T_3 (-6.91) and L_2 x T_3 (-6.62).

4.1.5.13 Capsaicin content (%)

All the hybrids showed significant positive heterosis over standard variety except L_1 x T_1 (-17.52). The highest magnitude of standard heterosis was recorded for L_2 x T_2 (186.22) followed by L_4 x T_2 (154.54) and L_1 x T_2 (127.57). All the hybrids showed significant negative heterobeltiosis with maximum value for L_2 x T_3 (-68.24) followed by L_4 x T_2 (-65.80). Except L_2 x T_2 (27.60), all the hybrids showed significant negative relative heterosis. The maximum negative relative heterosis was noticed for L_2 x T_3 (-50.08) followed by L_5 x T_2 (-41.93) and L_3 x T_2 (-35.47).

4.2 Evaluation of genotypes for resistance to chilli thrips and mite

The results of the experiment conducted with 23 genotypes (5 lines + 3 testers + 15 hybrids) for the evaluation of resistance to chilli thrips and yellow mite are presented below. For both thrips and mite, number of insects per leaf and leaf damage intensity were taken as the criteria for evaluation of resistance. The combining ability and heterosis were also estimated for resistance. Analysis of variance revealed significant differences among the genotypes for the number of insects per leaf and leaf damage intensity of chilli thrips and yellow mite individually. Further ANOVA revealed that there is no significant difference among testers for both insects count and

Table 24 Number of chilli thrips per leaf in different genotypes

Genotypes	Number of chilli thrips per leaf		
	30 DAT	45 DAT	60 DAT
L_1	2.17 (3.70)	2.81 (6.91)	2.61 (5.84)
L_2	2.05 (3.22)	3.07 (8.40)	2.33 (4.42)
L_3	2.18 (3.74)	2.86 (7.20)	2.34 (4.49)
L_4	1.93 (2.74)	2.76 (6.60)	2.22 (3.92)
L_5	2.21 (3.89)	3.34 (10.15)	2.85 (7.15)
T_1	1.98 (2.93)	2.48 (5.15)	2.40 (4.77)
T_2	1.85 (2.42)	2.48 (5.14)	1.85 (2.41)
T_3	1.96 (2.84)	2.42 (4.86)	2.07 (3.29)
$L_1 \times T_1$	1.72 (1.95)	2.61 (5.80)	2.58 (5.68)
$L_1 \times T_2$	1.62 (1.62)	2.73 (6.44)	2.20 (3.84)
$L_1 \times T_3$	2.19 (3.80)	3.31 (9.94)	2.78 (6.75)
$L_2 \times T_1$	1.96 (2.85)	3.31 (9.96)	3.24 (9.50)
$L_2 \times T_2$	2.13 (3.54)	3.43 (10.76)	2.98 (7.86)
$L_2 \times T_3$	2.19 (3.80)	3.60 (11.95)	3.13 (8.77)
$L_3 \times T_1$	1.82 (2.30)	2.46 (5.03)	2.37 (4.62)
$L_3 \times T_2$	2.30 (4.29)	3.54 (11.53)	2.90 (7.44)
$L_3 \times T_3$	1.88 (2.45)	2.81 (6.91)	2.66 (6.08)
$L_4 \times T_1$	2.13 (3.53)	2.91 (7.49)	2.89 (7.33)
$L_4 \times T_2$	1.95 (2.82)	3.00 (8.00)	2.60 (5.75)
$L_4 \times T_3$	2.13 (3.56)	3.53 (11.48)	3.02 (8.11)
$L_5 \times T_1$	2.02 (3.08)	3.05 (8.33)	2.63 (5.90)
$L_5 \times T_2$	1.91 (2.66)	2.54 (5.44)	2.44 (4.95)
$L_5 \times T_3$	2.05 (3.22)	2.80 (6.82)	2.74 (6.50)
CD	0.11	0.16	0.15
SE±	0.04	0.06	0.05
MSE	0.004	0.009	0.009

$\sqrt{x+1}$ transformation values in parenthesis

Table 25 Leaf damage intensity of chilli thrips

Genotypes	Leaf damage intensity of chilli thrips		
	30 DAT	45 DAT	60 DAT
L_1	1.53 (1.33)	1.75 (2.07)	1.73 (2.00)
L_2	1.69 (1.33)	1.90 (2.60)	1.88 (2.53)
L_3	1.71 (1.87)	1.93 (2.73)	1.90 (2.59)
L_4	1.55 (1.93)	1.77 (2.13)	1.71 (1.93)
L_5	1.53 (1.33)	1.91 (2.66)	1.79 (2.19)
T_1	1.32 (0.73)	1.53 (1.33)	1.55 (1.40)
T_2	1.12 (0.26)	1.24 (0.53)	1.26 (0.60)
T_3	1.37 (0.87)	1.39 (0.93)	1.41 (1.00)
$L_1 \times T_1$	1.57 (1.46)	1.69 (1.87)	1.65 (1.73)
$L_1 \times T_2$	1.46 (1.13)	1.63 (1.66)	1.61 (1.60)
$L_1 \times T_3$	1.41 (1.00)	1.75 (2.06)	1.71 (1.93)
$L_2 \times T_1$	1.91 (2.67)	2.10 (3.40)	2.10 (3.40)
$L_2 \times T_2$	1.67 (1.80)	1.88 (2.53)	1.86 (2.47)
$L_2 \times T_3$	1.91 (2.66)	2.13 (3.53)	2.11 (3.47)
$L_3 \times T_1$	1.46 (1.13)	1.57 (1.46)	1.59 (1.53)
$L_3 \times T_2$	1.57 (1.47)	1.65 (1.73)	1.63 (1.66)
$L_3 \times T_3$	1.39 (0.93)	1.61 (1.60)	1.59 (1.53)
$L_4 \times T_1$	1.59 (1.53)	1.81 (2.27)	1.81 (2.26)
$L_4 \times T_2$	1.61 (1.60)	1.84 (2.40)	1.77 (2.13)
$L_4 \times T_3$	1.57 (1.46)	1.83 (2.33)	1.75 (2.06)
$L_5 \times T_1$	1.34 (0.80)	1.75 (2.06)	1.71 (1.93)
$L_5 \times T_2$	1.55 (1.40)	1.71 (1.93)	1.65 (1.73)
$L_5 \times T_3$	1.53 (1.33)	1.79 (2.20)	1.79 (2.20)
CD	0.08	0.08	0.09
SE±	0.03	0.03	0.03
MSE	0.003	0.002	0.003

$\sqrt{x + 1}$ transformation values in parenthesis

damage intensity. However, the lines were significantly different for thrips damage intensity but non significant for damage intensity of mite, thrips count and mite count per leaf. The hybrids were significantly different for number of insects per leaf and leaf damage intensity of both the pests.

4.2.1 Evaluation of resistance to chilli thrips

The number of thrips per leaf and the damage intensity are presented in Tables 24 and 25. The thrips count and damage intensity recorded at 45 DAT were higher than at other stages for most of the genotypes.

4.2.1.1 Number of thrips per leaf

The number of chilli thrips per leaf at 45 DAT ranged from 2.42 (Kiran) to 3.60 (L_2 xT_3). Ujwala (2.76) which was on par with Anugraha (2.81) and Jwalasakhi (2.86) recorded low counts, while Vellayani Athulya (3.34) recorded maximum count among lines. All the three testers were on par and recorded low number of thrips per leaf [Bhagyalakshmi (2.48), Bhaskar (2.48) and Kiran (2.42)]. Among the hybrids L_3 x T_1 (2.46), L_5 x T_2 (2.54) and L_1 x T_1 (2.61) recorded the low number of thrips per leaf. Thrips counts were high in L_2 x T_3 (3.60), L_3 x T_2 (3.54) and L_4 x T_3 (3.53).

