# INCORPORATION OF BACTERIAL WILT RESISTANCE IN GREEN CHILLI (*Capsicum annuum* L.)

By

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**THESIS**

submitted in partial fulfilment of the
requirement for the degree of

**Master of Science in Horticulture**

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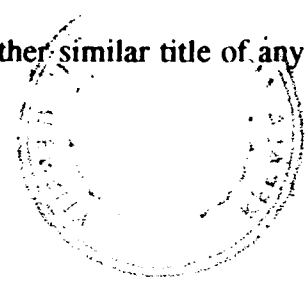
**1996**

## DECLARATION

I hereby declare that the thesis entitled "**Incorporation of bacterial wilt resistance in green chilli (*Capsicum annuum* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.



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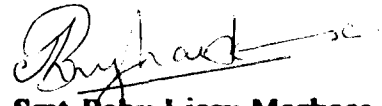
## CERTIFICATE

Certified that this thesis entitled **"Incorporation of bacterial wilt resistance in green chilli (*Capsicum annuum* L.)"** is a record of research work done independently by Miss.Seena,P.G. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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## CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss.Seena, P.G.**, a candidate for the degree of Master of Science in Horticulture with major in Olericulture, agree that the thesis entitled "**Incorporation of bacterial wilt resistance in green chilli (*Capsicum annuum* L.)**" may be submitted by Miss.Seena, P.G. in partial fulfilment of the requirement for the degree.

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# Introduction

# INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop grown throughout India. Believed to have been introduced by Portuguese, chilli has become almost an essential article of diet of rich and poor. Fruits are known to impart pungency, colour, aroma and taste to the food materials. The pungency is due to the presence of a crystalline volatile alkaloid called 'Capsaicin'. Chilli oleoresin is used in pharmaceutical and cosmetic preparations. Besides its indegenous uses, chilli has a very great export potential.

Annual trade of chilli in the world is 55 to 65 thousand tonnes which is 16.7 per cent of the total spice trade in the world. India ranks first in the world production of chilli with 7.79 lakh tonnes from an area of 9.17 lakh ha. Though chilli is grown throughout India, Andhra Pradesh leads in area and production.

The cultivation of chilli in India is threatened by many diseases and pests, the most damaging being the bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith. This is especially severe in acidic soils of the warm humid tropics seriously hampering the cultivation of crop in Kerala. Effective control measures have not yet been developed to combat this disease. Breeding for resistance is the most effective means of controlling bacterial wilt in chilli. The research on this direction conducted in the Kerala Agricultural University has resulted in the identification of two chilli varieties viz. Manjari and Ujjwala, resistant to the disease (Gopalakrishnan and Peter, 1991). But these varieties are small fruited, having high seed content and high pungency with less market acceptability as green chilli. The popular green chilli varieties cultivated in different parts

of the country are susceptible to bacterial wilt and thus unsuitable for cultivation in wilt sick areas of Kerala. A variety with acceptable green chilli characteristics and resistance to bacterial wilt would be a boon to the farmers of Kerala. So incorporation of bacterial wilt resistance in the commercially acceptable green chilli varieties will pave way for large scale chilli cultivation in our state.

The increasing importance of chillies in the economy of our country has made it necessary to evolve varieties with high productivity and good quality. Hybrids have a great role in boosting up yield in almost every crop. Heterosis in the economic characters of chillies has been reported by several workers (Gopalakrishnan *et al.*, 1989; Bhagyalakshmi *et al.*, 1991; Kordus, 1991; Ram and Lal, 1992 and Singh *et al.*, 1992).

Considering all the above aspects, the present study was undertaken to incorporate bacterial wilt resistance in commercial and popular green chilli varieties. The specific objectives of the present study are:

1. To evaluate the $F_1$ hybrids for bacterial wilt resistance and green chilli characteristics
2. To generate information on combining ability and gene action in chilli for different characters
3. To find out the extent of heterosis for different characters in the $F_1$s
4. To identify bacterial wilt resistant green chilli genotypes in the $F_2$ population.

# Review of Literature

# REVIEW OF LITERATURE

The informations on bacterial wilt resistance breeding and heterosis associated with wilt resistance in chilli are reviewed under the following heads.

2.1 Bacterial wilt disease of chilli

2.2 Sources of bacterial wilt resistance in chilli

2.3 Combining ability, gene action and heterosis in chilli

2.4 Heterosis associated with bacterial wilt resistance

## 2.1 Bacterial wilt disease of chilli

Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith is a serious disease of chilli limiting the cultivation of the crop in the acidic soils of Kerala.

The earliest report of the bacterial wilt was made by Burrill (1890) in connection with an unidentified bacterial disease of potato in U.S.A. But it was Smith (1896) who first described the bacterial wilt disease of solanaceous crops and its causal organism *Pseudomonas solanacearum*. The disease is prevalent in the warmer parts of USA, Philippines, Indonesia, Srilanka and India causing considerable damage. In India the disease is more serious in the parts of Karnataka, Kerala, Orissa, Maharashtra, Madhya Pradesh, Bihar and West Bengal (Rao, 1972).

In India, the bacterial wilt of chillies was reported first from Madhya Pradesh (ICAR, 1969). Chattopadhyay and Mukherjee (1969) noted that chilli could

be one of the hosts for the strains of *P. solanacearum*. Though there are stray reports that chilli (*Capsicum spp.*) could be one of the host plants of *Pseudomonas solanacearum*, the occurrence of bacterial wilt of chilli in India was first confirmed by Khan *et al.* (1979) from Karnataka state. They also reported a yield loss of 20-22 per cent in the chilli growing pockets of Bangalore and Kolar districts of Karnataka state.

In Kerala, studies on the management of bacterial wilt of chillies were conducted by Rahim (1972) and George (1973). They obtained excellent field control of the disease by spraying the foliage with streptomycin and streptocycline or by soil drenching with cheshunt compound.

### 2.1.1 Races and strains of *Pseudomonas solanacearum*

A wide geographical variation occurs in *Pseudomonas solanacearum*.

Buddenhagen *et al.* (1962) classified the isolate broadly in to 3 races on the basis of the pathogenicity and cultural characteristics. Race 1 affects solanaceous crops and certain diploid bananas. Race 2 is pathogenic to triploid bananas, *Heliconia sp.* and other musaceous hosts. Race 3 causes bacterial wilt in potato and few alternate hosts in tropics and subtropics. Hayward (1964) described *Pseudomonas solanacearum* as a complex species consisting of several biotypes differing in host range and pathogenicity and called them as biotype I, biotype II, biotype III and biotype IV.

Later two new races were proposed; one from ginger in Philippines as race 4 (Aragaki and Quinon, 1965) and the other from mulberry in China as race 5 (He *et al.*, 1983).

In Kerala, Devi (1978) compared twenty six different isolates of *P. solanacearum* from tomato, brinjal and chillies and grouped them in to 12 patho-groups under race 1 and biotype III.

Restriction Fragment Length Polymorphism (RFLP) technique was used by Cook and Sequeira (1988) to study the relationship between biotypes I to IV of Hayward and races 1, 2 and 3 of Buddenhagen *et al.* The main conclusion was that *Pseudomonas solanacearum* could be divided in to two distinct groups. Group I includes strains of race 1, biovars III and IV and Group II includes strains of race 1 biovar I and races 2 and 3. In addition, they were able to distinguish strains of the pathogen both by race and biotypes. For example, race 3 strains produced a very distinct gel pattern which suggests that race 3 is a homogeneous group. Similarly, race 2 strains fell in to three distinct groups. These three groups represented strains from different geographical origin. In contrast, race 1 strains exhibited highly variable RFLP patterns suggesting that race 1 is highly heterogeneous.

### 2.1.2 Factors influencing bacterial wilt disease

Resistance and susceptibility to the disease are conditioned by defined metabolic, environmental and genetic factors.

Bell (1981) observed the factors influencing resistance as intensity, duration and quality of light, moisture levels, nutrient levels and agricultural and industrial chemicals. Long photoperiods generally result in higher levels of resistance. Increasing the concentration of potassium and calcium enhances the level of

resistance, while nitrogen decreases. He also stated that each plant part changes in its level of resistance with age. Resistance level in stem and roots generally increases rapidly during the first two weeks of seedlings or when new shoot grows and slowly thereafter. Levels of resistance in leaves and fruits frequently decline with age. Coyne and Schuster (1983) also reported that resistance to *P. solanacearum* changes with plant age. Resistant plant become susceptible up to 21 days and becomes resistant again from 21 to 49 days.

Goth *et al.* (1983) observed that bacterial wilt resistance was broken down when rootknot nematode larvae were added at the rate of 100/10 cm pot at the time of inoculation with bacterial isolates.

Schell *et al.* (1988) have cloned and characterised the gene Pch A that is involved in the synthesis of the polygalacturonase which is responsible for the breakdown of plant tissues by pathogen. Allen *et al.* (1993) have shown that total galacturonase activity of the bacteria increases in the presence of the plant but that this induction involves mostly two additional PGS, Pch B and Pch C.

## 2.2 Sources of Bacterial wilt resistance

Reports on the development of bacterial wilt resistant varieties are rather few in chilli.

Goth *et al.* (1983) in a study of pepper cultivars for their reaction to eight races and one isolate and one race and three isolates of *Pseudomonas solanacearum*, found KAU cluster resistant to four races and one isolate and one race and three isolates of *Pseudomonas solanacearum*. On evaluation of the chilli cultivars Suryamukhi, Cluster, Jwala, G4 and G5 for yield and tolerance to

*Pseudomonas solanacearum* and fungal diseases like *Colletotrichum sp.* and *Cercospora capsici*, Rathalah (1983) found Suryamukhi as tolerant to all the diseases with the highest mean yield of 61.08 q/ha followed by cluster.

Peter *et al.* (1984) evaluated four hot peppers - Pant C-1 and KAU Cluster (*Capsicum annuum*) and White Kandhari and Chuna (*Capsicum frutescens*) along with six US cultivars for reaction to nine isolates of *Pseudomonas solanacearum* (race 1 and race 3). No pepper line tested was resistant to all nine isolates. Pant C-1 showed resistance to K 60, W 82, W 295 and FF isolates and moderate resistance to Tifton 80-1. KAU Cluster was resistant to K 60, W 82, W 295, FF and Tifton 80-1 isolates, but was susceptible to all other isolates used. Pious (1985) also observed resistance to bacterial wilt in KAU Cluster under Vellanikkara condition.

To study the response of four cultivars of sweet pepper to bacterial wilt, Jimenez *et al.* (1988) inoculated the plants with *Pseudomonas solanacearum* at two months after transplanting. Cholo was found most resistant showing a disease incidence of approximately 10 per cent after 60 days and '17245' fairly resistant with a disease incidence of 46 per cent after 60 days. Total yield was also significantly higher in Cholo and '17245'. In another study to identify the sources of resistance to *Pseudomonas solanacearum*, Matos *et al.* (1990) grew 50 genotypes and found that *Capsicum annuum* genotypes CNPH 143 (MC 4), CNPH 144 (MC 5) and CNPH 145 (HC 10) were highly resistant scoring 1.0 to 1.7 in a 1-4 scale of resistance to susceptibility. Six genotypes (with scores of 1.8 to 2.8) were rated as resistant and the remaining forty one as susceptible.

Gopalakrishnan and Peter (1991) screened the accessions belonging to *Capsicum annuum, C. frutescens* and *C. chinense* for resistance to bacterial wilt in a wilt sick soil after artificial inoculation. Out of 146 accessions, two cluster fruited types from *C. annuum*, CA 219 and CA 33 were resistant which were further improved by selection. Two selections each from CA 219 and CA 33 were completely resistant to bacterial wilt with good dry chilli yields of 31.2 and 42.0 g/plant and 61 and 13 g/plant respectively. Cluster fruited plants gave significantly better wilt resistance than solitary fruited types. Jyothi *et al.* (1993) also revealed resistance in chilli variety Manjari against bacterial wilt.

A total of 108 accessions of pepper have been screened for resistance to bacterial wilt at AVRDC, Taiwan (1993). Among these accessions MC 4, Cili lang kap, and PL 38475 had a high level of tolerance to infection by *Pseudomonas solanacearum*.

Matsunaga *et al.* (1993) of Japan evaluated seventy four accessions of sweet pepper and seven accessions of chile pepper including Pant C-1 and White Khandari to identify the varieties resistant to bacterial wilt. Fourteen accessions including the commercial varieties were resistant; and twelve moderately resistant. "Mie Midori" was assumed to be the origin of bacterial wilt resistance in bell type varieties since almost all of the resistant varieties of bell type were derived from this variety.

To identify the accessions resistant to bacterial wilt in related species of *C. annuum*, Matsunaga and Monma (1995) examined a total of 64 accessions consisting of 23 *C. chinense*, 14 *C. frutescens*, 25 *C. baccatum* and two

*C. pubescens*. Seven accessions viz. 'Ranche Khorsani' of *C. chinense*, Heiser 6240, LS 2390 and LS 1840 of *C. frutescens* and LS 1716, Casali BGH 1761 and Pickers gill 277 of *C. baccatum* were resistant. Three accessions of *C. chinense*, two of *C. frutescens* and six of *C. baccatum* were moderately resistant.

## 2.3 Combining ability, gene action and heterosis in chilli

### 2.3.1 Combining ability analysis and gene action in chilli

In a line x tester analysis, Pandey *et al.* (1981) crossed 12 lines with three pollen parents and studied the combining ability. Among the female parents G 4 and G 5 had higher gca effects for yield, fruits/plant, earliness, plant height and branches/plant. Among the males, Jwala and Pant C-2 had higher gca effects. The estimates of sca effects showed that the better combiners for yield were Kalyanpur Yellow x Pant C-2, CA 960 x Jwala, CA 63 x Sirhind and Patna Red x Sirhind. The crosses involving one or both parents with high gca effects exhibited high sca effects.

Singh and Rai (1981) reported high heritability estimates for plant height followed by days to flowering, fruit length, number of branches and fruits per plant. On studying the gene action, Ahmed *et al.* (1982) noted the importance of both additive and dominance effects for number of days to fruiting and height, whereas only the additive gene effects were important for seed number and fruit weight. Rao and Chhonkar (1982) also reported the importance of both additive and non additive components of variance for fruit yield, seed yield and fruit number in a 10 x 10 half diallel cross.

Gomez and Cuartero (1982) in a complete diallel cross and also in an artificial polycross observed greater magnitude of sca variance for yield/plant. Significant sca effect for yield/plant was also noticed by Singh (1982). Variance due to gca and sca observed by Rao and Chhonkar (1983) in a 10 x 10 diallel were highly significant for yield/plant and average fruit weight. CA 960 and G 4 was good combiners for yield. In another 6 x 6 diallel cross, Chen (1985) observed significant differences between the parents in general combining ability. Significant positive and negative correlation between the combining abilities of many of the characters were also noted.

When three male sterile lines were crossed with 37 pollinators, Dikii and Anikeenko (1986) noticed high general combining ability for yield for eight pollinators.