4.2.1.2 Damage intensity due to thrips infestation

Among lines, Anugraha (1.75) and Ujwala (1.77) recorded significantly low damage intensity compared to other lines. All the three testers suffered significantly lower damage compared to lines and Bhagyalakshmi (1.24) was the least affected one. The hybrids L_3 x T_1 (1.57), L_1 x T_2 (1.63), L_3 x T_2 (1.65) and L_3 x T_3 (1.61) recorded less damage intensity while the hybrids L_2 x T_3 (2.13) and L_2 x T_1 (2.10) suffered relatively high damage due to thrips infestation.

4.2.2 Evaluation of resistance to yellow mite

The number of mites per leaf and its damage intensity are presented in Tables 26 and 27. In general comparatively high mite count and damage consequent to infestation were noticed at 45 DAT than the other stages of

Table 26 Number of yellow mites per leaf in different genotypes

Genotypes	Number of yellow mites per leaf		
	30 DAT	45 DAT	60 DAT
L_1	2.28 (4.18)	2.94 (7.66)	2.75 (6.58)
L_2	2.38 (4.67)	3.41 (10.60)	3.19 (9.16)
L_3	2.51 (5.32)	3.27 (9.71)	3.05 (8.29)
L_4	2.25 (4.05)	3.00 (7.99)	2.61 (5.82)
L_5	2.53 (5.40)	3.45 (10.87)	2.88 (7.32)
T_1	2.21(3.88)	3.04 (8.26)	2.71 (6.37)
T_2	1.69 (1.87)	2.31 (4.32)	2.09 (3.35)
T_3	1.91 (2.65)	2.47 (5.11)	2.30 (4.28)
$L_1 \times T_1$	2.33 (4.41)	3.46 (10.97)	3.16 (8.97)
$L_1 \times T_2$	2.08 (3.31)	2.88 (7.29)	2.86 (7.19)
$L_1 \times T_3$	2.88 (7.27)	3.99 (14.92)	3.42 (10.70)
$L_2 \times T_1$	2.40 (4.76)	3.52 (11.41)	3.29 (9.85)
$L_2 \times T_2$	2.46 (5.05)	3.55 (11.59)	3.55 (11.57)
$L_2 \times T_3$	2.59 (5.72)	4.33 (17.72)	3.59 (11.91)
$L_3 \times T_1$	2.37 (4.62)	3.27 (9.66)	2.43 (4.92)
$L_3 \times T_2$	2.10 (3.44)	2.70 (6.30)	2.24 (4.04)
$L_3 \times T_3$	2.26 (4.13)	3.43 (10.75)	2.88 (7.27)
$L_4 \times T_1$	2.20 (3.83)	2.96 (7.75)	2.98 (7.86)
$L_4 \times T_2$	2.29 (4.25)	3.58 (11.83)	2.93 (7.60)
$L_4 \times T_3$	2.29 (4.25)	2.91 (7.48)	2.38 (4.67)
$L_5 \times T_1$	2.17 (3.70)	3.41 (10.60)	3.01 (8.07)
$L_5 \times T_2$	2.00 (3.00)	3.62 (12.12)	2.87 (7.24)
$L_5 \times T_3$	2.25 (4.07)	3.92 (14.38)	3.26 (9.66)
CD	0.12	0.17	0.14
SE±	0.04	0.06	0.05
MSE	0.005	0.001	0.007

$\sqrt{x + 1}$ transformation values in parenthesis

Table 27 Leaf damage intensity of yellow mite

Genotypes	Leaf damage intensity of yellow mite		
	30 DAT	45 DAT	60 DAT
L_1	1.53 (1.33)	1.73 (2.00)	1.75 (2.06)
L_2	1.75 (2.07)	1.90 (2.60)	1.90 (2.60)
L_3	1.69 (1.87)	1.93 (2.73)	1.91 (2.66)
L_4	1.53 (1.33)	1.75 (2.06)	1.77 (2.13)
L_5	1.53 (1.33)	1.93 (2.73)	1.95 (2.80)
T_1	1.29 (0.67)	1.53 (1.33)	1.51 (1.27)
T_2	1.12 (0.26)	1.29 (0.66)	1.32 (0.73)
T_3	1.34 (0.80)	1.44 (1.07)	1.41 (1.00)
$L_1 \times T_1$	1.46 (1.13)	1.71 (1.93)	1.71 (1.93)
$L_1 \times T_2$	1.55 (1.40)	1.81 (2.27)	1.81 (2.26)
$L_1 \times T_3$	1.39 (0.93)	1.63 (1.67)	1.65 (1.73)
$L_2 \times T_1$	1.77 (2.13)	2.10 (3.40)	2.11 (3.46)
$L_2 \times T_2$	1.53 (1.33)	1.73 (2.00)	1.75 (2.07)
$L_2 \times T_3$	1.75 (2.07)	2.11 (3.47)	2.08 (3.33)
$L_3 \times T_1$	1.51 (1.27)	1.77 (2.13)	1.79 (2.20)
$L_3 \times T_2$	1.46 (1.13)	1.57 (1.46)	1.50 (1.25)
$L_3 \times T_3$	1.39 (0.93)	1.73 (2.00)	1.67 (1.80)
$L_4 \times T_1$	1.44 (1.06)	1.59 (1.53)	1.57 (1.46)
$L_4 \times T_2$	1.53 (1.33)	1.86 (2.47)	1.81 (2.26)
$L_4 \times T_3$	1.32 (0.73)	1.59 (1.53)	1.57 (1.46)
$L_5 \times T_1$	1.31 (0.73)	1.63 (1.67)	1.65 (1.73)
$L_5 \times T_2$	1.44 (1.06)	1.57 (1.46)	1.48 (1.19)
$L_5 \times T_3$	1.48 (1.20)	1.77 (2.13)	1.73 (2.00)
CD	0.08	0.06	0.09
SE±	0.03	0.02	0.03
MSE	0.002	0.001	0.003

$\sqrt{x + 1}$ transformation values in parenthesis

evaluation. In view of this the observation relating to 45 DAT is given emphasis in the results presented.

4.2.2.1 Number of mites per leaf

The number of yellow mites per leaf at 45 DAT ranged from 2.31 (Bhaskar) to 4.33 (L_2 x T_3). Among the lines the lowest number of mites per leaf was recorded in Anugraha (2.94) which was on par with Ujwala (3.00) and the lines Vellayani Athulya (3.45) and Jwalamukhi (3.41) showed high mite counts. The tester Bhagyalakshmi (2.31) recorded minimum number of mite among all the genotypes. L_3 x T_2 (2.70) was the hybrid which recorded the least number of mites per leaf followed by L_1 x T_2 (2.88), whereas the hybrid L_2 x T_3 (4.33) showed maximum count followed by L_1 x T_3 (3.99) and L_5 x T_3 (3.92).

4.2.2.2 Damage intensity due to mite infestation

The genotypes, Anugraha (1.73) and Ujwala (1.75) recorded comparatively low damage intensity and Jwalamukhi (1.90), Jwalasakhi (1.93) and Vellayani Athulya (1.93) recorded high damage intensity among lines. The tester Bhaskar (1.29) suffered low damage. The hybrids L_3 x T_2 (1.57) and L_5 x T_2 (1.57) recorded less damage intensity and were on par with L_4 x T_1 (1.59), L_4 x T_3 (1.59), L_1 x T_3 (1.62) and L_5 x T_1 (1.63).

4.2.3 Combining ability analysis

The combining ability effects of lines, testers and hybrids were estimated for resistance parameters. The general combining ability (*gca*) effects of lines and testers and specific combining ability (*sca*) effects hybrids are presented in Tables (28 & 29) and Fig. (6, 7 & 8).

4.2.3.1 Number of thrips per leaf

The line Jwalamukhi (0.40) showed significant positive *gca* effect while Anugraha (-0.16), Jwalasakhi (-0.11), Ujwala (-0.11) and Vellayani Athulya (-0.25) showed significant negative *gca* effects. Among the testers, Kiran (0.17) and Bhagyalakshmi (-0.17) exhibited significant positive and negative *gca* effects respectively.

Table 28 General combining ability effects of lines and tester for insect count and damage intensity

Treatments	Number of thrips per leaf	Number of yellow mite per leaf	Damage intensity due to thrips	Damage intensity due to yellow mite
Lines				
Anugraha (L_1)	-0.16**	0.01	-0.09**	-0.03**
Jwalamukhi (L_2)	0.40**	0.36**	0.25**	0.24**
Jwalasakhi (L_3)	-0.11**	-0.30**	-0.17**	-0.05**
Ujwala (L_4)	-0.11**	-0.28**	0.04*	-0.06**
Vellayani Athulya (L_5)	-0.25**	-0.21**	-0.03	-0.09**
SE±	0.03	0.03	0.02	0.01
CD	0.09	0.10	0.04	0.04
Testers				
Bhagyalakshmi (T_1)	-0.17**	-0.11**	0.0004	0.01
Bhaskar (T_2)	-0.01	-0.17**	-0.04**	-0.04**
Kiran (T_3)	0.17**	0.28**	0.04**	0.02*
SE±	0.02	0.03	0.01	0.01
CD	0.07	0.08	0.03	0.03

**Significant at 1 per cent level, * Significant at 5 per cent level

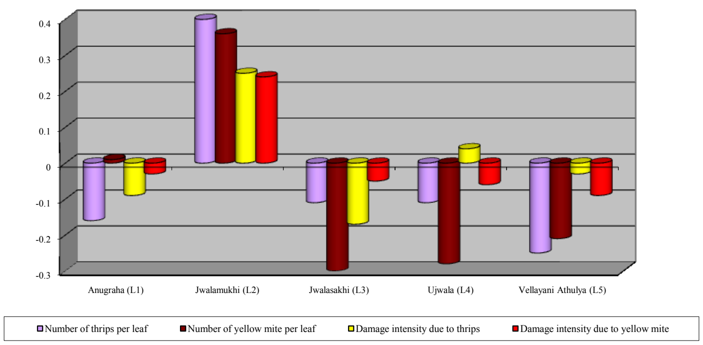


Fig. 6 General combining ability effects of lines for insect count and damage intensity

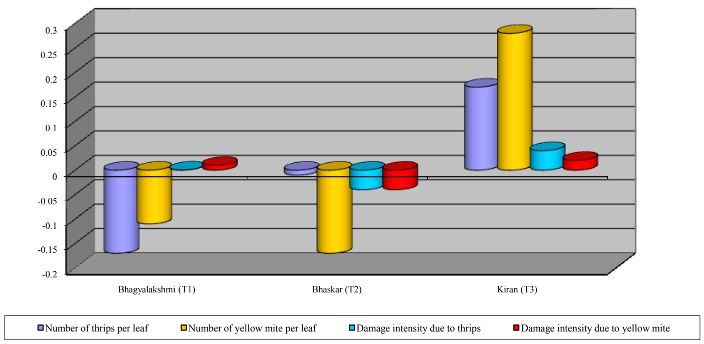


Fig. 7 General combining ability effects of testers for insect count and damage intensity

Table 29 Specific combining ability effects of hybrids for insect count and damage intensity

Treatments	Number of thrips per leaf	Number of yellow mite per leaf	Damage intensity due to thrips	Damage intensity due to mites
$L_1 \times T_1$	-0.10	0.13*	0.0007	-0.02
$L_1 \times T_2$	-0.16**	-0.40**	-0.02	0.13**
$L_1 \times T_3$	0.26**	0.27**	0.02	-0.11**
$L_2 \times T_1$	0.04	-0.16**	0.06*	0.10**
$L_2 \times T_2$	-0.02	-0.08	-0.12**	-0.21**
$L_2 \times T_3$	-0.01	0.25**	0.06*	0.11**
$L_3 \times T_1$	-0.31**	0.25**	-0.04	0.06**
$L_3 \times T_2$	0.60**	-0.26**	0.08**	-0.08**
$L_3 \times T_3$	-0.29**	0.02	-0.04	0.02
$L_4 \times T_1$	-0.06	-0.08	-0.02	-0.11**
$L_4 \times T_2$	-0.15*	0.60**	0.06*	0.22**
$L_4 \times T_3$	0.22**	-0.52**	-0.04	-0.11**
$L_5 \times T_1$	0.43**	-0.13*	-0.0005	-0.04*
$L_5 \times T_2$	-0.26**	0.14*	0.0007	-0.05**
$L_5 \times T_3$	-0.17**	-0.01	-0.0003	0.09**
SE±	0.06	0.06	0.03	0.02
CD	0.16	0.17	0.08	0.07

**Significant at 1 per cent level, * Significant at 5 per cent level

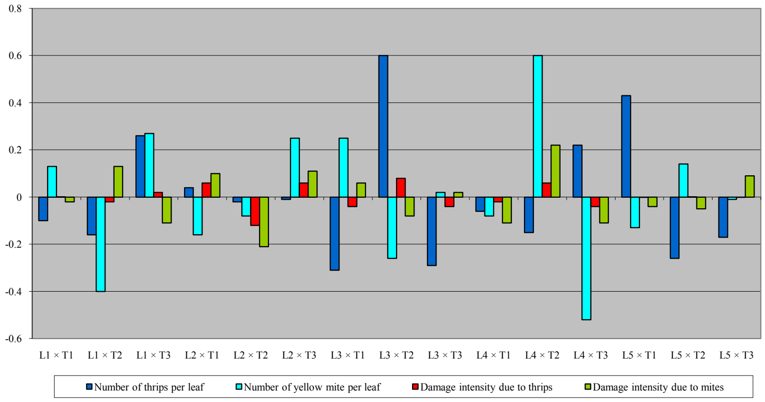


Fig. 8 Specific combining ability effects of hybrids for insect count and damage intensity

Significant positive *sca* effects were displayed by four hybrids, the maximum being shown by L_3 x T_2 (0.60) followed by L_5 x T_1 (0.43). Significant negative *sca* effects were shown by six hybrids, the maximum being for L_3 x T_1 (-0.31) followed by L_3 x T_3 (-0.29).

4.2.3.2 Damage intensity due to thrips infestation

The lines Jwalamukhi (0.25) and Ujwala (0.04) had positive and significant *gca* effects while Anugraha (-0.09) and Jwalasakhi (-0.17) had significant negative *gca* effects. Among the testers, Kiran (0.04) exhibited significant positive and Bhaskar (-0.04) significant negative *gca* effects. Four hybrids showed significant positive *sca* effects, the maximum being displayed by L_3 x T_2 (0.08). Only L_2 x T_2 (-0.12) showed significant negative *sca* effect.

4.2.3.3 Number of yellow mites per leaf

Among the lines Jwalasakhi (-0.30), Ujwala (-0.28) and Vellayani Athulya (-0.21) showed significant negative *gca* effects while Jwalamukhi (0.36) showed significant positive *gca* effect. Among the testers, Kiran (0.28) showed significant positive *gca* effect while Bhagyalakshmi (-0.11) and Bhaskar (-0.17) showed significant negative *gca* effects. Specific combining ability effects were positive and significant for six hybrids. The maximum value was for L_4 x T_2 (0.60) followed by L_1 x T_3 (0.27). Significant negative values were shown by five hybrids. The negative *sca* effect was maximum for L_4 x T_3 (-0.52) and minimum for L_5 x T_1 (-0.13).

4.2.3.4 Damage intensity due to yellow mite infestation

All the lines exhibited significant negative *gca* effects except Jwalamukhi (0.24). Among the testers Kiran (0.02) and Bhaskar (-0.04) showed significant positive and negative *gca* effects respectively. Among the hybrids, five showed significant positive *sca* effect. The maximum value was for L_4 x T_2 (0.22) and minimum for L_3 x T_1 (0.06). Significant negative *sca* effect was shown by seven hybrids with maximum value for L_2 x T_2 (-0.21) and minimum for L_1 x T_1 (-0.02).