Significant variances for gca and sca for all 11 traits studied were noticed by Khadi and Goud (1986) in a 11 x 11 half diallel cross, the magnitude of the gca being higher for 10 traits. The parents IC 18190 and 387 Local were good specific combiners and had high mean yields. In another 9 x 9 diallel cross, Joshi and Singh (1987) noted significant variances for both gca and sca, but gca effects predominated.

Thakur (1987) reported the predominance of non-additive gene effects in the $F_1$ from eight parental diallel cross. High heritability for yield and the predominance of non-additive gene effects suggested straight forward selection and utilization of heterosis to improve yield.

Cao and Su (1988) observed significant gca and sca variances for all the characters studied in a complete diallel cross involving nine inbred lines with gca variances being significantly higher than those of sca for five characters. The best general combiners for yield, disease index and earliness of flowering were Ai Gan Zao, 83-71 and Hua Jiao Yi Hao respectively, while the best specific combinations for the traits were Fu Di Jian x Liu Shi Zao, Chi Ban Jiao x Liu Shi Zao and Ai Gan Zao x Fu Di Jian, respectively.

Gaddagimath *et al.* (1988) crossed seven genotypes in all possible combinations and recorded the yield and yield related characters. The parents, Jwala and K 34-35 exhibited significant gca effects for most of the characters. A few cross combinations also showed significant sca effects as well as reciprocal effects for yield and its components.

In a line x tester analysis involving 12 lines and two testers, Kaul and Sharma (1988) noticed that HC 201, Sweet Banana, Selection 4 and Osh Region were good combiners for fruit length, where as for fruit diameter only Early prolific was a good combiner. Significant gca effects were noted for fruits/plant and fruit yield per plant in California Wonder.

In a nonreciprocal half diallel cross done by Bhagyalakshmi *et al.* (1991), the cultivars LCA 960, LCA 206 and G 4 were the best general combiners for most of the characters especially yield per plant and observed both the additive and non-additive gene action with the predominance of latter for days to 50 per cent flowering, days to fruit maturity, length, girth and fresh fruit weight of fruit. From a set of diallel crosses Gvozdenovic (1991) also observed the predominance of additive gene effect. The highest gca for yield was in the parents with the highest

mean fruit yield, Soroksari and California Wonder, which appeared promising for use in breeding for more fruits per plant.

Mishra *et al.* (1991) crossed 10 chilli varieties in a diallel fashion without reciprocals. The best general combiners for most of the quantitative characters were J 218 and BR Red. Pusa Jwala and Lam X-235 were good general combiners for dry yield/plant and fruits per plant. The cross Pusa Jwala x Sindhur exhibited significant sca effects for dry yield/plant as well as for the majority of the other characters.

Pandian and Shanmugavelu (1992) in a line x tester analysis involving 15 lines and six testers, observed the line 1777 and tester K2 as the best general combiners for yield and its components. A close agreement between gca and *per se* performance was observed among certain lines and testers indicating high genetic diversity. This also indicated that for selection of hybrids, *per se* performance is a reliable parameter in preference to sca effect. High heritability and additive gene action for fruits/plant, fruit weight, seeds per fruit, plant height and fruit length were recorded by Varalakshmi and Babu (1991). Importance of additive gene action in comparison with the additive x dominance component for fruit colour was reported by Ahmed *et al.* (1992).

### 2.3.2 Heterosis in chilli

Manifestation of heterosis in chilli has been recorded by several workers for yield and other related traits.

The first report on heterosis in chilli came from Deshpande (1933) for earliness, plant height, fruit girth, fruits/plant and yield/plant.

Dikii and Anikeenko (1981) obtained six hybrids of hot pepper by using cytoplasmic male sterility, which ripened more uniformly with higher contents of sugar and ascorbic acid in the fruits. Nowaczyk (1981) reported that heterosis for average fruit weight was rare, but was common for capsaicin content.

In a line x tester analysis involving 12 lines and three testers, Pandey *et al.* (1981) recorded heterobeltiosis for fruit yield and number of fruits/plant. Heterobeltiosis for yield to the extent of 61.4 per cent was reported by Sontakke (1981) in a 9 x 9 diallel cross. In another diallel analysis, 10 inbreds of *Capsicum annuum* and their 45 $F_1$ hybrids were studied for the ascorbic acid content of the fruits by Rao and Chhonkar (1982). Thirteen crosses exhibited significant positive heterosis over the mean parental value ranging from 2.2 to 30.9 per cent. Three crosses exhibited positive heterosis over the better parent ranging from 2.1 to 12.5 per cent.

In a line x tester analysis involving 10 lines and three testers, Balakrishnan *et al.* (1983) identified the hybrids, CA 247 x K 2, CA 385 x CA 380 and CA 63 x CA 380 as heterotic combinations. Hybrids exhibiting heterosis for yield also showed heterosis for more than one component of yield, but fruits per plant tended to be the most important contributing character.

Heterobeltiosis was observed for plant height (31.64), fruits per plant and dry fruit yield/plant in a 8 x 8 diallel cross by Murthy and Lakshmi (1983). The hybrid CA 197 x Santaka exhibited high heterosis (196.63) for yield/plant.

Krishnakumari (1984) studied the interspecific hybrids between two *Capsicum annuum* lines (Jwala and K 2) and three *Capsicum frutescens* lines (White

Kandhari, Chuna and Ornamental type). Significant heterosis was noted for days to flower, plant height, fruits/plant and yield/plant. Heterobeltiosis for yield ranged from -35.8 to 62.9 per cent and relative heterosis from -19.34 to 78.77 per cent. No heterosis was observed for primary branches/plant.

Highly significant heterosis was noted for plant height, number of fruits and total fruit weight by Uzo (1984) in a study involving peppers in Nigeria. Anand and Deshpande (1985) reported that all six hybrids from crosses between three pungent chilli types and two bell pepper lines were heterotic for green fruit yield. The highest yielding hybrid (704 g/plant) had 100 per cent higher yield than the best chilli parent (IHR 471-5). Flesh thickness in the $F_1$ was intermediate between that of the parents.

Chen (1985) observed heterosis for early and total yields in the 10 best hybrids from a 6 x 6 diallel cross. Early yields were 2-3 times higher than in the control and up to 35 per cent better than in the better parents. Total yields were > 20 per cent better than in the control and better parents. A few hybrids had better disease resistance than the better parent. Sekar and Arumugam (1985) crossed six diverse genotypes of chilli in all possible combinations to study the extent of hetero-beltiosis for yield and its primary components. Heterobeltiosis was observed for all the characters. The hybrid CO-2 x DS 3 exhibited high magnitude of heterosis for yield and its components.

Joshi (1986) compared the performance of 36 $F_1$ hybrids involving nine purelines to estimate the extent of heterosis for yield and its components. Range and mean of the $F_1$ hybrids were more than that of the parents in all the characters except in days to 75 per cent flowering and days to first picking. Heterosis for yield

resulted from the combined heterosis for plant height, number of primary branches, fruit size, average fruit weight, early yield and number of fruits per plant.

In crosses involving a genetically male sterile line and 12 homozygous varieties, Meshram and Mukewar (1986) noted significant heterosis over the superior parent for fruit yield in four hybrids. Nair *et al.* (1986) evaluated nine parental genotypes and their 36 $F_1$ hybrids for 18 yield related and quality characters. Average heterosis was highest for number of secondary branches followed by vitamin C and capsaicin content and primary branches. Heterosis was negative for days to flowering, and seeds per fruit and low for vitamin A content. Purple Round x Vellanotchi and Pant C-1 x Purple cluster were the most promising hybrids. Wang *et al.* (1986) on analysis of data on yield and quality characters in 12 $F_1$ hybrids from 15 parents, six crosses showed significant heterosis over the better parent for early yield and two for total yield.

Khadi and Goud (1987) when evaluated the yield components of 11 parents, their 55 $F_1$ hybrids and 55 $F_2$ progenies, observed that the early maturing hybrid EC-76459-2 x IC 18190 was the most promising specific combination with the highest dry fruit yield of 108.3 g (93% higher than its better parent) and a high fresh fruit yield of 250.8 g. In a study by Mak (1987) on hybrid vigour in chilli, all hybrids exceeded their midparental values for yield. Despite fewer flowers than their parents, most hybrids showed high heterosis for percentage fruit set resulting in more fruits/plant.

When a locally, produced male sterile line (MSL) was crossed with local cultivars as pollinators, Prakash *et al.* (1987) observed that the hybrids MSL x LCA 197 and MSL x Santaka exceeded their parents in yield and pod quality and showed

33 per cent and 47 per cent heterosis respectively. Of the 33 $F_1$ hybrids produced using 11 male parents, Singh (1987) observed the highest green yield for $MS_{12}$ x $S_{27}$ which gave 70.9 per cent more than the male parent and 235.7 per cent more than the standard variety, Punjab Lal.

Thakur (1987) noted that out of 28 cross combinations, eleven exceeded the mid parental value and also the better parent for yield; but only six outyielded the best parent, Russian Yellow. Maximum heterosis was observed in Harris Early Giant x Vinedale, but the highest yielding crosses in relation to the best parent were Russian Yellow x Harris Early Giant and Yolo Wonder x Harris Early Giant.

Ashtanear and Jaipurkar (1988) made 13 hybrids and most of them exhibited heterosis over mid parental values for the eight traits studied. Significant heterobeltiosis for yield (up to 23%) was recorded in six hybrids. Three of them also gave high average yields (82.0 - 105.8 g/plant). Inbreeding depression in the $F_2$ was recorded in most of the progenies for one or more of the traits. Cao and Su (1988) observed heterosis for early and total yield in a complete diallel cross involving nine inbred lines. Flowering period and disease index exhibited negative heterosis. Depestre and Espinosa (1988) reported that the $F_1$ populations of five crosses in which California Wonder was used as the female parent showed heterosis over the mean parental value for number of fruits/plant (11.0-27%) and yield/plant (16.6-29.5%). Although EC 1 x Chay showed an even greater increase in number of fruits/plant (28%), it suffered a decrease in yield/plant (8%).

Out of 24 $F_1$'s observed by Kaul and Sharma (1988) in a line x tester analysis involving 12 diverse lines and two testers, Sweet Banana x California Wonder, Osh Region x California Wonder, and HC 201 x California Wonder

recorded 34.0, 33.1 and 25.0 per cent heterosis respectively over the better parent for fruit yield per plant.

In a diallel cross of six *Capsicum annuum* cultivars, Miranda and Costa (1988) detected considerable heterosis for total yield per plant (7 to 54.7%), fruits per plant (3.5 to 30.8%), early fruit yield (9.1 to 109.2%) and average fruit weight (9.3 to 52.9%). Mishra *et al.* (1988) assessed 45 $F_1$ hybrids for 14 yield components and high heterosis was recorded for dry fruit yield per plant, especially in crosses J 218 x CA 586 (110.4%), Pusa Jwala x Sindur (98.1%) and BR Red x G4 (89.8%). Crosses between two poor yielding parents usually showed the highest heterosis over the better parent for yield and fruits per plant.

In intervarietal crosses involving six bell pepper lines and a hot chilli line KAU cluster, Thomas and Peter (1988) observed significant heterosis for days to flowering, green fruit harvest, days to fruit ripening, plant height, fruit length, fruit perimeter, fruit weight and green fruit yield per plant. The high yielding crosses were Bell Boy x KAU Cluster (464.9 g/plant) and 672 Hungarian Wax x KAU Cluster (401.5 g/plant). The hybrids showed good survival and better performance over the parents in less favourable environments.

Ado (1989) made six crosses between five varieties and the yield in the $F_1$ of SO 2 x KD 3 (240 gm) was higher than both the parents. In all crosses $F_1$ yields exceeded their respective mid parental value. When four chilli lines Jwala, Pant C-1, CA 33 and CA 23 were nonreciprocally crossed, Gopalakrishnan *et al.* (1989) observed Jwala x Pant C-1 as the best hybrid, yielding 201 g of fruit/plant followed by Jwala x CA 23 (160 g/plant). All the hybrids showed heterosis for earliness and three hybrids showed heterosis over the better parent.

Sahoo and Mishra (1990) evaluated 10 cultivars and 45 $F_2$ progenies from a half diallel cross and observed residual heterosis for number of fruits/plant (72.6%) and dry fruit yield/plant (116.8%) for the cross J 218 x KCS 1 which indicated the superiority of cross.

To estimate heterosis and combining ability, Bhagyalakshmi *et al.* (1991) crossed six chilli varieties in a half diallel fashion. Taking in to consideration the *per se* performance, sca effects and heterosis, LCA 206 x LCA 960 was the best hybrid, yielding 638.3 g/plant, followed by LCA 206 x LCA 1079 (535 g/plant). Out of the three characters studied, the manifestation of heterosis over midparent was maximum (up to 160.3%) for branches/plant. Kordus (1991) studied six parental lines and thirty $F_1$ hybrids of hot pepper from a complete diallel crossing. The highest heterosis effects were noted in the yield and number of physiologically matured fruits.

Out of six $F_1$ hybrids involving four parents, Ram and Lal (1992) noted significant relative and standard heterosis in the required direction for all characters except pods/plant and the highest standard heterosis for pod yield/plant.

Singh *et al.* (1992) reported heterosis for red ripe fruit yield and its components from line x tester crosses of three male and 11 female parents. Maximum and significant heterosis in favourable direction was observed for fruit yield, fruit number, fruit length, fruit breadth and fruit weight. Tiwari could be utilized as female parent in exploiting heterosis when crossed with Jawahar-218, Tam Mild Jalpeno and Anaheim Thick.

## 2.4 Heterosis associated with bacterial wilt resistance

Information on this aspect is generally scanty in chilli. The available information on solanaceous crops in general is reviewed here.

In Bulgaria, Mihov (1969) observed that peppers produced from crosses between *Capsicum annuum* and *Capsicum fasciculatum* were wilt resistant and of good quality.

Yazawa *et al.* (1980) compared the hybrids of three *Capsicum annuum* cultivars with *Capsicum chinense* '3341' from Bolivia and found that the vigorous Murasaki x 3341, was the best and resistant to *Pseudomonas solanacearum*.

Bosch *et al.* (1985) selected tomato hybrid Rodade from the cross Flora Dade x (Flora-Dade x Ld 2048) as resistant to race one of *Pseudomonas solanacearum*.

Gangappa (1986) reported a high degree of heterosis for resistance to bacterial wilt in brinjal hybrid West Coast Green Round x Pusa Kranti.

Devi (1987) studied five varieties of bell pepper (*Capsicum annuum* var. *grossum*) viz. Hungarian Wax, Sweet Red Cherry Pickling, Early Calwonder, Cubanelle and Yolowonder Improved, one variety each of *Capsicum annuum* var. *longum* (Pant C-1) and *Capsicum annuum* var. *fasciculatum* (KAU Cluster) and their 10 $F_1$ hybrids for bacterial wilt incidence and found that KAU Cluster was resistant to bacterial wilt.

In an evaluation of *Solanum melongena* germplasm in the United States Department of Agriculture (USDA), Li *et al.* (1987) intercrossed the tolerant plant introductions and the populations so developed showed a genetic advance in the level of tolerance in the $F_1$ and $F_2$ of the crosses PI 176761 x PI 169663 and PI 173106 x PI 220120. Thomas (1987) in an evaluation of brinjal for wilt resistance and fruit yield observed that the hybrids SMI 10 x Pusa Purple Round, SMI 10 x Pusa Purple Long, SM 6 x Black Beauty and SM 6 x Pusa Purple Round were prominent.