Table 30 Components of genetic variance (F=1)

Sl. No.	Observation	Additive variance (σ^2A)	Dominance variance (σ^2D)	σ^2A/σ^2D
1	Number of chilli thrips per leaf	0.005	0.12	0.042
2	Number of yellow mite per leaf	0.01	0.15	0.071
3	Damage intensity due to thrips	0.005	0.004	1.25
4	Damage intensity due to mites	0.001	0.02	0.05

Table 31 Heterosis (%) for number of thrips per leaf

Genotypes	SH	HB	RH
$L_1 \times T_1$	-8.91**	5.24	-1.46**
$L_1 \times T_2$	-4.70**	10.08**	3.13**
$L_1 \times T_3$	15.56**	36.78**	26.44**
$L_2 \times T_1$	15.62**	34.30**	19.35**
$L_2 \times T_2$	19.81**	38.31**	23.71**
$L_2 \times T_3$	25.73**	48.76**	31.19**
$L_3 \times T_1$	-14.20**	-0.81	-8.05**
$L_3 \times T_2$	23.64**	42.74**	32.54**
$L_3 \times T_3$	-1.77**	16.12**	6.44**
$L_4 \times T_1$	1.77**	17.34**	11.25**
$L_4 \times T_2$	4.80**	20.97**	14.60**
$L_4 \times T_3$	23.40**	45.87**	36.45**
$L_5 \times T_1$	6.68**	22.98**	4.97**
$L_5 \times T_2$	-11.33**	2.42	-12.73**
$L_5 \times T_3$	-2.34**	15.70**	-2.92**
CD	0.16	0.16	0.14

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 32 Heterosis (%) for number of mites per leaf

Genotypes	SH	HB	RH
$L_1 \times T_1$	5.74**	17.69**	15.61**
$L_1 \times T_2$	-12.03**	24.68**	9.67**
$L_1 \times T_3$	21.93**	61.54**	47.39**
$L_2 \times T_1$	7.66**	15.79**	9.25**
$L_2 \times T_2$	8.45**	43.72**	24.25**
$L_2 \times T_3$	32.23**	75.30**	47.25**
$L_3 \times T_1$	-0.21	7.57**	3.41**
$L_3 \times T_2$	-17.44**	16.88**	-3.15**
$L_3 \times T_3$	4.75**	38.87**	19.37**
$L_4 \times T_1$	-9.62**	-1.33	-2.11**
$L_4 \times T_2$	9.45**	54.98**	35.01**
$L_4 \times T_3$	-11.00**	17.81**	6.49**
$L_5 \times T_1$	4.09**	12.17**	4.99**
$L_5 \times T_2$	10.67**	56.71**	25.92**
$L_5 \times T_3$	19.83**	58.70**	32.55**
CD	0.17	0.17	0.15

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

4.2.4 Components of genetic variance

The additive variance (σ^2a) and dominance variance (σ^2d) estimated for resistance parameters are presented in Table 30. The dominance variance was greater than additive variance for chilli thrips and mite count and damage intensity due to mite whereas the additive variance was greater for thrips damage intensity.

4.2.5 Heterosis

Tables 31 to 34 and Fig. 9 shows the standard heterosis, heterobeltiosis and relative heterosis for the fifteen crosses with respect to insect count and damage intensity. Jwalasakhi was used as the check variety for the estimation of standard heterosis.

4.3.5.1 Number of chilli thrips per leaf

Six hybrids showed significant negative standard heterosis of which L_3 x T_1 (-14.20) exhibited maximum value. Significant negative relative heterosis was shown by four hybrids. The highest negative value was recorded for L_5 x T_2 (-12.73) followed by L_3 x T_1 (-8.05), L_5 x T_3 (-2.92) and L_1 x T_1 (-1.46).

4.2.5.2 Damage intensity due to thrips infestation

All the hybrids showed significant negative standard heterosis except L_2 x T_1 (8.60) and L_2 x T_3 (10.25). The maximum negative standard heterosis was shown by L_3 x T_1 (-18.77) followed by L_3 x T_3 (-16.54) and L_1 x T_2 (-15.49). Only two hybrids, L_3 x T_1 (-9.26) and L_3 x T_3 (-2.91) exhibited significant negative heterosis over mid parent. None of the hybrids showed desirable negative heterobeltiosis.

4.2.5.3 Number of yellow mites per leaf

Significant negative standard heterosis was noticed L_3 x T_2 (-17.44), L_1 x T_2 (-11.00), L_1 x T_2 (-12.03) and L_4 x T_1 (-9.62). None of the hybrids showed significant negative heterobeltiosis. Only the hybrids L_3 x T_2 (-3.15)

Table 33 Heterosis (%) for damage intensity due to chilli thrips infestation

Genotypes	SH	HB	RH
$L_1 \times T_1$	-12.33**	10.46**	3.31**
$L_1 \times T_2$	-15.49**	31.45**	9.21**
$L_1 \times T_3$	-9.36**	25.90**	11.49**
$L_2 \times T_1$	8.60**	37.25**	22.53**
$L_2 \times T_2$	-2.67**	51.61**	19.92**
$L_2 \times T_3$	10.25**	53.24**	29.59**
$L_3 \times T_1$	-18.77**	2.61	-9.26**
$L_3 \times T_2$	-14.40**	33.06**	4.33**
$L_3 \times T_3$	-16.54**	15.83**	-2.91**
$L_4 \times T_1$	-6.42**	18.30**	9.65**
$L_4 \times T_2$	-4.51**	48.39**	22.62**
$L_4 \times T_3$	-5.46**	31.65**	15.59**
$L_5 \times T_1$	-9.36**	14.38**	1.75
$L_5 \times T_2$	-11.32**	37.90**	8.66**
$L_5 \times T_3$	-7.40**	28.77**	8.28**
CD	0.08	0.08	0.07

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Table 34 Heterosis (%) for damage intensity due to yellow mite infestation

Genotypes	SH	HB	RH
$L_1 \times T_1$	-11.40**	11.76**	5.06**
$L_1 \times T_2$	-6.46**	40.31**	-19.67**
$L_1 \times T_3$	-15.49**	13.19**	3.06**
$L_2 \times T_1$	8.55**	37.25**	22.50**
$L_2 \times T_2$	-10.38**	34.11**	8.70**
$L_2 \times T_3$	9.38**	46.53**	26.77**
$L_3 \times T_1$	-8.39**	15.69**	2.33**
$L_3 \times T_2$	-18.77**	21.71**	-2.55**
$L_3 \times T_3$	-10.38**	20.14**	2.78**
$L_4 \times T_1$	-17.63**	3.92	-2.89**
$L_4 \times T_2$	-3.64**	44.19**	22.52**
$L_4 \times T_3$	-17.67**	10.42**	-0.20
$L_5 \times T_1$	-15.49**	6.54**	-5.59**
$L_5 \times T_2$	-18.77**	21.71**	-2.54**
$L_5 \times T_3$	-8.39**	22.92**	5.08**
CD	0.07	0.07	0.06

**Significant at 1 per cent level, * Significant at 5 per cent level

SH – Standard heterosis, HB – Heterobeltiosis, RH – Relative heterosis

Fig. 9 Heterosis for resistance parameters

and L_4 x T_1 (-2.11) showed significant negative heterosis over mid parent values.

4.2.5.4 Damage intensity due to mite infestation

Thirteen hybrids showed significant negative standard heterosis. The maximum negative standard heterosis was noticed for L_3 x T_2 (-18.77) and L_5 x T_2 (-18.77). None of the hybrids showed significant negative heterobeltiosis. Significant negative relative heterosis was noticed for L_1 x T_2 (-19.67), L_5 x T_1 (-5.59), L_4 x T_1 (-2.89), L_3 x T_2 (-2.25) and L_5 x T_2 (-2.54).