Tikoo *et al.* (1987) evolved tomato hybrids using IHR 663-12-3 (BWR I) as female and wilt susceptible varieties as male parents and 14 $F_1$ hybrids exhibited 100 per cent survival even up to 120 days after planting. Out of the hybrids only one (BWR I x KH det) had significantly higher yield of 2.24 kg/plant as against 1.4 kg/plant in BWR I.

Heterosis breeding programme conducted by Geetha (1989) resulted in the development of two brinjal hybrids SM 6-2 x Pusa Purple Cluster and SM 6-6 x SM 132 resistant to bacterial wilt. Ali *et al.* (1990) observed that *Solanum integrifolium* and its hybrids with egg plant (*Solanum melongena*) were highly tolerant to strains of *Pseudomonas solanacearum*. Study by Varghese (1991) revealed that two hybrids namely SM 6-2 x Pusa Purple Cluster and SM 6-6 x SM 132 as promising with regard to yield and resistance to bacterial wilt.

Devi and Tikoo (1992) made crosses between six tomato lines resistant to bacterial wilt and 12 commercially important lines susceptible to bacterial wilt and resistant to rootknot nematode. The $F_1$ hybrids BWR x Rossol, 83 BWR 12-2 x 998, 83 BWR 120 x Patriot and MITA 668 x BWR 120 were highly resistant to both *P. solanacearum* and *Meloidogyne incognita*.

In a line x tester analysis of brinjal involving seven lines which were wilt susceptible and two testers which were resistant, Sawant *et al.* (1992) observed that the most promising hybrids for yield having resistance to wilt were Manjari Gota x Local Brinjal and Arka Kusumakar x Local Brinjal (3055 and 2832.3 g/plant respectively).

Asao *et al.* (1994) electrofused protoplasts of *Solanum sanitwongsei* cv. Karehan and *S. melongena* cv. Senryou II, in order to transfer the growth habit and resistance to *P. solanacearum* of *S. sanitwongsei* to *S. melongena*. The fused protoplasts were cultured on KM (8P) medium containing 1000 ppm wilt inducing product secreted by a virulent strain of *P. solanacearum*. The regenerated plants were further screened on soil contaminated with *P. solanacearum*. The somatic hybrid exhibited a resistance to *P. solanacearum* comparable to that of *S. sanitwongsei*.

# Materials and Methods

# MATERIALS AND METHODS

The present investigations were carried out at the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara during the period from 1993 to 1995. The experimental plot is located at an altitude of 22.5 M above MSL, and between 70° 32' N latitude and 76° 16' E longitude. The area enjoys a warm humid tropical climate. The experimental site has a sandy loam soil with a pH of 5.0.

The study consisted of the following experiments.

3.1 Evaluation of $F_1$ hybrids for resistance to bacterial wilt and green chilli characteristics

3.2 Line x tester analysis for yield attributes

3.3 Evaluation of $F_2$ population for resistance to bacterial wilt and green chilli characteristics

## 3.1 Evaluation of $F_1$ hybrids for resistance to bacterial wilt and green chilli characteristics

### 3.1.1 Experimental materials

The materials for the study comprised of 12 diverse genotypes of *Capsicum annuum*. Of these, two genotypes resistant to wilt were used as lines and 10 genotypes selected from different parts of country based on commercial importance, green chilli characteristics and susceptibility to wilt were used as testers.

Sources and distinct morphological characters of the parents selected are given in Table 1.

Table 1. Genotypes, sources and morphological characters of the parents selected

| Sl. No. | Genotype | Source | Fruit orientation | Fruiting habit | Fruit colour |
|---|---|---|---|---|---|
| 1 | Ujjwala (CA-219) | KAU Vellanikkara | Upright | Clustered | Dark green |
| 2 | Manjari | KAU Vellanikkara | Upright | Clustered | Light green |
| 3 | DPLC-1 | KKV Dapoli | Pendulous | Solitary | Dark green |
| 4 | AKC 86-39 | PRKV Akola | Pendulous | Solitary | Light green |
| 5 | RHRC Clustering Erect | MPKVV Rahuri | Upright | Clustered | Dark green |
| 6 | Jwala Sakhi | KAU Vellayani | Pendulous | Solitary | Light green |
| 7 | Jwala Mukhi | KAU Vellayani | Pendulous | Solitary | Light green |
| 8 | Jwala | IARI, New Delhi | Pendulous | Solitary | Light green |
| 9 | Phule-5 | Rahuri | Pendulous | Solitary | Light green |
| 10 | Surektha | Akola | Pendulous | Solitary | Dark green |
| 11 | LCA 305 | RRS, Lam, Guntur | Pendulous | Solitary | Dark green |
| 12 | JCA 283 | JNKVV Jabalpur | Pendulous | Solitary | Dark green |

### 3.1.2 Development of $F_1$ hybrids

The twelve parents for crossing were grown in pots. The pots were filled with potting mixture containing sand, soil and FYM in the ratio of 1:1:1. The medium was sterilized with 40 per cent formaldehyde solution. After two weeks, 30

days old seedlings were transplanted in to the pots. The management practices as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1993) were followed. When the plants flowered, female parents (lines) were emasculated on the previous day of flower opening. The emasculated flowers were covered with butter paper bags. The flower buds from male parents (testers) were also similarly protected to avoid contamination by foreign pollen grains. Pollination was performed on the next day between 7 am and 8.30 am. Pollinated flowers were labelled and again covered. Thus the following 20 $F_1$'s were generated.

1. Ujjwala x DPLC-1
2. Ujjwala x AKC 86-39
3. Ujjwala x RHRC Clustering Erect
4. Ujjwala x Jwala Sakhi
5. Ujjwala x Jwala Mukhi
6. Ujjwala x Jwala
7. Ujjwala x Phule-5
8. Ujjwala x Surektha
9. Ujjwala x LCA 305
10. Ujjwala x JCA 283
11. Manjari x DPLC-1
12. Manjari x AKC 86-39
13. Manjari x RHRC Clustering Erect
14. Manjari x Jwala Sakhi
15. Manjari x Jwala Mukhi
16. Manjari x Jwala
17. Manjari x Phule-5

18. Manjari x Surektha
19. Manjari x LCA 305
20. Manjari x JCA 283

3.1.3 Evaluation of $F_1$ hybrids and parents for bacterial wilt resistance

The twenty hybrids along with their 12 parents were evaluated in a randomised block design with two replications. Thirty days old seedlings were transplanted in a bacterial wilt sick field at a spacing of 60 x 45 cm accomodating 30 plants/genotype/replication. Both the hybrids and parents were spot planted with a known suscept (Pusa Jwala) to study the host reaction to the bacteria. The incidence of bacterial wilt was confirmed through ooze test. All cultural and management practices were adopted as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1993).

The number of plants wilted at three different stages viz. vegetative, flowering and fruiting and final harvest were recorded and percentage worked out. The genotypes were scored according to Mew and Ho (1976).

R - Resistant (< 20% wilted plants)
MR - Moderately resistant (20-40% wilted plants)
MS - Moderately susceptible (40-60% wilted plants)
S - Susceptible (> 60% wilted plants)

3.1.4 Evaluation for green chilli characteristics

Five plants were randomly tagged in each genotype/ replication and the following observations were recorded on ten randomly selected fruits.

a) Average fruit weight (g)

Fruits having a weight of more than 2 g were given a score of '1' and others were given a score of '0'.

b) Fruit length (cm)

Fruits having a length of more than 6 cm were given a score of '1' and others were given a score of '0'.

c) Seeds/fruit

Fruits having a seed content of less than 50 were given a score of '1' and others were given a score of '0'.

d) Fruit perimeter

Fruits having perimeter more than 3 cm were given a score of '1' and others were given a score of '0'.

e) Pedicel length

Fruits having pedicel length of less than 3 cm were given a score of '1' and others were given a score of '0'.

**Genotypes having a score of '1' for the above five characteristics were classified as green chilli types.**

## 3.2 Line x tester analysis for yield attributes

### 3.2.1 Mean performance

Five plants were randomly tagged in each genotype/ replication and the following observations were recorded.

a) Plant height (cm)

Plant height from the ground level to the top of the canopy was measured in cm at the final harvest of the crop.

b) Plant spread (cm)

Canopy spread of the plant was measured in cm using a meter scale at the final harvest of crop.

c) Primary branches/plant

The number of primary branches/plant was counted at final harvest of the plant.

d) Days to flowering

The number of days from transplanting to the appearance of first flower was recorded.

e) Days to first harvest

The days taken from transplanting to the first harvest of green chilli was recorded.

f) Fruits/plant

Fruits harvested periodically from each plant were added to obtain the total number of fruits/plant.

g) Fruit yield/plant

Fruit yield/plant (g) was recorded at green chilli stage.

3.2.2 Combining ability and gene action

General combining ability (gca) effects of the parents and the specific combining ability (sca) effects of the hybrids were estimated using line x tester analysis as suggested by Kempthorne (1957).

3.2.3 Estimation of heterosis

The performance of parents and their $F_1$ hybrids was considered for estimation of heterosis. Heterosis over better parent (heterobeltiosis), mid parent (relative heterosis) and standard variety, Manjari (standard heterosis) were calculated (Briggle, 1963; Hayes *et al.*, 1965).

The formulae used were

$$\text{Heterobeltiosis} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Relative heterosis} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Standard heterosis} = \frac{F_1 - SV}{SV} \times 100$$

where, $F_1$, BP, MP and SV were the mean performance of $F_1$ hybrid over better parent, mid parent and standard variety respectively. Significance of heterosis was tested using student 't' test.

To test the significance of differences of $F_1$ means over mid, better and standard parent, critical differences (CD) were calculated from their standard error of differences as given below (Briggle, 1963).

To test the significance over the mid parent

$$CD = t \text{ value} \times SE$$

$$CD_{(0.05)} = te'_{(0.05)} \times \sqrt{\frac{3MSE}{2r}}$$

To test the significance over better parent and standard parent

$$CD_{(0.05)} = te'_{(0.05)} \times \sqrt{\frac{2MSE}{r}}$$

## 3.3 Evaluation of $F_2$ population for resistance to bacterial wilt and green chilli characteristics

The $F_1$'s were selfed and $F_2$'s were developed. The field evaluation of the $F_2$'s along with their parents was done during January to May 1995. The $F_2$ population was raised in a bacterial wilt sick field in randomised block design with two replications. There were 30 plants and 150 plants each for the parents and $F_2$s respectively. Spot planting with susceptible Pusa Jwala was done and ooze test was carried out to confirm the resistance.

The $F_2$ progenies were observed for the incidence of bacterial wilt and green chilli characteristics as done in the case of $F_1$ population. Analysis of variance was performed to test the significance of differences among the $F_2$ populations.

In the $F_2$ population, segregants showing resistance to bacterial wilt and having green chilli characteristics were selected for further study.

# Results

# RESULTS

The results of the investigations are presented under the following heads.

4.1 Evaluation of $F_1$ hybrids and parents for bacterial wilt resistance and green chilli characteristics

4.2 Line x tester analysis for yield attributes

4.3 Evaluation of $F_2$ progenies for bacterial wilt resistance and green chilli characteristics

## 4.1 Evaluation of $F_1$ hybrids and parents for bacterial wilt resistance and green chilli characteristics

### 4.1.1 Evaluation for bacterial wilt resistance

Twenty $F_1$ hybrids developed from line x tester crossing and their twelve parents were grown in a bacterial wilt-sick field. The percentage of wilt incidence at vegetative, flowering and fruiting and the harvesting stages are presented in the Table 2. The genotypes were classified in to resistant, moderately resistant, moderately susceptible and susceptible as per Mew and Ho (1976).

All the $F_1$ hybrids were susceptible/moderately susceptible to bacterial wilt. Among the $F_1$ hybrids, minimum wilt incidence was noticed in Manjari x Jwala Sakhi (42.88%) followed by Ujjwala x Jwala Sakhi (43.33%) and Manjari x Phule-5 (45.00%).

Among the parents the lowest wilt incidence was observed in Ujjwala (8.59%) followed by Manjari (11.67%). Jwala, Surektha, RHRC Clustering Erect,

Table 2. Evaluation of $F_1$ hybrids and parents for bacterial wilt resistance

| Genotypes | Incidence of bacterial wilt (%) | | | |
|---|---|---|---|---|
| | Vegetative stage | Up to flowering and fruiting | Up to final harvest (Total) | Score |
| Ujjwala | 1.66 | 6.43 | 8.59 | R |
| Manjari | 3.50 | 8.67 | 11.67 | R |
| DPLC-1 | 10.96 | 44.85 | 62.15 | S |
| AKC 86-39 | 8.34 | 43.33 | 56.72 | MS |
| RHRC Clustering Erect | 11.25 | 43.96 | 72.54 | S |
| Jwala Sakhi | 7.28 | 34.88 | 48.72 | MS |
| Jwala Mukhi | 8.12 | 34.25 | 48.12 | MS |
| Jwala | 11.11 | 58.33 | 86.98 | S |
| Phule-5 | 5.00 | 37.58 | 59.66 | MS |
| Surektha | 11.79 | 57.14 | 76.01 | S |
| LCA 305 | 8.59 | 41.79 | 57.30 | MS |
| JCA 283 | 10.35 | 44.52 | 61.01 | S |
| Ujjwala x DPLC-1 | 13.34 | 42.50 | 64.67 | S |
| Ujjwala x AKC 86-39 | 8.59 | 31.67 | 52.83 | MS |
| Ujjwala x RHRC Clustering Erect | 10.00 | 51.67 | 70.00 | S |
| Ujjwala x Jwala Sakhi | 8.33 | 30.33 | 43.33 | MS |
| Ujjwala x Jwala Mukhi | 6.9 | 33.33 | 53.82 | MS |
| Ujjwala x Jwala | 11.66 | 41.07 | 71.07 | S |
| Ujjwala x Phule-5 | 10.00 | 38.50 | 58.35 | MS |
| Ujjwala x Surektha | 8.34 | 48.33 | 68.67 | S |
| Ujjwala x LCA 305 | 5.26 | 36.43 | 52.27 | MS |
| Ujjwala x JCA 283 | 3.33 | 41.67 | 61.67 | S |
| Manjari x DPLC-1 | 2.16 | 41.83 | 63.32 | S |
| Manjari x AKC 86-39 | 3.33 | 33.33 | 56.67 | MS |
| Manjari x RHRC Clustering Erect | 11.66 | 15.00 | 60.00 | S |
| Manjari x Jwala Sakhi | 6.67 | 31.67 | 42.88 | MS |
| Manjari x Jwala Mukhi | 6.66 | 32.50 | 55.00 | MS |
| Manjari x Jwala | 6.93 | 55.61 | 79.67 | S |
| Manjari x Phule-5 | 5.00 | 26.67 | 45.00 | MS |
| Manjari x Surektha | 11.67 | 41.67 | 66.33 | S |
| Manjari x LCA 305 | 3.33 | 33.33 | 50.00 | MS |
| Manjari x JCA 283 | 13.33 | 38.33 | 61.83 | S |

R - Resistant (< 20% wilt)
MR - Moderately resistant (20-40% wilt)
MS - Moderately susceptible (40-60% wilt)
S - Susceptible (> 60% wilt)

Plate 1. A view of chilli crop in the field


INCORPORATION OF BACTERIAL
WILT RESISTANCE IN GREEN CHILLI
M.Sc. Thesis Programme of SEENA P G
Design RBD Replication 2
Parents 12 F1 hybrids 20

Plate 2. Bacterial wilt affected field

Plate 3. Spot planting technique

DPLC-1 and JCA 283 were susceptible with wilt incidence of 86.98%, 76.01%, 72.54%, 62.15% and 61.01% respectively.