DISCUSSION

5. DISCUSSION

Proper identification of the genetically superior parents is done on the basis of the performance of the hybrids which inturn is dependent on the information obtained from the analysis of the combining ability in terms of *gca* of the parents and *sca* of the hybrids. Line x Tester analysis is one of the method for evaluating the performance of varieties or strains in terms of their combining ability. The present study was carried out in a line x tester model using five high yielding varieties which are susceptible to chilli thrips and mites as lines and three tolerant varieties as testers. The combining ability effects, gene action and heterosis for yield and resistance were studied and superior crosses were identified. A brief discussion regarding the results obtained is furnished below.

Analysis of variance had shown that the treatments were significant for all characters, suggesting that there was significant difference among the genotypes.

5.1 Evaluation of genotypes for yield and yield components

5.1.1 Mean performance

Among the five lines used Jwalasakhi was found to be superior to others with respect to green fruit yield per plant and showed high per se performance for fruit length, fruit girth and fruit weight. Likewise, Vellayani Athulya displayed superiority for fruit length, fruit girth and fruit weight. Among testers, Bhaskar was found to be superior for green fruit yield per plant.

Among crosses, L_5 x T_2 apart from giving high fruit yield of 805.28 g per plant possessed desirability in fruit characters *viz*., fruit length (12.58 cm), fruit girth (5.74 cm) and fruit weight (11.18 g). The early flowering hybrid L_1 x T_3 showed maximum mean performance for number of fruits per plant (190.56), number of primary branches (8.12) and number of secondary branches (28.92). L_2 x T_1 was the tallest hybrid with a plant height of 67.52 cm. The maximum plant canopy width was noticed for L_4 x T_2 (57.93 cm). The hybrid L_3 x T_2 had long fruit bearing period of 74.08 days and the crop duration was minimum for L_4 x T_1 (152.11 days). High capsaicin content was noticed for L_2 x T_2 (0.408 %) and minimum for L_1 x T_1 (0.118 %).

5.1.2 Gene action

Analysis of variance for combining ability gives an estimate of the variances due to lines, testers and line x tester which imply the type of gene action responsible for the variation in each character. Significant mean sum of squares due to lines and testers indicate that additive gene action is operative while significant mean sum of squares due to line x tester shows non additive gene action (dominance and epistatic) is controlling the character. The existence of significant amount of dominance variance is a prerequisite for the exploitation of heterosis. The analysis of variance revealed that mean squares due to line x tester interaction was significant for days to 50 per cent flowering, plant height, number of primary branches, plant canopy width, fruit bearing period, number of fruits per plant, capsaicin content and duration. This indicated that *sca* variance was significant for these characters suggesting the involvement of non additive gene action in the expression of these traits. Bhagyalakshmi (1991) and Nandadevi and Hosamani (2003) reported non additive gene action for days to 50 per cent flowering while Philip (2004) reported it for crop duration. Corroborative reports by Ahmed (2003), Pandey et al. (2003) and Patel et al. (2004) for plant height, number of fruits per plant and number of primary branches supports the present findings. Non additive gene action was reported by Gouda (2003) for plant canopy width while Sousa and Maluf (2003), Philip (2004), Prasath and Ponnuswami (2008) reported it for capsaicin content. Significance of both *gca* and *sca* variances were revealed, as the mean squares due to line and line x tester interactions were significant for green fruit yield per plant, fruit length, fruit girth and fruit weight, while tester and line x tester interactions were significant for number of secondary branches. This indicated the involvement of both additive and non additive gene action. But the ratio of additive to dominance variance was less than unity for these characters except fruit girth and fruit weight indicating the preponderance of non additive gene action. Similar findings were reported for green fruit yield by Ahmed (2003), Pandey et al. (2003) and Patel et al. (2004). Gouda (2003) reported non additive gene action for number of secondary branches while Doshi (2003) reported non additive gene action for fruit length. For fruit girth and fruit weight the ratio of additive to dominance variance was more than unity indicating the preponderance of additive gene action. Additive gene action for both fruit weight and fruit girth was earlier reported by Patel et al. (2002), Sathiyamurthy (2002) and Jagadeesh et al. (2004). Ahmed et al. (1997) also observed additive gene action for fruit weight while Sundram and Irulappan (1998) and Chadchan (2008) observed for fruit girth. Jagadeesha and Wali (2008) recorded higher proportion of additive gene action for fruit characters. But, Patel et al. (2004) observed non additive gene action for fruit weight and fruit girth.

5.1.3 Combining ability analysis

Estimation of combining ability effects is done to assess the relative ability of a genotype to transmit its desirable performance to its crosses. Combining ability analysis provides information about the components of genetic variance involved in the expression of various polygenic characters and thus help in the selection of desirable parents for hybridization and also in deciding the breeding procedure for the genetic improvement of such characters.

5.1.3.1 General combining ability effects of parents

General combining ability is the average performance of a strain in a series of hybrid combination, which reflects the additive gene effects of parents.

In chilli, the characters viz., plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period, number of fruits per plant, fruit length, fruit girth, fruit weight, green fruit yield and capsaicin content are important demanding attention in crop improvement efforts. A parent which transmits genes for the improvement of these traits is regarded as a desirable combiner. Thus, parental strains with significant and positive *gca* effects are desirable combiners. While for the traits day to 50 per cent flowering and crop duration, a parent which transmit genes for lesser period to its progeny (earliness) is regarded as a desirable combiner. Thus, parental strains with significant and negative *gca* effects are desirable combiners.

Among lines, Vellayani Athulya exhibited remarkable significant *gca* effects for yield and fruit characters like fruit length, fruit girth and fruit weight. Muthuswamy (2004) reported high *gca* effects for fruit yield, fruit length, fruit girth and fruit weight. Significant *gca* effects for yield was earlier reported by Jadhav *et al*. (2001), Nandadevi and Hosamani (2003), Ajith (2004), Haridass (2007), Reddy et al. (2008) and Khereba et al. (2008). In addition to this, Vellayani Athulya also showed significant desirable *gca* effects for number of primary branches and number of secondary branches per plant. Mulge (1992), Jagadeesh (1995) and Chadchan (2008) noticed significant *gca* effects for number of primary branches.

Anugraha was the good general combiner for number of fruits per plant and also showed significant desirable *gca* effects for number of primary branches, number of secondary branches, fruit length and duration. Jwalamukhi was the only line with good *gca* effect for plant height. The high *gca* effects for number of fruits per plant is supported by the reports of Ahmed (1999), Jadhav et al. (2001), Nandadevi and Hosamani (2003), Ajith (2004), Muthuswamy (2004), Saritha et al. (2005), Gondane et al. (2007) and Haridass (2007). Significant *gca* effects for plant height was reported by Lohithaswa et al. (2000), Jadhav et al. (2001), Saritha et al. (2005) and Gondane et al. (2007).

Jwalasakhi displayed significant *gca* effects for fruit bearing period, fruit length, fruit girth and fruit weight. Ujwala showed significant desirable *gca* effect for number of primary branches, number of fruits per plant and capsaicin content. Muthuswamy (2004), Saritha et al. (2005), Srivatsava et al. (2005) and Chadchan (2008) reported significant *gca* effect for capsaicin content.

Nandadevi and Hosamani (2003), Gondane et al. (2007) and Reddy et al. (2008) reported significant *gca* effects for days to 50 per cent flowering. However, in the present study, the *gca* effects of the lines with respect to character were not significant.

Among testers, Bhagyalakshmi expressed desirable significant *gca* effects for plant height, number of primary branches and fruit bearing period. Bhaskar showed remarkably high *gca* effects for fruit girth, fruit weight, capsaicin content and green fruit yield and hence is a good general combiner for these traits. Kiran was the good combiner for days to 50 per cent flowering, number of secondary branches and duration.