4.1.2 Evaluation for green chilli characteristics

Twenty $F_1$ hybrids and twelve parents were evaluated for green chilli characteristics and the results are presented in Table 3.

a) Average fruit weight

All the $F_1$ hybrids had an average fruit weight of more than 2 g. Maximum average fruit weight was recorded by Ujjwala x Jwala Sakhi (4.22 g) followed by Manjari x Phule-5 (3.68 g) and Ujjwala x Jwala Mukhi (3.50 g). Average fruit weight in the parents ranged from 1.73 g in Manjari to 4.01 g in Jwala Sakhi.

b) Fruit length

Fruit length was maximum in the $F_1$ hybrid Manjari x Phule-5 (8.46 cm) followed by Ujjwala x Jwala Sakhi (7.89 cm) and minimum in Manjari x DPLC-1 (5.38 cm). Fruit length varied from 4.47 cm (Manjari) to 8.55 cm (Jwala) among parents.

c) Fruit perimeter

All the $F_1$ hybrids had an average fruit perimeter of more than 3 cm. Fruit perimeter ranged from 3.03 cm (Manjari x Surektha) to 4.75 cm (Ujjwala x Jwala Sakhi) among the $F_1$ hybrids and from 3.01 cm (Manjari) to 5.35 cm (Jwala Sakhi) among the parents. Other hybrids recorded high values for fruit perimeter were

Table 3. Evaluation of $F_1$ hybrids and parents for green chilli characteristics

| Genotypes | Average fruit weight (g) | Score | Fruit length (cm) | Score | Fruit perimeter (cm) | Score | Seeds/fruit | Score | Pedicel length (cm) | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala | 1.95 | 0 | 5.88 | 0 | 3.04 | 1 | 61.75 | 0 | 3.30 | 0 |
| Manjari | 1.73 | 0 | 4.47 | 0 | 3.01 | 1 | 75.00 | 0 | 3.10 | 0 |
| DPLC-1 | 2.05 | 1 | 5.29 | 0 | 3.28 | 1 | 39.45 | 1 | 2.91 | 1 |
| AKC 86-39 | 2.15 | 1 | 6.11 | 1 | 3.36 | 1 | 47.50 | 1 | 3.05 | 0 |
| RHRC Clustering Erect | 2.14 | 1 | 6.02 | 1 | 3.24 | 1 | 44.25 | 1 | 2.95 | 1 |
| Jwala Sakhi | 4.01 | 1 | 7.25 | 1 | 5.35 | 1 | 35.85 | 1 | 2.89 | 1 |
| Jwala Mukhi | 3.85 | 1 | 6.90 | 1 | 4.57 | 1 | 42.15 | 1 | 2.94 | 1 |
| Jwala | 2.03 | 1 | 8.55 | 1 | 3.08 | 1 | 39.15 | 1 | 2.75 | 1 |
| Phule-5 | 2.95 | 1 | 8.32 | 1 | 3.40 | 1 | 42.15 | 1 | 2.95 | 1 |
| Surektha | 1.98 | 0 | 6.08 | 1 | 3.11 | 1 | 39.95 | 1 | 2.96 | 1 |
| LCA 305 | 2.43 | 1 | 6.15 | 1 | 3.36 | 1 | 37.95 | 1 | 2.73 | 1 |
| JCA 283 | 2.07 | 1 | 6.01 | 1 | 3.17 | 1 | 43.20 | 1 | 2.95 | 1 |
| Ujjwala x DPLC-1 | 2.17 | 1 | 6.48 | 1 | 3.37 | 1 | 33.60 | 1 | 2.98 | 1 |
| Ujjwala x AKC 86-39 | 2.19 | 1 | 6.55 | 1 | 3.43 | 1 | 37.80 | 1 | 3.11 | 0 |
| Ujjwala x RHRC Clustering Erect | 2.23 | 1 | 6.06 | 1 | 3.28 | 1 | 38.30 | 1 | 3.19 | 0 |
| Ujjwala x Jwala Sakhi | 4.22 | 1 | 7.89 | 1 | 4.75 | 1 | 45.82 | 1 | 2.95 | 1 |
| Ujjwala x Jwala Mukhi | 3.50 | 1 | 7.13 | 1 | 3.95 | 1 | 37.20 | 1 | 3.05 | 0 |
| Ujjwala x Jwala | 2.23 | 1 | 7.07 | 1 | 3.39 | 1 | 55.70 | 0 | 3.28 | 0 |
| Ujjwala x Phule-5 | 3.30 | 1 | 7.42 | 1 | 3.47 | 1 | 46.20 | 1 | 3.28 | 0 |
| Ujjwala x Surektha | 2.34 | 1 | 6.41 | 1 | 3.21 | 1 | 59.80 | 0 | 3.20 | 0 |
| Ujjwala x LCA 305 | 3.26 | 1 | 7.05 | 1 | 4.05 | 1 | 36.50 | 1 | 2.88 | 1 |
| Ujjwala x JCA 283 | 2.42 | 1 | 7.57 | 1 | 3.34 | 1 | 53.80 | 0 | 3.28 | 0 |
| Manjari x DPLC-1 | 2.68 | 1 | 5.38 | 0 | 3.50 | 1 | 63.50 | 0 | 3.09 | 0 |
| Manjari x AKC 86-39 | 2.66 | 1 | 6.56 | 1 | 3.56 | 1 | 72.90 | 0 | 3.09 | 0 |
| Manjari x RHRC Clustering Erect | 2.78 | 1 | 6.09 | 1 | 3.32 | 1 | 53.90 | 0 | 2.97 | 1 |
| Manjari x Jwala Sakhi | 3.46 | 1 | 7.39 | 1 | 4.72 | 1 | 59.60 | 0 | 3.75 | 0 |
| Manjari x Jwala Mukhi | 3.01 | 1 | 6.40 | 1 | 4.55 | 1 | 38.45 | 1 | 2.71 | 1 |
| Manjari x Jwala | 2.04 | 1 | 6.31 | 1 | 3.55 | 1 | 47.10 | 1 | 3.23 | 0 |
| Manjari x Phule-5 | 3.68 | 1 | 8.46 | 1 | 4.28 | 1 | 41.00 | 1 | 2.97 | 1 |
| Manjari x Surektha | 2.00 | 1 | 5.43 | 0 | 3.03 | 1 | 40.50 | 1 | 3.28 | 0 |
| Manjari x LCA 305 | 2.68 | 1 | 6.62 | 1 | 3.64 | 1 | 61.40 | 0 | 3.45 | 0 |
| Manjari x JCA 283 | 2.34 | 1 | 5.86 | 0 | 3.57 | 1 | 49.10 | 1 | 3.48 | 0 |

Scores for green chilli characteristics

| 1. Average fruit weight | Scores |
|---|---|
| > 2 g | 1 |
| < 2 g | 0 |

| 2. Fruit length | |
|---|---|
| > 6 cm | 1 |
| < 6 cm | 0 |

| 3. Fruit perimeter | |
|---|---|
| > 3 cm | 1 |
| < 3 cm | 0 |

| 4. Seeds/fruit | Scores |
|---|---|
| < 50 | 1 |
| > 50 | 0 |

| 5. Pedicel length | |
|---|---|
| < 3 cm | 1 |
| > 3 cm | 0 |

Manjari x Jwala Sakhi, Manjari x Jwala Mukhi and Manjari x Phule-5 (4.72 cm, 4.55 cm and 4.28 cm respectively).

d) Seeds/Fruit

Minimum number of seeds per fruit was observed in the $F_1$ hybrid Ujjwala x DPLC-1 (33.6 seeds) followed by Ujjwala x LCA 305 (36.5 seeds), Ujjwala x Jwala Mukhi (37.2 seeds) and the maximum in Manjari x AKC 86-39 (72.9 seeds). Parental range was from 35.85 in Jwala Sakhi to 75.00 in Manjari.

e) Pedicel length

Pedicel length was minimum for the hybrid Manjari x Jwala Mukhi (2.71 cm) followed by Ujjwala x LCA 305 (2.88 cm) and Ujjwala x Jwala Sakhi (2.95 cm). For the parents it ranged from 2.73 cm (LCA 305) to 3.30 cm (Ujjwala). Parents Jwala (2.75 cm) and Jwala Sakhi (2.89 cm) also recorded lower values for pedicel length.

**Based on the above observations, the following $F_1$ hybrids were grouped under green chilli types.**

i. Manjari x Phule-5
ii. Ujjwala x LCA 305
iii. Ujjwala x Jwala Sakhi
iv. Manjari x Jwala Mukhi
v. Ujjwala x DPLC-1

Plate 4. Bacterial wilt resistant genotypes

(a) Ujjwala (CA-219)

(b) Manjari


CA 219

Plate 5. Genotypes having green chilli characteristics

(a) Jwala Mukhi

(b) Phule-5


JWALA MUKHI
($P_2$)


PHULE-5
$P_2$

Plate 5. Genotypes having green chilli characteristics

(c) Jwala Sakhi

(d) RHRC Clustering Erect


JWALA SAKHI
($F_2$)

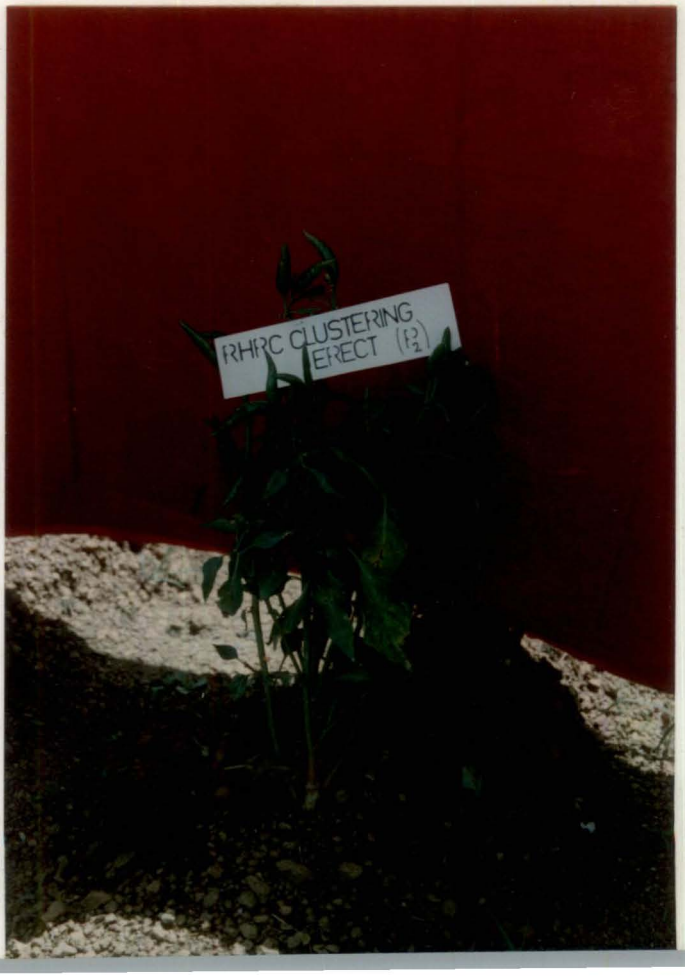

RHRC CLUSTERING
ERECT ($F_2$)

Plate 6. Promising $F_1$ hybrids having green chilli characteristics and resistance to bacterial wilt

(a) Manjari x Phule-5

(b) Ujjwala x LCA 305


MANJARI
X
PHULE-5


CA-219 -
X
LCA 3

Plate 6. Promising $F_1$ hybrids having green chilli characteristics and resistance to bacterial wilt

(c) Ujjwala x Jwala Sakhi

(d) Manjari x Jwala Mukhi


CA-219
X
JWALA SAKHI


MANJARI
X
JWALA MUKHI

## 4.2 Line x tester analysis for yield attributes

### 4.2.1. Mean performance

The mean performance of lines, testers and $F_1$ hybrids for different characters is given in Table 4.

Plant height

The mean plant height for the hybrids ranged from 35.49 cm in Ujjwala x DPLC-1 to 62.90 cm in Ujjwala x LCA 305. But for parents the range was from 33.15 cm in JCA 283 to 45.10 cm in LCA 305.

Plant spread

Maximum plant spread was in the cross Ujjwala x LCA 305 (49.9 cm) followed by Manjari x LCA 305 (46.96 cm), Manjari x Phule-5 (46.80 cm) and the minimum in Ujjwala x RHRC Clustering Erect (32.32 cm). Among the parents, the range was from 24.35 cm in RHRC Clustering Erect to 38.55 cm in LCA 305.

Primary branches/plant

Number of primary branches/plant ranged from 6.15 in Jwala Mukhi to 9.65 in LCA 305. Among the hybrids maximum primary branches per plant was for Manjari x RHRC Clustering Erect (14.2) followed by Manjari x Phule-5 (13.0) and the minimum was for Ujjwala x Jwala Mukhi (6.6).