5.1.3.2 Specific combining ability effects of crosses

Specific combining ability indicates those situations in which certain crosses do relatively better or worse than would be expected on the basis of average performance of their respective parents. It is an indication of non additive gene action.

The hybrid L_4 x T_2 (Plate 6) exhibited high *sca* effects for plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period and number of fruits per plant but the hybrid performance was not promising for fruit yield per plant. The significance *sca* effects for plant height and number of branches per plant are in conformity with the reports of Shukla et al. (1999), Ghandi et al. (2000) and Saritha et al. (2005).

L_4 x T_1 had desirable *sca* effects for fruit length, fruit girth, capsaicin content and duration. L_5 x T_2 showed highly significant desirable *sca* effects for green fruit yield, fruit length, fruit girth, fruit weight and duration. Saritha et al. (2005) and Khereba et al. (2008) observed high significant *sca* effects for fruit length and fruit yield. While, Jadhav et al. (2001), Nandadevi and Hosamani (2003) and Khereba et al. (2008) noticed significant *sca* effects for fruit weight and number of fruits per plant, significant *sca* effects for fruit width was reported by Chadchan (2008).

L_1 x T_3 recorded high *sca* effects for number of fruits per plant and had desirable *sca* effects for fruit length, fruit weight, capsaicin content and green fruit yield. L_2 x T_1 and L_2 x T_2 had maximum significant *sca* effects for plant height and capsaicin content respectively. Saritha et al. (2005) and Chadchan (2008) reported significant *sca* effects for capsaicin content. None of the hybrids showed significant *sca* effects for days to 50 per cent flowering but six hybrids showed desirable *sca* effects. However, Ahmed (1999) and Khereba et al. (2008) observed significant *sca* effects for days to flowering.

5.1.4 Heterosis

Heterosis breeding makes use of the hybrid vigour in the crosses for attaining noticeable increase in production and productivity of crop plants. Existence of significant amount of dominance variance is essential for undertaking heterosis breeding programme. Even, the expression of small magnitude of heterosis for certain characters may be much rewarding in breeding.

In the present study, the relative heterosis, heterobeltiosis and standard heterosis were estimated for the 15 crosses with respect to the different characters.

Negative heterosis indicating earliness was observed for days to 50 per cent flowering and crop duration for most of the hybrids. The maximum significant standard heterosis, heterobeltiosis and relative heterosis in the desirable direction was recorded by L_1 x T_3 followed by L_4 x T_1 and L_3 x T_2 for days to 50 per cent flowering. The hybrid L_1 x T_2 showed maximum heterosis over mid, better and standard parent for crop duration followed by L_4 x T_1. Significant negative heterosis for days to first flowering was reported by Bhagyalakshmi et al. (1991), Saraladevi (1994) and Ahmed et al. (1999) and for crop duration by Ajith (2004).

Positive heterosis indicates the superiority of the hybrid for remaining characters viz., plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period, number of fruits per plant, fruit length, fruit girth, fruit weight, green fruit yield and capsaicin content.

High magnitude of all three types of heterosis for green fruit yield was recorded by L_5 x T_2 followed by L_5 x T_3 and L_5 x T_1. This was conformity with the reports of Singh and Hundal (2001), Adpawar et al. (2006), Haridass (2007), Kamble and Mulge (2008b) and Reddy et al. (2008).

The hybrid L_5 x T_2 and L_5 x T_3 also showed high standard heterosis for fruit length, fruit weight and fruit girth. Significant positive heterosis for fruit length and fruit girth were recorded by Saraladevi (1994), Muthuswamy (2004) and Reddy et al. (2008). Similar findings were reported for fruit weight by Mohamed et al. (1995), Muthuvel (2003) and Reddy et al. (2008).

L_2 x T_1 exhibited highly significant standard and relative heterosis for plant height but heterosis over better parent was not significant. Eight other hybrids showed significant standard heterosis for plant height. This result agree with the reports of Saraladevi (1994), Joshi et al. (1995), Anandanayati (1997), Malathi (2001) and Muthuvel (2003).

The hybrid L_1 x T_3 had highest magnitude of positive heterosis over mid, better and standard parent for number of primary branches, number of secondary branches and number of fruits per plant. L_3 x T_1 also showed high magnitude of all three types of heterosis for number of primary branches and number of secondary branches. Malathi (2001), Satiyamurthy (2002) and Muthuswamy (2004) reported positive heterosis for number of branches per plant.

All the hybrids exhibited significant positive standard heterosis for plant canopy width. The hybrid L_4 x T_2 showed maximum standard heterosis, heterobeltiosis and relative heterosis for plant canopy width followed by L_5 x T_1 and L_2 x T_1. Reddy et al. (2008) observed significant heterosis for plant spread.

Heterosis for fruit bearing period over standard parent was positive and high for L_3 x T_2 while all the hybrids showed negative heterobeltiosis and relative heterosis except L_2 x T_1 which was positive though not significant. Six hybrids including L_1 x T_3 exhibited significant desirable heterosis over mid, better and standard parent for number of fruits per plant. Hemavathy (2000), Malathi (2001), Philip (2004), Haridass (2007), Kamble and Mulge (2008b) and Reddy et al. (2008) published reports in conformity to the present results with respect to number of fruits per plant.

The hybrids, L_1 x T_3 and L_3 x T_2 had significant positive heterosis in all three cases followed by L_1 x T_2 for fruit length. The maximum standerd heterosis for fruit length was recorded for L_5 x T_2 and L_5 x T_3. L_3 x T_3 and L_3 x T_1 exhibited significant positive heterosis for fruit girth and fruit weight respectively over mid, better and standard parent. Only one hybrid L_2 x T_2 showed significant positive relative and standard heterosis for capsaicin content. Doshi and Shukla (2000), Muthuvel (2003), Muthuswamy (2004), Kumar et al. (2005), Haridass (2007) and Patel et al. (2008) reported positive heterosis for capsaicin content.

From the results it is inferred that L_1 x T_3 (Plate 6) was superior hybrid showing desirable heterosis of all kind for most of the character like number of primary branches, number of secondary branches, number of fruits per plant, plant canopy width, fruit length and green fruit yield and had desirable *sca* effects for all these characters. It also had negative heterosis for days to 50 per cent flowering indicating earliness in flowering.

The hybrids L_5 x T_2 and L_5 x T_3 (Plate 6) showed maximum heterosis for green fruit yield and fruit characters viz., fruit length, fruit girth and fruit weight further these hybrids had desirable heterosis for number of secondary branches and days to 50 per cent flowering. However, only L_5 x T_2 had good *sca* effects for green fruit yield and fruit characters.

5.1.5 Proportional contribution of lines, testers and crosses

In general, the hybrids contributed maximum towards the total variability for all the characters except number of secondary branches, fruit length, fruit girth, fruit weight and green fruit yield per plant. The proportional contribution of lines exceeded that of testers for all the characters except plant height. The lines contributed maximum towards the total variance for fruit weight, fruit girth, fruit length, green fruit yield per plant and number of secondary branches.

L_1 x T_3

L_5 x T_2

L_4 x T_2

L_5 x T_3

Plate 6. High yielding hybrids

5.2 Evaluation of genotypes for resistance to chilli thrips and yellow mite

Chilli thrips (*Scirtothirps dorsalis* Hood) and yellow mite (*Polyphagotarsenems latus* Banks) are important sucking pests of chilli that inflict heavy yield loss in the event of serious infestation. Unscrupulous use of chemical insecticides to control these pests leads to pest resurgence, destruction of natural enemies and environmental pollution, apart from pesticide residue related health hazards. Host plant resistance is an economic and ecofriendly pest control tactic. Even a low level of host plant resistance can substantially reduce the dependence on chemical insecticides. Cultivars harboring lesser pest population and/or suffering lesser damage in comparison with others can be considered as relatively resistant. In the present study, the chilli hybrids produced by crossing in line x tester fashion, five high yielding lines and three thrips and mite tolerant testers were evaluated in a field experiment for resistance to these pests. Resistance was evaluated based on population count and intensity of leaf damage due to pest infestation. Combining ability, gene action and heterosis for resistance were also estimated.