Days to flowering

The most precocious genotypes were Ujjwala x Jwala Mukhi and Manjari x Jwala Sakhi (29.5 days). Days to flower was maximum in Manjari x RHRC

Table 4. Mean performance of lines, testers and $F_1$ hybrids for yield and other attributes

| Genotypes Parents/crosses | Plant height (cm) | Plant spread (cm) | Primary branches/ plant | Days to flowering | Days to first harvest | Fruits/ plant | Fruit yield/ plant (g) |
|---|---|---|---|---|---|---|---|
| Lines | | | | | | | |
| Ujjwala | 40.95 | 31.15 | 8.50 | 43.25 | 72.20 | 63.05 | 102.10 |
| Manjari | 36.30 | 30.85 | 8.00 | 46.30 | 72.50 | 52.65 | 86.95 |
| Testers | | | | | | | |
| DPLC-1 | 33.70 | 28.50 | 7.35 | 42.90 | 76.15 | 53.00 | 100.20 |
| AKC 86-39 | 38.85 | 29.40 | 7.45 | 47.25 | 74.50 | 60.85 | 116.70 |
| RHRC Clustering Erect | 33.95 | 24.35 | 9.00 | 46.25 | 82.35 | 44.20 | 83.15 |
| Jwala Sakhi | 39.00 | 29.75 | 6.50 | 36.25 | 61.25 | 41.55 | 119.75 |
| Jwala Mukhi | 38.05 | 30.75 | 6.15 | 36.45 | 65.65 | 39.45 | 126.80 |
| Jwala | 35.35 | 30.75 | 6.45 | 41.25 | 74.95 | 59.20 | 109.35 |
| Phule-5 | 40.85 | 35.35 | 8.35 | 39.40 | 70.20 | 81.10 | 129.25 |
| Surektha | 36.90 | 29.75 | 6.95 | 45.15 | 80.90 | 68.35 | 90.85 |
| LCA 305 | 45.10 | 38.55 | 9.65 | 48.15 | 82.90 | 80.50 | 122.05 |
| JCA 283 | 33.15 | 34.00 | 7.95 | 43.25 | 76.30 | 69.20 | 112.50 |
| $F_1$ hybrids | | | | | | | |
| Ujjwala x DPLC-1 | 35.49 | 33.00 | 8.00 | 45.25 | 78.20 | 60.30 | 93.20 |
| Ujjwala x AKC 86-39 | 54.64 | 41.87 | 9.80 | 37.70 | 63.00 | 77.60 | 141.10 |
| Ujjwala x RHRC Clustering Erect | 45.07 | 32.32 | 9.90 | 48.30 | 81.38 | 52.30 | 93.80 |
| Ujjwala x Jwala Sakhi | 51.55 | 43.60 | 10.90 | 31.95 | 61.75 | 83.50 | 211.93 |
| Ujjwala x Jwala Mukhi | 44.00 | 43.95 | 6.60 | 29.50 | 59.50 | 87.55 | 227.50 |
| Ujjwala x Jwala | 49.52 | 41.09 | 10.20 | 40.00 | 72.25 | 64.80 | 135.30 |
| Ujjwala x Phule-5 | 45.20 | 37.00 | 9.50 | 40.38 | 69.00 | 80.80 | 206.30 |
| Ujjwala x Surektha | 53.69 | 37.40 | 10.90 | 48.00 | 85.12 | 100.50 | 206.00 |
| Ujjwala x LCA 305 | 62.90 | 49.90 | 10.40 | 42.10 | 85.80 | 104.10 | 257.00 |
| Ujjwala x JCA 283 | 52.20 | 42.30 | 9.60 | 46.20 | 78.40 | 101.90 | 201.50 |
| Manjari x DPLC-1 | 41.00 | 35.35 | 10.70 | 38.33 | 67.00 | 79.20 | 163.00 |
| Manjari x AKC 86.39 | 46.85 | 37.60 | 11.70 | 29.86 | 60.00 | 76.40 | 173.70 |
| Manjari x RHRC Clustering Erect | 53.30 | 39.20 | 14.20 | 50.00 | 87.00 | 97.70 | 216.50 |
| Manjari x Jwala Sakhi | 44.60 | 34.00 | 7.60 | 29.50 | 52.72 | 63.70 | 171.40 |
| Manjari x Jwala Mukhi | 46.80 | 44.85 | 9.40 | 31.25 | 58.50 | 79.00 | 205.00 |
| Manjari x Jwala | 41.75 | 37.40 | 9.50 | 38.25 | 70.38 | 61.40 | 104.10 |
| Manjari x Phule-5 | 55.50 | 46.80 | 13.00 | 33.38 | 63.38 | 110.10 | 318.30 |
| Manjari x Surektha | 42.00 | 33.15 | 7.60 | 40.38 | 73.12 | 77.30 | 127.00 |
| Manjari x LCA 305 | 45.45 | 46.96 | 11.90 | 46.70 | 81.30 | 86.90 | 194.00 |
| Manjari x JCA 283 | 48.45 | 45.30 | 10.00 | 44.12 | 77.50 | 83.70 | 170.10 |
| SE | 3.36 | 3.62 | 0.99 | 1.99 | 3.20 | 7.03 | 12.53 |
| CD (0.05) | 6.85 | 7.39 | 2.02 | 4.05 | 6.54 | 14.34 | 25.56 |

Plate 7. $F_1$ hybrids, Manjari x RHRC Clustering Erect with maximum primary branches/plant

Plate 8. $F_1$ hybrids showing earliness to flowering

(a) Manjari x Jwala Sakhi
(b) Ujjwala x Jwala Mukhi


MANJARI X RHRC


MANJARI
X
JWALA SAKHI


CA-219
X
JWALA MUKHI

Clustering Erect (50.0 days). Parental range was 36.25 days (Jwala Sakhi) to 48.15 days (LCA 305).

Days to first harvest

Days to first harvest was minimum in Manjari x Jwala Sakhi (52.72 days) followed by Manjari x Jwala Mukhi (58.5 days) and the maximum in Manjari x RHRC Clustering Erect (87 days). Among the parents, the earliest matured hybrid was Jwala Sakhi (61.25 days) and the latest being LCA 305 (82.9 days).

Fruits/plant

Maximum number of fruits was recorded in Manjari x Phule-5 (110.10 fruits) followed by Ujjawala x LCA 305 (104.10 fruits) and the minimum in Ujjwala x RHRC Clustering Erect (52.3 fruits). Among the parents number of fruits ranged from 39.45 in Jwala Mukhi to 81.10 in Phule-5.

Fruit yield/plant

Among the $F_1$ hybrids, yield was maximum in Manjari x Phule-5 (318.30 g) followed by Ujjwala x LCA 305 (257 g) and Ujjwala x Jwala Mukhi (227.5 g). Fruit yield/plant of parents ranged from 83.15 g in RHRC Clustering Erect to 129.25 g in Phule-5.

4.2.2 Combining ability and gene action

The analysis of variance revealed highly significant differences for the characters studied among the different genotypes (Appendix-I). Based on line x

tester analysis general combining ability effects of parents and specific combining ability effects of hybrid combinations were estimated (Tables 5 and 6).

Yield and it's components

Plant height

Significant positive gca effects were observed for LCA 305 (6.18) and Ujjwala (1.43). Significant negative gca effects were noted for DPLC-1 (-9.75) and Manjari (-1.43). Ujjwala x LCA 305 showed the highest value for sca effect (7.30), followed by Manjari x Phule-5 (6.58) and Manjari x RHRC Clustering Erect (5.54). Preponderance of non-additive variance over the additive variance was noticed. Heritability was -0.023 (Table 7).

Plant spread

Significant sca effect was noticed for plant spread. General combining ability effect was highly significant for the testers. But for lines mean square due to general combining ability was not significant. Significant gca effects were observed for LCA 305 (8.28) and Jwala Mukhi (4.25).

DPLC-1 showed significant negative gca value for plant spread (-5.98). The crosses with high positive effects were Manjari x Phule-5 (4.99) and Ujjwala x Jwala Sakhi (4.71). The lowest sca value was recorded in Ujjwala x Phule-5 (-4.99). Predominance of non-additive variance over the additive variance was noted for plant spread. Heritability value was 0.045.

Primary branches/plant

General combining ability effects and specific combining ability effects

were highly significant for primary branches/plant. RHRC Clustering Erect possessed highest positive gca effect (1.98). Significant negative gca effect was shown by Jwala Mukhi (-2.07). Ujjwala x Jwala Sakhi and Ujjwala x Surektha had highest positive sca effect (2.14) followed by Manjari x RHRC Clustering Erect (1.66).

Preponderance of non-additive variance over the additive variance was noticed. Heritability value was 0.02.

Days to flowering

Significant gca and sca effects were observed for days to flowering. Jwala Mukhi (-9.18) and Jwala Sakhi (-8.83) had high negative values of gca effect. AKC 86-39 (-5.78) and Manjari (-1.38) also showed significant negative gca effects. Ujjwala x LCA 305 (-3.68) showed highest sca effect followed by Manjari x AKC 86-39 (-2.54), Manjari x Surektha (-2.43) and Ujjwala x Jwala Mukhi (-2.26). Heritability was 0.14. Preponderance of additive genetic variance was noticed.

Days to first harvest

Days to first harvest showed significant gca and sca effects. The parents with significant negative gca effects were Jwala Sakhi (-14.03), Jwala Mukhi (-12.26), AKC 86-39 (-9.76), Phule-5 (-5.08) and Manjari (2.18). Maximum positive gca effect was in RHRC Clustering Erect (12.92), followed by LCA 305 (12.29). Ujjwala x RHRC Clustering Erect (-4.99) had maximum negative sca effect. High value of heritability was noted for days to first harvest (0.71). Predominance of additive variance over non-additive variance was noted.

Fruits/plant

Specific combining ability effect was highly significant for this character. Gca effect was significant only for testers. LCA 305 (14.06) possessed the maximum value for gca followed by Phule-5 (14.01) and JCA 283 (11.36). Significant sca effects were recorded in Manjari x RHRC Clustering Erect (22.60) and Manjari x Phule-5 (14.55). Predominance of non-additive variance over additive variance was observed. Heritability was -0.187.

Fruit yield/plant

Highly significant gca effect was observed for testers. Sca effect was also found highly significant. Phule-5 (81.46) had the maximum gca effect followed by LCA 305 (44.66), Jwala Mukhi (35.41) etc. Significant sca effects were observed in Manjari x RHRC Clustering Erect (57.88), Manjari x Phule-5 (52.53), Ujjwala x Surektha (42.97), Ujjwala x LCA 305 (34.97) etc. Predominance of non-additive variance over additive variance was noticed. Heritability value was -0.068.

Average fruit weight

Gca effects were significant only for testers. Sca effect was found significant. Maximum gca effect was for Jwala Sakhi (1.08) followed by Phule-5 (0.73) and Jwala Mukhi (0.50). General combining ability effects were negative for Jwala (-0.63), Surektha (-0.59), JCA 283 (-0.38) etc. The hybrids with high sca effects were Ujjwala x Jwala Sakhi, Manjari x RHRC Clustering Erect, Manjari x DPLC-1, Ujjwala x LCA 305, Manjari x AKC 86-39 etc. (0.35, 0.30, 0.28, 0.27,

0.26 respectively). Preponderance of non-additive genetic variance was noticed. Heritability was 0.369.

Fruit length

Significant gca and sca effects were observed for fruit length. Phule-5 (1.24) and Jwala Sakhi (0.94) had higher positive gca effects. Surektha (-0.78) possessed highest negative gca effect followed by DPLC-1 (-0.77) and RHRC Clustering Erect (-0.63). High sca values were recorded in Manjari x Phule-5 (0.77) and Ujjwala x JCA 283 (0.57). Additive genetic variance showed high value than non-additive variance. Value of heritability for fruit length was 0.452.

Fruit perimeter

General combining ability effect was significant only for testers. The mean square due to specific combining ability was not significant for fruit perimeter. Out of the 10 testers, only Jwala Sakhi (1.04) and Jwala Mukhi (0.55) showed significant positive gca effect. Surektha and RHRC Clustering Erect showed significant negative gca effects (-0.58 and -0.40 respectively). Additive genetic variance showed high value compared to non-additive variance. Heritability value for fruit perimeter was 0.482.

Seeds/fruit

Both gca and sca variances were highly significant for this character. Maximum negative gca was recorded with Jwala Mukhi (-10.78) followed by Phule-5 (-5.01). AKC 86-39 (6.74) and Manjari (4.14) showed significant positive values for gca. The combinations Manjari x Surektha (-13.79), Ujjwala x

Table 5. Estimates of general combining ability effects of lines and testers for yield and its components in chilli

| Lines/testers | Plant height | Plant spread | Primary branches/ plant | Days to flowering | Days to first harvest | Fruits/ plant | Fruit yield/ plant | Average fruit weight | Fruit length | Fruit perimeter | Seeds/ fruit | Pedicel length |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala | 1.43* | 0.09 | -0.49* | 1.38** | 2.18** | -0.10 | -3.47 | 0.03 | 0.25** | -0.07 | -4.14** | -0.04** |
| Manjari | -1.43* | -0.09 | 0.49* | -1.38** | -2.18** | 0.10 | 3.47 | -0.03 | -0.25** | 0.07 | 4.14** | 0.04** |
| SE ($g_i$) | 0.42 | 0.44 | 0.14 | 0.25 | 0.44 | 0.54 | 1.43 | 0.02 | 0.03 | 0.03 | 0.49 | 0.01 |
| SE ($g_i$-$g_j$) | 0.59 | 0.62 | 0.20 | 0.35 | 0.62 | 0.76 | 2.02 | 0.03 | 0.04 | 0.04 | 0.69 | 0.01 |
| DPLC-1 | -9.75** | -5.98** | -0.72 | 2.23* | 1.33 | -11.69** | -52.74** | -0.34** | -0.77** | -0.26 | -0.06 | -0.13** |
| AKC 86-39 | 2.75 | -0.42 | 0.68 | -5.78** | -9.76** | -4.44 | -23.44** | -0.34** | -0.15 | -0.20 | 6.74** | -0.06 |
| RHRC Clustering Erect | 1.19 | -4.39* | 1.98** | 9.59** | 12.92** | -6.44** | -25.69** | -0.26** | -0.63** | -0.40** | -2.51 | -0.08 |
| Jwala Sakhi | 0.08 | -1.35 | -0.82 | -8.83** | -14.03** | -7.84** | 10.83 | 1.08** | 0.94** | 1.04** | 4.10 | 0.19** |
| Jwala Mukhi | -2.60 | 4.25* | -2.07** | -9.18** | -12.26** | 1.84 | 35.41** | 0.50** | 0.06 | 0.55** | -10.78** | -0.28** |
| Jwala | -2.36 | -0.91 | -0.22 | -0.43 | 0.05 | -18.34** | -61.14** | -0.63** | -0.01 | -0.23 | 2.79 | 0.09* |
| Phule-5 | 2.35 | 1.75 | 1.18 | -2.68* | -5.08** | 14.01** | 81.46** | 0.73** | 1.24** | 0.18 | -5.01* | -0.03 |
| Surektha | -0.15 | -4.88* | -0.82 | 4.63** | 7.86** | 7.46** | -14.34* | -0.59** | -0.78** | -0.58** | 1.54 | 0.08 |
| LCA 305 | 6.18** | 8.28** | 1.08 | 4.84** | 12.29** | 14.06** | 44.66** | 0.21* | 0.13 | 0.15 | 0.34 | 0.01 |
| JCA 283 | 2.33 | 3.65 | -0.27 | 5.60** | 6.68** | 11.36** | 4.96 | -0.38** | -0.02 | -0.24 | 2.84 | 0.22** |
| SE ($g_i$) | 1.25 | 1.33 | 0.42 | 0.76 | 1.31 | 1.61 | 4.28 | 0.06 | 0.09 | 0.10 | 1.47 | 0.03 |
| SE ($g_i$-$g_j$) | 1.77 | 1.88 | 0.59 | 1.08 | 1.85 | 2.28 | 6.05 | 0.09 | 0.13 | 0.14 | 2.08 | 0.04 |