5.2.1 Evaluation for resistance to chilli thrips

The ANOVA revealed significant differences among the genotypes for number of thrips per leaf as well as leaf damage intensity due to thrips infestation.

Among the lines, Anugraha, Jwalasakhi and Ujwala recorded low number of thrips per leaf, but Jwalasakhi showed significantly high damage intensity compared to Anugraha and Ujwala. Hence it is inferred that Anugraha and Ujwala were relatively resistant among the lines.

Among testers, Bhaskar recorded less number of thrips per leaf (2.48) and showed least damage intensity (1.24). Kiran recorded least number of thrips per leaf (2.42) but suffered more leaf damage (1.39) than Bhaskar but less compared to Bhagyalakshmi. In view of low damage and lesser population count, Bhaskar is identified as the variety relatively resistant among the testers.

While considering hybrids L_3 x T_1, L_5 x T_2 and L_1 x T_1 recorded low number of thrips per leaf. The leaf damage intensity was low in L_3 x T_2 followed b L_3 x T_3, L_1 x T_2 and L_3 x T_2. The hybrids L_5 x T_2 and L_1 x T_1 recorded less number of thrips per leaf but suffered high damage. The hybrids, L_3 x T_3, L_1 x T_2 and L_3 x T_2 suffered less damage inspite of the higher population of insects harboring on leaves. Hence these hybrids appeared to be tolerant to chilli thrips. While considering both thrips population and leaf damage intensity simultaneously, L_3 x T_1 (Plate 7) was identified as the most promising one among the hybrids regarding resistance to chilli thrips. It recorded 2.46 thrips per leaf and a low damage intensity of 1.57.

5.2.2 Evaluation for resistance to yellow mite

The resistance evaluation to yellow mite was based on population count and damage intensity due to mite infestation. Among lines, Anugraha and Ujwala recorded less number of mites per leaf (2.94 and 3.00 respectively) and low damage intensity (1.73 and 1.75 respectively). Among testers, both Bhaskar and Kiran recorded less number of mites per leaf (2.31 and 2.47 respectively). But Kiran showed more damage symptom (1.44) than Bhaskar (1.29).

Among the hybrids, L_3 x T_2 recorded less number of mites per leaf (2.70) as well as low damage intensity (1.57). Five other hybrids viz., L_5 x T_2, L_4 x T_1, L_4 x T_3, L_1 x T_3 and L_5 x T_1 showed less leaf damage next to L_3 x T_2. Except L_4 x T_3 and L_4 x T_1 other three recorded more number of thrips per leaf. Considering both thrips population and leaf damage intensity simultaneously, it is inferred that hybrids L_3 xT_2, L_4 x T_3 and L_4 x T_1 are relatively resistant to yellow mite. Whereas the hybrids L_5 x T_2, L_1 x T_3 and L_5 x T_1 suffered lesser damage inspite of high insect count suggesting their ability to tolerate attack.

5.2.3 Genotypes showing resistance to chilli thrips and yellow mite

Among lines, Anugraha and Ujwala are relatively resistant to both chilli thrips and yellow mite. The testers, Bhaskar and Kiran are the most resistant ones to these pests among the genotypes studied. L_3 x T_2 (Plate 7) is found to be the most resistant hybrid to both chilli thrips and yellow mite.

5.2.4 Gene action

The mean square due to line x tester interaction was significant while the mean squares due to lines and testers were not significant for number of chilli thrips per leaf, number of yellow mites per leaf and the damage intensity of mite, which showed that the *sca* variance was significant for these traits indicating the involvement of non additive gene action. Significant variance was recorded by lines and line x tester interaction for thrips damage intensity. So both *gca* and *sca* variances were significant showing the involvement of both additive and non additive gene action. But the additive to dominance variance ratio was greater than unity indicating the predominance of additive gene action. In agreement to this, Jagadeesha and Wali (2006) observed non additive gene action for leaf curl index of mite. However, thrips leaf curl index was found to be predominantly under the control of non additive gene action. Jagadeesha et al. (2004) reported that resistance to both thrips and mite were under the control of non additive gene action.

5.2.5 Combining ability analysis

The genotypes with significant negative *gca* effects for both count and damage intensity of chilli thrips and yellow mite can hopefully used as parents in combination breeding programme for imparting resistance to these pests. In such endeavors stress should be given to the damage intensity since the ultimate crop loss would depend upon the extent of damage inflicted consequent infestation.

The superior performance of a variety is not always reflected in its combining ability. When a genotype is employed as a parent in crosses, it may appear as poor combiner and the hybrid performance may not be in line with the expectation. Such a behaviour could result from intra-and/or inter-allelic interaction of genes concerned with the character (Dabholkar, 1992). Here also Anugraha and Ujwala were tolerant among lines for both thrips and mite. But

L_3 x T_1 **(Relatively resistant to chilli thrips)**

L_3 x T_2 **(Relatively resistant to both chilli thrips and yello mite)**

Plate 7. Hybrids resistant to chilli thrips and yellow mite

Ujwala was the good general combiner only for mite resistance whereas, Anugraha was the good general combiner for both thrips and mite resistance. The line Jwalasakhi also a good general combiner for both thrips and mite resistance which showed significant desirable *gca* effect for both count and damage intensity of these pests. Among testers, Bhaskar showed significant desirable *gca* effects for both chilli thrips and yellow mite resistance. Among hybrids, only L_2 x T_2 showed significant negative *sca* effects for both thrips and mite resistance. None of the hybrids were good specific combiner for thrips resistance except L_2 x T_2. The hybrids, L_1 x T_3, L_3 x T_2, L_4 x T_1, L_4 x T_3, L_5 x T_1 and L_5 x T_2 were good specific combiners for mite resistance.

5.2.6 Heterosis

The hybrid which shows significant negative heterosis for insect resistance parameters would be desirable for exploitation of resistance. None of the hybrid showed desirable heterosis for both pests simultaneously.

Four hybrids L_5 x T_2, L_3 x T_1, L_5 x T_3 and L_1 x T_1 showed significant negative standard and relative heterosis for number of thrips per leaf. Among these only L_3 x T_1 showed significant negative heterosis for thrips damage intensity over standard and mid parent. The hybrid L_3 x T_3 also showed significant negative heterosis for thrips damage intensity. None of the hybrids showed significant desirable heterobeltiosis for thrips resistance parameters.

The hybrids L_3 x T_2 and L_4 x T_1 showed significant negative heterosis over mid parent and standard variety for mite count and its damage intensity. None of the hybrids showed significant desirable heterobeltiosis for mite resistance parameters.

5.3 Promising high yielding hybrids showing relatively resistance to pests

Considering both yield and resistance simultaneously, the hybrid L_3 x T_1 was high yielding and relatively resistant to chilli thrips whereas, L_5 x T_2 was high yielding and relatively resistant to yellow mite.

SUMMARY

6. SUMMARY

Chilli (*Capsicum annuum*) is an important commercial crop of India grown for its green fruits as vegetable and red form as spice. Though India is the largest producer, consumer and exporter of chillies in the world, productivity of chilli in India has remained low compared to the world average. One of the reasons for low productivity is the damage due to various pests and diseases. Among the insect pests, chilli thrips (*Scirtothrips dorsalis* Hood) and yellow mite (*Polyphagotarsonemus latus* Banks) are serious ones. Breeding for resistance to these pests demands great attention. Information on the gene action underlying the characters of interest is a prerequisite for devising crop improvement programme. Hence the present investigation was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2008-2009 to estimate combining ability and gene action for yield and resistance to chilli thrips and yellow mite by line x tester analysis and to identify high yielding hybrids resistant to these pests.

Five lines with high yield but susceptible to chilli thrips and yellow mite and three testers resistant to chilli thrips and yellow mite were crossed in L x T pattern and 15 hybrids were produced. The hybrids along with the parents were evaluated for yield and resistance to chilli thrips and yellow mite in two parallel experiments. The experiments were laid out in randomized block design with three replications.

Observation on 13 characters viz., days to 50 per cent flowering, plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period, number of fruits per plant, fruit length, fruit weight, fruit girth, green fruit yield, duration and capsaicin content were recorded from the yield evaluation trial. Analysis of variance

indicated highly significant differences among the genotypes for all the characters.

Sca variance was significant for days to 50 per cent flowering, plant height, primary branches, plant canopy width, fruit bearing period, duration, number of fruits per plant and capsaicin content. Hence these characters are governed by non additive gene action. The characters fruit length, fruit girth, fruit weight, number of secondary branches and green fruit yield per plant are governed by both additive and non additive gene action. But the ratio of additive to dominance variance was less than unity for these characters except fruit girth and fruit weight indicating the preponderance of non additive gene action. For fruit girth and fruit weight the ratio of additive dominance was more than unity indicating the preponderance of additive gene action.

Among lines, Vellayani Athulya was superior in performance for fruit length, fruit girth and fruit weight. Jwalasakhi was superior line for green fruit yield per plant and showed good performance for fruit length, fruit girth and fruit weight. Among testers, Bhaskar topped in mean performance for green fruit yield. Among the hybrids, L_5 x T_2 was superior with respect to green fruit yield and fruit characters viz., fruit length, fruit girth and fruit weight. The early flowering hybrid L_1 x T_3 showed maximum number of fruits per plant, number for primary branches and secondary branches. L_2 x T_2 was high in capsaicin content and L_2 x T_1 was tallest among the hybrids.

Combining ability analysis indicated that the line Vellayani Athulya was the best general combiner for yield and several yield contributing characters including weight, girth and length of fruits. Anugraha was the best general combiner for number of fruits per plant, number of primary branches, number of secondary branches, fruit length and duration. Jwalamukhi was the best combiner for plant height whereas Ujwala was the good combiner for capsaicin. Among testers, Bhaskar was the good general combiner for green fruit yield and fruit characters like fruit length, fruit girth, fruit weight and capsaicin content. Bhagyalakshmi was the good general combiner for plant canopy width and fruit bearing period whereas Kiran was the combiner for days to 50 per cent flowering and duration.

Among the 15 hybrids, L_1 x T_3 was the best cross combination for most for the characters viz., number of primary branches, number of secondary branches, number of fruits per plant, plant canopy width, fruit length, fruit weight, capsaicin content and green fruit yield. It showed significant heterosis for all these characters except fruit weight, fruit girth and capsaicin content. The combination L_5 x T_2 showed significantly high *sca* effects and heterosis for green fruit yield and fruit characters like fruit length, fruit girth and fruit weight. The hybrids L_2 x T_1 and L_2 x T_2 are desirable for plant height and capsaicin content respectively. These combinations also showed heterosis for the respective characters.

Taking into consideration the heterosis, *sca* effect and mean performance of hybrids, L_5 x T_2 was identified as superior in yield, earliness and fruit characters whereas L_1 x T_3 was superior in number of primary branches, number of secondary branches, plant canopy width, fruit length and number of fruits per plant. The hybrids L_2 x T_1 and L_2 x T_2 were superior for plant height and capsaicin content respectively.

The hybrids and parents were evaluated in a field experiment for resistant to chilli thrips and yellow mite. The resistance evaluation was based on population count and damage intensity to chilli thrips and yellow mite. The analysis of variance for combining ability revealed that variance due to *sca* was significant for all the resistance parameters except damage intensity due to thrips infestation. Hence it is inferred that the parameters number of thrips per leaf, number of yellow mites per leaf and damage intensity due to mite infestation are governed by non additive gene action. The damage intensity due to thrips infestation is governed by both additive and non additive gene action with preponderance to additive gene action.

Among the lines, Anugraha and Ujwala were relatively resistant to both the pests. But Anugraha was a good general combiner for thrips resistance while Ujwala was good general combiner for mite resistance. The line Jwalasakhi was a good general combiner for both chilli thrips and yellow mite resistance.

Among the testes, Bhaskar and Kiran are relatively resistant to these pests, among which Bhaskar was the best general combiner for both chilli thrips and yellow mite resistance.

The hybrid L_3 x T_1 was relatively resistant to chilli thrips whereas L_3 x T_2 was relatively resistant to both chilli thrips and yellow mite. The hybrids L_3 x T_1 and L_3 x T_2 showed highest heterosis over mid and better parent for resistance to thrips and mite respectively.

Considering both yield and resistance simultaneously, the hybrids L_3 x T_1 and L_5 x T_2 are high yielding and relatively resistant to chilli thrips and yellow mite respectively. These hybrids would hopefully yield desirable genotypes with high yield and resistance to chilli thrips or yellow mite in segregating generations. The hybrid L_3 x T_2 identified as relatively resistant to both chilli thrips and yellow mite was not remarkable with respect to yield.

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BREEDING FOR YIELD AND RESISTANCE TO CHILLI THRIPS (*Scirtothrips dorsalis* Hood) AND YELLOW MITE (*Polyphagotarsonemus latus* Banks) IN CHILLI (*Capsicum annuum* L.)

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ABSTRACT

The present study aimed to estimate the combining ability and gene action for yield and resistance to chilli thrips and yellow mite by line x tester analysis and to identify high yielding hybrids resistant to these pests. The research work was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2008-09.

Five susceptible high yielding chilli genotypes (lines) and three chilli thrips and mite tolerant chilli genotypes (testers) were crossed in a line x tester fashion to obtain 15 hybrid combinations.

The lines, testers and their hybrids were evaluated in replicated field trials for yield and resistance to chilli thrips and yellow mite. The yield trial observations were recorded for 13 characters viz., days to 50 per cent flowering, plant height, number of primary branches, number of secondary branches, plant canopy width, fruit bearing period, number of fruits per plant, fruit length, fruit girth, fruit weight, green fruit yield, crop duration and capsaicin content. ANOVA revealed that the genotypes were significantly different for all the characters. Combining ability analysis indicated that the characters number of secondary branches, fruit length, fruit girth, fruit weight and green fruit yield were governed by both additive and non additive gene action. Among them fruit girth and fruit weight showing preponderance to additive gene action while others showing preponderance to non additive gene action. The remaining characters viz., days to 50 per cent flowering, plant height, primary branches, plant canopy width, fruit bearing period, number of fruits per plant, crop duration and capsaicin content are mainly governed by non additive gene action.

Based on mean performance and gca effects, Vellayani Athulya was identified as the best general combiner among the lines and Bhaskar among the testers for yield and several yield contributing characters. The crosses, L_1 x T_3

and L_5 x T_2 were found to be promising chilli hybrids for yield and its component traits based on mean performance, sca effects and heterosis.

The resistance was based on population count and damage intensity to chilli thrips and yellow mite. Combining ability analysis revealed that number of thrips per leaf, number of yellow mites per leaf and damage intensity due to mite were governed by non additive gene action whereas thrips damage intensity was governed by both additive and non additive gene action with preponderance to additive gene action. Among lines, Anugraha and Ujwala were tolerant to both the pests whereas, Bhaskar and Kiran were highly tolerant among testers. Anugraha, Jwalasakhi and Bhaskar were found to be best general combiner for both thrips and mite resistance among the parents.

Considering both yield and resistance simultaneously, the hybrids L_3 x T_1 and L_5 x T_2 are high yielding and relatively resistant to chilli thrips and yellow mite respectively. These hybrids would hopefully yield desirable genotypes with high yield and resistance to chilli thrips or yellow mite in segregating generations. The hybrid L_3 x T_2 identified as relatively resistant to both chilli thrips and yellow mite was not remarkable with respect to yield.