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

Table 6. Estimates of specific combining ability effects for yield and its components in chilli hybrids

| Genotypes | Plant height | Plant spread | Primary branches/ plant | Days to flowering | Days to first harvest | Fruits per plant | Fruit yield/ plant | Average fruit weight | Fruit length | Fruit perimeter | Seeds/ fruit | Pedicel length |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x DPLC-1 | -4.18* | -1.27 | -0.86* | 2.08 | 3.42 | -9.35** | -31.43** | -0.28** | 0.30* | 0.01 | -10.81** | -0.01 |
| Ujjwala x AKC 86-39 | 2.47 | 2.04 | -0.46 | 2.54* | -0.68 | 0.70 | -12.83* | -0.26** | -0.26* | 0.01 | -13.41** | 0.05 |
| Ujjwala x RHRC Clustering Erect | -5.54** | -3.53 | -1.66** | -2.23* | -4.99* | -22.60** | -57.88** | -0.30** | -0.27* | 0.05 | -3.66 | 0.15** |
| Ujjwala x Jwala Sakhi | 2.05 | 4.71* | 2.14** | -0.15 | 2.34 | 10.00** | 23.74** | 0.35** | 0.00 | 0.09 | -2.76 | -0.36** |
| Ujjwala x Jwala Mukhi | -2.83 | -0.54 | -0.91 | -2.26* | -1.68 | 4.38 | 14.72* | 0.22* | 0.11 | -0.23 | 3.51 | 0.21** |
| Ujjwala x Jwala | 2.46 | 1.75 | 0.84 | -0.51 | -1.24 | 1.80 | 19.07** | 0.07 | 0.13 | -0.01 | 8.44** | 0.07 |
| Ujjwala x Phule-5 | -6.58** | -4.99* | -1.26* | 2.12 | 0.64 | -14.55** | -52.53** | -0.22* | -0.77** | -0.33* | 6.74** | 0.19** |
| Ujjwala x Surektha | 4.42* | 2.03 | 2.14** | 2.43* | 3.82* | 11.70** | 42.97** | 0.14 | 0.24 | 0.16 | 13.79** | 0.00 |
| Ujjwala x LCA 305 | 7.30** | 1.38 | -0.26 | -3.68** | 0.07 | 8.70** | 34.97** | 0.27** | -0.04 | 0.28 | -8.31** | -0.24** |
| Ujjwala x JCA 283 | 0.45 | -1.59 | 0.29 | -0.34 | -1.73 | 9.20** | 19.17** | 0.02 | 0.57** | -0.04 | 6.49** | -0.06 |
| Manjari x DPLC-1 | 4.18* | 1.27 | 0.86 | -2.08 | -3.42 | 9.35** | 31.43** | 0.28** | -0.30* | -0.01 | 10.81** | 0.01 |
| Manjari x AKC 86.39 | -2.47 | -2.04 | 0.46 | -2.54* | 0.68 | -0.70 | 12.83* | 0.26** | 0.26* | -0.01 | 13.41** | -0.05 |
| Manjari x RHRC Clustering Erect | 5.54** | 3.53 | 1.66** | 2.23* | 4.99* | 22.60** | 57.88** | 0.30** | 0.27* | -0.05 | 3.66 | -0.15** |
| Manjari x Jwala Sakhi | -2.05 | -4.71* | -2.14** | 0.15 | -2.34 | -10.00** | -23.74** | -0.35** | 0.00 | -0.09 | 2.76 | 0.36** |
| Manjari x Jwala Mukhi | 2.83 | 0.54 | 0.91 | 2.26* | 1.68 | -4.38 | -14.72* | -0.22* | -0.11 | 0.23 | -3.51 | -0.21** |
| Manjari x Jwala | -2.46 | -1.75 | -0.84 | 0.51 | 1.24 | -1.80 | -19.07** | -0.07 | -0.13 | 0.01 | -8.44** | -0.07 |
| Manjari x Phule-5 | 6.58** | 4.99* | 1.26* | -2.12 | -0.64 | 14.55** | 52.53** | 0.22* | 0.77** | 0.33* | -6.74** | -0.19** |
| Manjari x Surektha | -4.42* | -2.03 | -2.14** | -2.43* | -3.82* | -11.70** | -42.97** | -0.14 | -0.24 | -0.16 | -13.79** | 0.00 |
| Manjari x LCA 305 | -7.30** | -1.38 | 0.26 | 3.68** | -0.07 | -8.70** | -34.97** | -0.27** | 0.04 | -0.28 | 8.31** | 0.24** |
| Manjari x JCA 283 | -0.45 | 1.59 | -0.29 | 0.34 | 1.73 | -9.20** | -19.17** | -0.02 | -0.57** | 0.04 | -6.49** | 0.06 |
| SE (Sij) | 1.25 | 1.33 | 0.42 | 0.76 | 1.31 | 1.61 | 4.28 | 0.06 | 0.09 | 0.10 | 1.47 | 0.03 |
| SE (Sij Sik) | 1.77 | 1.88 | 0.59 | 1.08 | 1.85 | 2.28 | 6.05 | 0.09 | 0.13 | 0.14 | 2.08 | 0.04 |

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

Table 7. Components of additive and non-additive variances and heritability for yield and its components

| | Plant height | Plant spread | Primary branches/ plant | Days to flowering | Days to first harvest | Fruits/ plant | Fruit yield/ plant | Average fruit weight | Fruit length | Fruit perimeter | Seeds/ Fruit | Pedicel length |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma^2_A$ | -1.06 | 1.14 | 0.09 | 16.94 | 44.09 | -49.46 | -171.78 | 0.08 | 0.27 | 0.08 | 10.09 | -0.01 |
| $\sigma^2_D$ | 36.41 | 10.90 | 2.96 | 8.01 | 8.29 | 264.10 | 2566.36 | 0.11 | 0.25 | 0.02 | 158.59 | 0.06 |
| $h^2$ | -0.023 | 0.045 | 0.02 | 0.14 | 0.71 | -0.187 | -0.068 | 0.369 | 0.452 | 0.482 | 0.055 | -0.172 |

AKC 86-39 (-13.41), Ujjwala x DPLC-1 (-10.81), Manjari x Jwala (-8.44), Ujjwala x LCA 305 (-8.31) etc. exhibited considerable negative values for sca. Predominance of non-additive variance over additive variance was noted. Heritability value was 0.055.

Pedicel length

Pedicel length exhibited highly significant variance due to gca and sca effects. The highest negative gca effect was shown by Jwala Mukhi (-0.28), followed by DPLC-1 (-0.13). The gca effect was positive and maximum in JCA 283 (0.22). The highest negative sca effect was shown by Ujjwala x Jwala Sakhi (-0.36) followed by Ujjwala x LCA 305 (-0.24), Manjari x Jwala Mukhi (-0.21) and Manjari x Phule-5 (-0.19). Heritability was -0.172. Non-additive variances were more compared to additive variances.

4.2.3 Heterosis in chilli

Analysis of variance showed significant differences among the genotypes for all the characters studied. The mean performance of parents and hybrids and heterosis over better parent (Heterobeltiosis), mid parent (relative heterosis) and standard parent (standard heterosis) are presented in Table 8.

Plant height

Heterobeltiosis, relative heterosis and standard heterosis were significant for plant height (Table 8a).. Estimates of heterobeltiosis, relative heterosis and standard heterosis ranged from -13.33 to 46.83 per cent, -4.92 to 51.74 per cent and -2.23 to 73.28 per cent respectively. Maximum heterobeltiosis of 46.83 per cent was

in Manjari x RHRC Clustering Erect followed by Ujjwala x LCA 305 (39.47%), Manjari x Phule-5 (35.86%) and Manjari x JCA 283 (33.47%). All the $F_1$ hybrids except Ujjwala x DPLC-1, showed significant relative heterosis. Relative heterosis was also maximum in Manjari x RHRC Clustering Erect (51.74%) followed by Ujjwala x LCA 305 (46.19%). Standard heterosis observed in Ujjwala x LCA 305 (73.28%) was the highest followed by Manjari x Phule-5 (52.89%). Ujjwala x DPLC-1 was the only cross showed negative standard heterosis (-2.23%).

Plant spread

Relative heterosis was significant in all the 20 hybrids for plant spread (Table 8a). Except three hybrids (Ujjwala x DPLC-1, Ujjwala x RHRC Clustering Erect and Ujjwala x Phule-5) all others showed significant heterobeltiosis. Eighteen hybrids exhibited significant standard heterosis. The $F_1$ hybrid Manjari x Jwala Mukhi recorded the highest heterobeltiosis and relative heterosis (45.38 and 45.62% respectively) for plant spread. Other $F_1$ hybrids with high heterobeltiosis were Ujjwala x Jwala Mukhi (41.09%) and Ujjwala x Jwala Sakhi (39.97%). Relative heterosis was also high in Ujjwala x Jwala Sakhi and Ujjwala x LCA 305 (43.19%) and Manjari x RHRC Clustering Erect (42.03%). Standard heterosis was maximum in Ujjwala x LCA 305 (61.75%) followed by Manjari x LCA 305 (52.22%), Manjari x Phule-5 (51.70%) and the minimum was in Ujjwala x RHRC Clustering Erect (4.76%).

Primary branches/plant

Highly significant heterobeltiosis was observed in all the crosses (Table 8a). Except one hybrid all others showed significant relative heterosis and standard

Table 8a. Mean performance of parental lines and heterosis of $F_1$ hybrids for plant height, plant spread and primary branches/plant

| Genotypes | Plant height (cm) | | | | Plant spread (cm) | | | | Primary branches/plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parents/crosses | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Ujjwala | 40.95 | | | | 31.15 | | | | 8.50 | | | |
| Manjari | 36.30 | | | | 30.85 | | | | 8.00 | | | |
| DPLC-1 | 33.70 | | | | 28.50 | | | | 7.35 | | | |
| AKC 86-39 | 38.85 | | | | 29.40 | | | | 7.45 | | | |
| RHRC Clustering Erect | 33.95 | | | | 24.35 | | | | 9.00 | | | |
| Jwala Sakhi | 39.00 | | | | 29.75 | | | | 6.50 | | | |
| Jwala Mukhi | 38.05 | | | | 30.75 | | | | 6.15 | | | |
| Jwala | 35.35 | | | | 30.75 | | | | 6.45 | | | |
| Phule-5 | 40.85 | | | | 35.35 | | | | 8.35 | | | |
| Surektha | 36.90 | | | | 29.75 | | | | 6.95 | | | |
| LCA 305 | 45.10 | | | | 38.55 | | | | 9.65 | | | |
| JCA 283 | 33.15 | | | | 34.00 | | | | 7.95 | | | |
| Ujjwala x DPLC-1 | 35.49 | -13.33** | -4.92 | -2.23 | 33.00 | 5.94 | 10.65** | 6.97 | 8.00 | -5.88** | 0.95 | 0.00 |
| Ujjwala x AKC 86-39 | 54.64 | 33.43** | 36.94** | 50.52** | 41.87 | 34.41** | 38.30** | 35.72** | 9.80 | 15.29** | 22.88** | 22.50** |
| Ujjwala x RHRC Clustering Erect | 45.07 | 10.06** | 20.35** | 24.16** | 32.32 | 3.76 | 16.47** | 4.76 | 9.90 | 10.00** | 13.14** | 23.75** |
| Ujjwala x Jwala Sakhi | 51.55 | 25.89** | 28.96** | 42.01** | 43.60 | 39.97** | 43.19** | 41.33** | 10.90 | 28.24** | 45.33** | 36.25** |

Contd.

Table 8a. Continued

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala Mukhi | 44.00 | 7.45* | 11.39** | 21.21** | 43.95 | 41.09** | 42.00** | 42.46** | 6.60 | -22.35** | -9.90** | -17.50** |
| Ujjwala x Jwala | 49.52 | 20.93** | 29.80** | 36.42** | 41.09 | 31.91** | 32.76** | 33.19** | 10.20 | 20.00** | 36.45** | 27.50** |
| Ujjwala x Phule-5 | 45.20 | 10.38** | 10.51** | 24.52** | 37.00 | 4.67 | 11.28** | 19.94** | 9.50 | 11.76** | 12.76** | 18.75** |
| Ujjwala x Surektha | 53.69 | 31.11** | 37.93** | 47.91** | 37.40 | 20.06** | 22.82** | 21.23** | 10.90 | 28.24** | 41.10** | 36.25** |
| Ujjwala x LCA 305 | 62.90 | 39.47** | 46.19** | 73.28** | 49.90 | 29.44** | 43.19** | 61.75** | 10.40 | 7.77** | 14.60** | 30.60** |
| Ujjwala x JCA 283 | 52.20 | 27.47** | 40.89** | 43.80** | 42.30 | 24.41** | 29.85** | 37.12** | 9.60 | 12.94** | 16.72** | 20.00** |
| Manjari x DPLC-1 | 41.00 | 12.95** | 17.14** | 12.95** | 35.35 | 14.59** | 19.12** | 14.59** | 10.70 | 33.75** | 39.41** | 33.75** |
| Manjari x AKC 86-39 | 46.85 | 20.59** | 24.68** | 29.06** | 37.60 | 21.88** | 24.81** | 21.88** | 11.70 | 46.25** | 51.46** | 46.25** |
| Manjari x RHRC Clustering Erect | 53.30 | 46.83** | 51.74** | 46.83** | 39.20 | 27.07** | 42.03** | 27.07** | 14.20 | 57.78** | 67.06** | 77.50** |
| Manjari x Jwala Sakhi | 44.60 | 14.36** | 18.46** | 22.87** | 34.00 | 10.21** | 12.21** | 10.21** | 7.60 | -5.00** | 4.83** | 50.00** |
| Manjari x Jwala Mukhi | 46.80 | 23.00** | 25.89** | 28.93** | 44.85 | 45.38** | 45.62** | 45.38** | 9.40 | 17.50** | 32.86** | 17.50** |
| Manjari x Jwala | 41.75 | 15.01** | 16.54** | 15.01** | 37.40 | 21.23** | 21.43** | 21.23** | 9.50 | 18.75** | 31.49** | 18.75** |
| Manjari x Phule-5 | 55.50 | 35.86** | 43.88** | 52.89** | 46.80 | 32.39** | 41.39** | 51.70** | 13.00 | 55.69** | 59.02** | 62.50** |
| Manjari x Surektha | 42.00 | 13.82** | 14.75** | 15.70** | 33.15 | 7.46* | 9.41** | 7.46* | 7.60 | 9.35** | 1.67* | 5.00** |
| Manjari x LCA 305 | 45.45 | 0.78 | 11.67** | 25.21** | 46.96 | 21.82** | 35.33** | 52.22** | 11.90 | 23.32** | 34.84** | 48.75** |
| Manjari x JCA 283 | 48.45 | 33.47** | 39.52** | 33.47** | 45.30 | 33.24** | 39.71** | 46.84** | 10.00 | 25.79** | 25.39** | 25.00** |
| SE | | 3.356 | 2.906 | 3.356 | | 3.63 | 3.14 | 3.63 | | 0.99 | 0.86 | 0.99 |
| CD (0.01) | | 9.195 | 7.96 | 9.195 | | 9.94 | 8.60 | 9.94 | | 2.72 | 2.35 | 2.72 |
| CD (0.05) | | 6.846 | 5.93 | 6.846 | | 7.397 | 6.41 | 7.397 | | 2.02 | 1.75 | 2.02 |

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

heterosis. Heterobeltiosis, Relative heterosis and Standard heterosis were maximum in Manjari x RHRC Clustering Erect (57.78, 67.06 and 77.5% respectively) and the minimum in Ujjwala x Jwala Mukhi (-22.35, -9.90 and -17.5% respectively).

Days to flowering

Significant and negative standard heterosis was observed in 14 hybrids (Table 8b). Relative heterosis and heterobeltiosis were significant and negative for many of the hybrids. For heterobeltiosis and relative heterosis maximum negative value was recorded in Manjari x AKC 86-39 (-35.5 and -36.15% respectively). The hybrid which showed the lowest heterobeltiosis was Ujjwala x RHRC Clustering Erect (11.68%). For standard heterosis, maximum negative value was recorded in two hybrids, Ujjwala x Jwala Mukhi and Manjari x Jwala Sakhi (-36.29%) followed by Manjari x AKC 86-39 (-35.51%) and Manjari x Jwala Mukhi (-32.51%).

Days to first harvest

Most of the hybrids exhibited significant and negative heterobeltiosis, relative heterosis and standard heterosis (Table 8b). The heterobeltiosis ranged from -17.24 per cent in Manjari x AKC 86-39 to 20 per cent in Manjari x RHRC Clustering Erect. Significant heterobeltiosis for days to first harvest was also observed in Manjari x Jwala Sakhi (-13.92%) and Ujjwala x AKC 86-39 (-12.74%). The cross Manjari x Jwala Sakhi was having the highest relative heterosis and standard heterosis (-21.16 and -27.28% respectively).

Fruits/plant

Analysis revealed that 15 out of 20 cross combinations showed

Table 8b. Mean performance of parental lines and heterosis of $F_1$ hybrids for Days to flowering, Days to first harvest and Fruits/plant

| Genotypes | Days to flowering | | | | Days to first harvest | | | | Fruits/plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parents/crosses | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Ujjwala | 43.25 | | | | 72.20 | | | | 63.05 | | | |
| Manjari | 46.30 | | | | 72.50 | | | | 52.65 | | | |
| DPLC-1 | 42.90 | | | | 76.15 | | | | 53.00 | | | |
| AKC 86-39 | 47.25 | | | | 74.50 | | | | 60.85 | | | |
| RHRC Clustering Erect | 46.25 | | | | 82.35 | | | | 44.20 | | | |
| Jwala Sakhi | 36.25 | | | | 61.25 | | | | 41.55 | | | |
| Jwala Mukhi | 36.45 | | | | 65.65 | | | | 39.45 | | | |
| Jwala | 41.25 | | | | 74.95 | | | | 59.20 | | | |
| Phule-5 | 39.40 | | | | 70.20 | | | | 81.10 | | | |
| Surektha | 45.15 | | | | 80.90 | | | | 68.35 | | | |
| LCA 305 | 48.15 | | | | 82.90 | | | | 80.50 | | | |
| JCA 283 | 43.25 | | | | 76.30 | | | | 69.20 | | | |
| Ujjwala x DPLC-1 | 45.25 | 5.48** | 5.05** | -2.27 | 78.20 | 8.31* | 5.43 | 7.86* | 60.30 | -4.36 | 3.92 | 14.53** |
| Ujjwala x AKC 86-39 | 37.70 | -12.83** | -16.69** | -18.57** | 63.00 | -12.74** | -14.11** | -13.10** | 77.60 | 23.08** | 25.26** | 47.39** |
| Ujjwala x RHRC Clustering Erect | 48.30 | 11.68** | 7.93** | 4.32* | 81.38 | 12.71** | 5.31 | 12.25** | 52.30 | -17.05* | -2.47 | 0.67 |
| Ujjwala x Jwala Sakhi | 31.95 | -11.85** | -19.61** | -30.99** | 61.75 | 0.82 | -7.46* | -15.17** | 83.50 | 32.43** | 59.66** | 58.59** |

Contd.

Table 8 b. Continued

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala Mukhi | 29.50 | -19.07** | -25.97** | -36.29** | 59.50 | -9.37** | -13.67** | -17.93** | 87.55 | 38.86** | 70.83** | 66.25** |
| Ujjwala x Jwala | 40.00 | -3.03 | -5.33** | -13.61** | 72.25 | 0.07 | -1.80 | -0.34 | 64.80 | 2.78 | 6.01 | 23.08** |
| Ujjwala x Phule-5 | 40.38 | 2.47 | -2.30 | -12.77** | 69.00 | -1.71 | -3.09 | -4.83 | 80.80 | -0.37 | 12.11 | 53.47** |
| Ujjwala x Surektha | 48.00 | 10.98** | 8.60** | 3.67 | 85.12 | 17.90** | 11.20** | 17.41** | 100.50 | 47.04** | 52.97** | 90.88** |
| Ujjwala x LCA 305 | 42.10 | -2.66 | -7.88** | -9.07** | 85.80 | 18.84** | 10.64** | 18.34** | 104.10 | 30.04** | 45.49** | 97.72** |
| Ujjwala x JCA 283 | 46.20 | 6.82** | 6.82** | -0.22 | 78.40 | 8.59* | 5.59 | 8.14* | 101.90 | 47.25** | 54.10** | 93.54** |
| Manjari x DPLC-1 | 38.33 | -10.64** | -14.05** | -17.21** | 67.00 | -7.59* | -9.86** | -7.59* | 79.20 | 49.43** | 49.93** | 50.43** |
| Manjari x AKC 86-39 | 29.86 | -35.50** | -36.15** | -35.51** | 60.00 | -17.24** | 18.37** | -17.24** | 76.40 | 25.55** | 34.63** | 45.11** |
| Manjari x RHRC Clustering Erect | 50.00 | 8.11** | 8.05** | 7.99 | 87.00 | 20.00** | 12.37** | 20.00** | 97.70 | 85.57** | 101.76** | 85.57** |
| Manjari x Jwala Sakhi | 29.50 | -18.62** | -28.53** | -36.29** | 52.72 | -13.92** | -21.16** | -27.28** | 63.70 | 20.99** | 35.24** | 20.99** |
| Manjari x Jwala Mukhi | 31.25 | -14.27** | -24.47** | -32.51** | 58.50 | -10.89** | -15.31** | -19.31** | 79.00 | 50.05** | 71.55** | 50.05** |
| Manjari x Jwala | 38.25 | -7.27** | -12.62** | -17.39** | 70.38 | -2.93 | -4.54 | -2.92 | 61.40 | 16.62** | 9.79 | 16.62* |
| Manjari x Phule-5 | 33.38 | -15.29** | -22.11** | -27.90** | 63.38 | -9.72** | -11.18** | -12.58** | 110.10 | 35.76** | 64.64** | 109.12** |
| Manjari x Surektha | 40.38 | -10.58** | -11.70** | -12.77** | 73.12 | 0.86 | -4.66 | 0.86 | 77.30 | 13.09 | 27.77** | 46.82** |
| Manjari x LCA 305 | 46.70 | 0.86 | -1.11 | 0.86 | 81.30 | 12.14** | 4.63 | 12.14** | 86.90 | 8.56 | 30.97** | 65.05** |
| Manjari x JCA 283 | 44.12 | 2.02 | -1.45 | -4.70* | 77.50 | 6.90* | 4.17 | 6.89* | 83.70 | 20.95** | 37.38** | 58.97** |
| SE | | 1.99 | 1.72 | 1.99 | | 3.21 | 2.78 | 3.21 | | 7.03 | 6.09 | 7.03 |
| CD (0.01) | | 4.06 | 3.51 | 4.06 | | 6.55 | 5.67 | 6.55 | | 19.25 | 16.68 | 19.25 |
| CD (0.05) | | 5.46 | 4.72 | 5.46 | | 8.81 | 7.63 | 8.81 | | 14.34 | 12.42 | 14.34 |

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

significant heterobeltiosis, with the maximum value in Manjari x RHRC Clustering Erect (85.57%), followed by Manjari x Jwala Mukhi (50.05%) and Manjari x DPLC-1 (49.43%). Same trend was noticed in relative heterosis also with the highest value being 101.76 per cent in Manjari x RHRC Clustering Erect followed by 71.55 per cent in Manjari x Jwala Mukhi and 70.83 per cent in Ujjwala x Jwala Mukhi. Standard heterosis was significant in all hybrids except Ujjwala x RHRC Clustering Erect. Manjari x Phule-5 (109.12%) showed the high standard heterosis followed by Ujjwala x LCA 305 (97.72%). Ujjwala x RHRC Clustering Erect showed the lowest heterosis in terms of heterobeltiosis, relative heterosis and standard heterosis (-17.05, -2.47 and 0.67% respectively).

Fruit yield/plant

Most of the hybrids exhibited highly significant heterosis for fruit yield/plant (Table 8c). Manjari x RHRC Clustering Erect (148.99%) showed the highest value for heterobeltiosis followed by Manjari x Phule-5 (146.27%) and Ujjwala x LCA 305 (110.57%). Three hybrids recorded negative heterobeltiosis. Except these, all other hybrids showed significant relative and standard heterosis. The combinations Manjari x Phule-5 (194.45%), Manjari x RHRC Clustering Erect (154.56%) and Ujjwala x LCA 305 (129.31%) recorded higher values of relative heterosis. Same hybrid Manjari x Phule-5 which expressed the maximum relative heterosis showed highest standard heterosis also (266.07%). Other hybrids recorded larger values for standard heterosis are Ujjwala x LCA 305 (195.57%), Ujjwala x Jwala Mukhi (161.64%) and Manjari x RHRC Clustering Erect (148.99%). Ujjwala X DPLC-1 gave the lowest value for heterobeltiosis, relative heterosis as well as standard heterosis (-8.72%, -7.86% and 7.2% respectively).

Average fruit weight

Ujjwala x LCA 305 (34.36%) had the highest heterobeltiosis followed by Manjari x DPLC-1 (30.73%) and Manjari x RHRC Clustering Erect (29.91%) (Table 8c). All the $F_1$ hybrids were significantly superior to their respective mid parents and standard parents. Relative heterosis was 57.43 per cent in Manjari x Phule-5, 49.09 per cent in Ujjwala x LCA 305 and 43.86 per cent in Manjari x RHRC Clustering Erect. Standard heterosis was highest in Ujjwala x Jwala Sakhi (143.9%) followed by Manjari x Phule-5 (112.72%), Ujjwala x Jwala Mukhi (102.31%), Manjari x Jwala Sakhi (100%) and the lowest in Manjari x Surektha (15.61%).

Fruit length

There was significant heterobeltiosis for fruit length in all the $F_1$ hybrids except Ujjwala x RHRC Clustering Erect (0.50%) (Table 8c). Heterobeltiosis was maximum in the $F_1$ hybrid Ujjwala x JCA 283 (24.96%) followed by Ujjwala x LCA 305 (14.63%). Out of twenty $F_1$ hybrids, eighteen exhibited significant positive relative heterosis. The relative heterosis was maximum in Manjari x Phule-5 (32.29%) and the minimum in Manjari x Jwala (-3.03%). The standard heterosis ranged from 20.36 per cent in Manjari x DPLC-1 to 89.26 per cent in Manjari x Phule-5. Higher values for standard heterosis were also observed in the $F_1$ hybrids Ujjwala x Jwala Sakhi (76.51%), Ujjwala x JCA 283 (68.01%), Ujjwala x Phule-5 (66.0%) and Manjari x Jwala Sakhi (65.32%).

Table 8c. Mean performance of parental lines and heterosis of $F_1$ hybrids for fruit yield/plant, average fruit weight and fruit length

| Genotypes | Fruit yield/plant (g) | | | | Average fruit weight (g) | | | | Fruit length (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parents/crosses | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Ujjwala | 102.10 | | | | 1.95 | | | | 5.88 | | | |
| Manjari | 86.95 | | | | 1.73 | | | | 4.47 | | | |
| DPLC-1 | 100.20 | | | | 2.05 | | | | 5.29 | | | |
| AKC 86-39 | 116.70 | | | | 2.15 | | | | 6.11 | | | |
| RHRC Clustering Erect | 83.15 | | | | 2.14 | | | | 6.02 | | | |
| Jwala Sakhi | 119.75 | | | | 4.01 | | | | 7.25 | | | |
| Jwala Mukhi | 126.80 | | | | 3.85 | | | | 6.90 | | | |
| Jwala | 109.35 | | | | 2.03 | | | | 8.55 | | | |
| Phule-5 | 129.25 | | | | 2.95 | | | | 8.32 | | | |
| Surektha | 90.85 | | | | 1.98 | | | | 6.08 | | | |
| LCA 305 | 122.05 | | | | 2.43 | | | | 6.15 | | | |
| JCA 283 | 112.50 | | | | 2.07 | | | | 6.01 | | | |
| Ujjwala x DPLC-1 | 93.20 | -8.72 | -7.86 | 7.20 | 2.17 | 5.85** | 8.50** | 25.43** | 6.48 | 10.30** | 16.08** | 44.97** |
| Ujjwala x AKC 86-39 | 141.10 | 20.91 | 28.98* | 62.28** | 2.19 | 1.62** | 6.70** | 26.59** | 6.55 | 7.29** | 9.35** | 46.53** |
| Ujjwala x RHRC Clustering Erect | 93.80 | -8.13 | 1.27 | 7.88 | 2.23 | 4.21** | 9.05** | 28.90** | 6.06 | 0.50 | 1.76** | 35.57** |
| Ujjwala x Jwala Sakhi | 211.93 | 76.97** | 91.05** | 143.74** | 4.22 | 5.37** | 41.73** | 143.90** | 7.89 | 8.83** | 20.23** | 76.51** |

Contd.

Table 8c. Continued

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala Mukhi | 227.50 | 79.42** | 98.78** | 161.64** | 3.50 | -9.09** | 20.69** | 102.31** | 7.13 | 3.26** | 11.58** | 59.51** |
| Ujjwala x Jwala | 135.30 | 23.73 | 27.97* | 55.61** | 2.23 | 9.58** | 11.92** | 28.90** | 7.07 | -17.31** | -1.98** | 58.17** |
| Ujjwala x Phule-5 | 206.30 | 59.61** | 78.34** | 137.26** | 3.30 | 11.86** | 34.69** | 90.75** | 7.42 | -10.87** | 4.51** | 66.00** |
| Ujjwala x Surektha | 206.00 | 101.76** | 113.53** | 136.92** | 2.34 | 18.48** | 19.24** | 35.26** | 6.41 | 5.43** | 7.24** | 43.40** |
| Ujjwala x LCA 305 | 257.00 | 110.57** | 129.31** | 195.57** | 3.26 | 34.36** | 49.09** | 88.44** | 7.05 | 14.63** | 17.26** | 57.72** |
| Ujjwala x JCA 283 | 201.50 | 79.11** | 87.79** | 131.74** | 2.42 | 17.15** | 20.65** | 39.88** | 7.57 | 24.96** | 26.30** | 68.01** |
| Manjari x DPLC-1 | 163.00 | 62.87** | 74.19** | 87.46** | 2.68 | 30.73** | 41.99** | 54.91** | 5.38 | 1.70** | 10.30** | 20.36** |
| Manjari x AKC 86-39 | 173.70 | 48.84** | 70.59** | 99.77** | 2.66 | 23.43** | 37.11** | 53.76** | 6.56 | 7.45** | 24.12** | 46.76** |
| Manjari x RHRC Clustering Erect | 216.50 | 148.99** | 154.56** | 148.99** | 2.78 | 29.91** | 43.86** | 60.69** | 6.09 | 1.08** | 16.11** | 36.24** |
| Manjari x Jwala Sakhi | 171.40 | 43.13** | 65.84** | 97.12** | 3.46 | -13.61** | 20.77** | 100.00** | 7.39 | 1.93** | 26.16** | 65.32** |
| Manjari x Jwala Mukhi | 205.00 | 61.67** | 91.81** | 135.77** | 3.01 | -21.69** | 8.16** | 73.99** | 6.40 | -7.31** | 12.58** | 43.18** |
| Manjari x Jwala | 104.10 | -4.80 | 6.06 | 19.72 | 2.04 | 0.25 | 8.51** | 17.92** | 6.31 | -26.20** | -3.03** | 41.16** |
| Manjari x Phule-5 | 318.30 | 146.27** | 194.45** | 266.07** | 3.68 | 24.75** | 57.43** | 112.72** | 8.46 | 1.62** | 32.29** | 89.26** |
| Manjari x Surektha | 127.00 | 39.79** | 42.86** | 46.06** | 2.00 | 1.27** | 8.11** | 15.61** | 5.43 | -10.62** | 2.99** | 21.48** |
| Manjari x LCA 305 | 194.00 | 58.95** | 85.65** | 123.12** | 2.68 | 10.29** | 29.00** | 54.90** | 6.62 | 7.64** | 24.73** | 48.10** |
| Manjari x JCA 283 | 170.10 | 51.20** | 70.57** | 95.63** | 2.34 | 13.04** | 23.32** | 35.26** | 5.86 | -2.50** | 11.89** | 31.10** |
| SE | | 12.55 | 10.87 | 12.55 | | 0.16 | 0.14 | 0.16 | | 0.28 | 0.24 | 0.28 |
| CD (0.01) | | 34.39 | 29.78 | 34.39 | | 0.45 | 0.39 | 0.45 | | 0.76 | 0.66 | 0.76 |
| CD (0.05) | | 25.60 | 22.17 | 25.60 | | 0.33 | 0.29 | 0.33 | | 0.57 | 0.49 | 0.57 |

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

Fruit perimeter

Significant relative heterosis and standard heterosis were observed in all the $F_1$ hybrids. Except one, all others showed significant heterobeltiosis also (Table 8d). The cross Manjari x Phule-5 recorded the highest heterobeltiosis and relative heterosis (25.88% and 32.82% respectively). Other $F_1$ hybrids which showed high heterobeltiosis were Ujjwala x LCA 305 (20.54%), Manjari x Jwala (15.26%), Manjari x JCA 283 (12.62%) and the lowest value in Ujjwala x Jwala Mukhi (-13.47%). High relative heterosis was recorded in Ujjwala x LCA 305 (27.16%) and Manjari x Jwala Mukhi (19.58%). Standard heterosis was maximum in Ujjwala x Jwala Sakhi (55.73%) followed by Manjari x Jwala Sakhi (54.75%), Manjari x Jwala Mukhi (49.18%) and Manjari x Phule-5 (40.33%).

Seeds/fruit

Many of the hybrids showed significant and negative heterobeltiosis, relative heterosis and standard heterosis for seed content (Table 8d). Ujjwala x AKC 86-39 exhibited largest value of negative heterobeltiosis (-20.42%), followed by Ujjwala x DPLC-1 (-14.83%), Ujjwala x RHRC Clustering Erect (-13.45%) and the lowest in Manjari x Jwala Sakhi (66.25%). Relative heterosis was the maximum in Manjari x Jwala Mukhi (-34.36%). Other $F_1$ hybrids which had showed high relative heterosis for seed content are Ujjwala x DPLC-1 (-33.60%), Ujjwala x AKC 86-39 (-30.80%) and Manjari x Phule-5 (-30.00%). Maximum standard heterosis was observed in Ujjwala x DPLC-1 (-55.20%) followed by Ujjwala x LCA 305 (-51.30%) and Ujjwala x Jwala Mukhi (-50.40%). Lowest values of relative heterosis and standard heterosis were recorded for the same hybrid, Manjari x AKC 86-39 (19.02 and -2.80% respectively).

Table 8d. Mean performance of parental lines and heterosis of $F_1$ hybrids for fruit perimeter, seeds/fruit and pedicel length

| Genotypes | Fruit perimeter (cm) | | | | Seeds/fruit | | | | Pedicel length (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parents/crosses | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % | Mean | HB % | RH % | SH % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Ujjwala | 3.04 | | | | 61.75 | | | | 3.30 | | | |
| Manjari | 3.01 | | | | 75.00 | | | | 3.10 | | | |
| DPLC-1 | 3.28 | | | | 39.45 | | | | 2.91 | | | |
| AKC 86-39 | 3.36 | | | | 47.50 | | | | 3.05 | | | |
| RHRC Clustering Erect | 3.24 | | | | 44.25 | | | | 2.95 | | | |
| Jwala Sakhi | 5.35 | | | | 35.85 | | | | 2.89 | | | |
| Jwala Mukhi | 4.57 | | | | 42.15 | | | | 2.94 | | | |
| Jwala | 3.08 | | | | 39.15 | | | | 2.75 | | | |
| Phule-5 | 3.40 | | | | 42.15 | | | | 2.95 | | | |
| Surektha | 3.11 | | | | 39.95 | | | | 2.96 | | | |
| LCA 305 | 3.36 | | | | 37.95 | | | | 2.73 | | | |
| JCA 283 | 3.17 | | | | 43.20 | | | | 2.95 | | | |
| Ujjwala x DPLC-1 | 3.37 | 2.90** | 7.24** | 10.49** | 33.60 | -14.83** | -33.60** | -55.20** | 2.98 | 2.23** | -4.10** | -3.80** |
| Ujjwala x AKC 86-39 | 3.43 | 2.24** | 7.78** | 12.46** | 37.80 | -20.42** | -30.80** | -49.60** | 3.11 | 2.13** | -1.97** | 3.32** |
| Ujjwala x RHRC Clustering Erect | 3.28 | 1.08** | 4.88** | 6.57** | 38.30 | -13.45** | -27.74** | -48.90** | 3.19 | 8.14** | 2.08** | 5.99** |
| Ujjwala x Jwala Sakhi | 4.75 | -11.13** | 13.70** | 55.73* | 45.82 | 27.80** | -6.12 | -38.90** | 2.95 | 1.73** | -4.92** | -1.99** |

Contd.

Table 8d. Continued

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala Mukhi | 3.95 | -13.47** | 4.29** | 29.51** | 37.20 | -11.74** | -28.39** | -50.40** | 3.05 | 3.74** | -2.24** | 1.33** |
| Ujjwala x Jwala | 3.39 | 10.06** | 11.33** | 11.15** | 55.70 | 42.27** | 10.41** | -25.73** | 3.28 | 19.27** | 8.43** | 8.97** |
| Ujjwala x Phule-5 | 3.47 | 2.21** | 8.42** | 13.77** | 46.20 | 9.61* | -11.07** | -38.40** | 3.28 | 11.19** | 4.96** | 8.97** |
| Ujjwala x Surektha | 3.21 | 3.38** | 4.99** | 5.24** | 59.80 | 49.69** | 17.60** | -20.27** | 3.20 | 8.11** | 2.24** | 6.31** |
| Ujjwala x LCA 305 | 4.05 | 20.54** | 27.16** | 32.79** | 36.50 | -3.82 | -26.78** | -51.30** | 2.88 | 5.68** | -4.31** | -4.32** |
| Ujjwala x JCA 283 | 3.34 | 5.36** | 8.09** | 9.50** | 53.80 | 24.54** | 2.53 | -28.26** | 3.28 | 11.00** | 4.88** | 8.97** |
| Manjari x DPLC-1 | 3.50 | 6.87** | 10.76** | 14.75** | 63.50 | 60.96** | 10.97** | -15.33** | 3.09 | 6.00** | 4.22** | 2.66** |
| Manjari x AKC 86-39 | 3.56 | 6.11** | 11.25** | 16.72** | 72.90 | 53.47** | 19.02** | -2.80 | 3.09 | 1.48** | 1.98** | 2.66** |
| Manjari x RHRC Clustering Erect | 3.32 | 2.47** | 5.72** | 8.85** | 53.90 | 21.81** | -9.60** | -28.13** | 2.97 | 0.51** | -0.59** | -1.33** |
| Manjari x Jwala Sakhi | 4.72 | -11.69** | 12.51** | 54.75** | 59.60 | 66.25** | 7.53* | -20.53** | 3.75 | 29.53** | 26.90** | 24.58** |
| Manjari x Jwala Mukhi | 4.55 | -0.33 | 19.58** | 49.18** | 38.45 | -8.78* | -34.36** | -48.67** | 2.71 | -7.82** | -8.98** | -9.97** |
| Manjari x Jwala | 3.55 | 15.26** | 15.92** | 16.39** | 47.10 | 20.31** | -17.48** | -37.20** | 3.23 | 17.45** | 12.06** | 7.31** |
| Manjari x Phule-5 | 4.28 | 25.88** | 32.82** | 40.33** | 41.00 | -2.73 | -30.00** | -45.30** | 2.97 | 0.85** | -0.25** | -1.33** |
| Manjari x Surektha | 3.03 | -2.42** | -1.46** | -0.66** | 40.50 | 1.38 | -29.53** | -46.00** | 3.28 | 10.64** | 9.62** | 8.97** |
| Manjari x LCA 305 | 3.64 | 8.33** | 13.66** | 19.34** | 61.40 | 61.79** | 8.72* | -18.13** | 3.45 | 26.37** | 20.10** | 14.62** |
| Manjari x JCA 283 | 3.57 | 12.62** | 14.88** | 17.05** | 49.10 | 13.66** | -16.92** | -34.53** | 3.48 | 17.77** | 16.58** | 15.61** |
| SE | | 0.26 | 0.22 | 0.26 | | 3.94 | 3.41 | 3.94 | | 0.09 | 0.08 | 0.09 |
| CD (0.01) | | 0.70 | 0.61 | 0.70 | | 10.79 | 9.35 | 10.79 | | 0.24 | 0.21 | 0.24 |
| CD (0.05) | | 0.52 | 0.46 | 0.52 | | 8.03 | 6.96 | 8.03 | | 0.18 | 0.16 | 0.18 |

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

Pedicel length

All the 20 hybrids exhibited significant values for heterobeltiosis, relative heterosis and standard heterosis for pedicel length (Table 8d). Heterobeltiosis was the maximum and negative in Manjari x Jwala Mukhi (-7.82%) and a minimum of 29.53 per cent was observed in Manjari x Jwala Sakhi. Manjari x Jwala Mukhi (-8 98%) recorded the highest and negative relative heterosis followed by Ujjwala x Jwala Sakhi (-4.92%). Crosses which showed high negative values for standard heterosis were Manjari x Jwala Mukhi (-9.97%) and Ujjwala x LCA 305 (-4.32%).

## 4.3 Evaluation of $F_2$ progenies for bacterial wilt resistance and green chilli characteristics

### 4.3.1 Analysis of variance for yield and its components

Analysis of variance showed significant differences among the 32 genotypes of chilli for all the characters studied (Appendix-2). The mean values are presented in Table 9.

Plant height

Plant height ranged from 30.02 cm to 51.93 cm in the $F_2$ progenies. Maximum height was recorded in the cross Ujjwala x Jwala Sakhi (51.93 cm) followed by Manjari x RHRC Clustering Erect (50.3 cm), Manjari x JCA 283 (49.75 cm) and the minimum was in Ujjwala x Jwala Mukhi (30.02 cm). Among the parents, the range was from 30.72 cm (JCA 283) to 44.75 cm (Phule-5).

Plant spread

The plant spread in the $F_2$ progenies ranged from 49.25 cm (Ujjwala x Jwala Sakhi) followed by 45.24 cm (Manjari x JCA 283) and the minimum being 27.55 cm in Ujjwala x RHRC Clustering Erect. Parental spread ranged from 24.85 cm to 37.80 cm.

Primary branches/plant

Highest number of primary branches per plant was produced in the $F_2$ progenies of Ujjwala x Jwala Sakhi (8.6) followed by Manjari x JCA 283 (8.35). The lowest primary branches per plant was in the $F_2$ progenies of Ujjwala x AKC 86-39 (4.67). Among the parents, both Phule-5 and LCA 305 (8.4) had the maximum number of primary branches per plant.

Days to flowering

The $F_2$ progenies of Ujjwala x Jwala Sakhi was the earliest to flower opening (29.7 days) followed by Manjari x Jwala Mukhi (30.10 days). Most precocious parent was Jwala Sakhi (35.10 days) and the latest was LCA 305 (51.3 days).

Days to first harvest

The $F_2$ progenies of Manjari x Jwala Mukhi (55.85 days) was the earliest to first harvest followed by Ujjwala x Jwala Sakhi (60.85 days) and the latest was Ujjwala x RHRC Clustering Erect (88.05 days). Parental range was 61.05 days to 85.55 days.

Fruits/plant

The highest number of fruits was produced by the $F_2$ population of Ujjwala x Jwala Sakhi (71.9 fruits) followed by Manjari x JCA 283 (69.65 fruits) and Manjari x RHRC Clustering Erect (66.85 fruits). The parental range was from 25.75 fruits in Surektha to 63.25 in LCA 305.

Fruit yield/plant

Yield/plant varied from 46.10 g to 202.75 g. Among the $F_2$ population, Ujjwala x Jwala Sakhi (202.75 g), Manjari x Jwala Mukhi (187.80 g), Manjari x Phule-5 (173 g) and Manjari x RHRC Clustering Erect (164.35 g) gave high yield. Minimum was recorded for Manjari x Surektha (49.35 g). Jwala Sakhi recorded the maximum yield among parents (112.65 g) and Surektha, the minimum (46.1 g).

Average fruit weight

The average fruit weight ranged from 1.88 g to 4.09 g in $F_2$ population. $F_2$ progenies of Ujjwala x Jwala Sakhi produced fruits with maximum fruit weight (4.09 g) followed by Manjari x Phule-5 (3.25 g) and Manjari x Jwala Sakhi (3.18 g). The minimum weight was in the $F_2$ progenies Manjari x Surektha (1.88 g). Average fruit weight ranged from 1.75 g to 3.80 g among parents.

Fruit length

Jwala (8.23 cm) recorded the maximum fruit length and Manjari (4.65 cm) the minimum. Among the $F_2$ progenies, fruit length was maximum in Ujjwala x Jwala Sakhi (7.78 cm) closely followed by Manjari x Phule-5 (7.60 cm).

Seeds/fruit

Number of seeds per fruit ranged from 31.75 in Jwala Sakhi to 72.75 in Manjari. The range in $F_2$ population was from 37.03 in Ujjwala x Jwala Sakhi to 71.65 in Manjari x DPLC-1.

Fruit perimeter

Fruit perimeter varied from 2.82 cm in the $F_2$ progenies of Manjari x Surektha to 4.29 cm in Ujjwala x Jwala Sakhi. Among the parents, the highest value was recorded by Jwala Mukhi (5.14 cm) and lowest value by Manjari (2.99 cm).

Pedicel length

The minimum pedicel length of 2.64 cm was recorded by Ujjwala x Jwala Mukhi followed by Manjari x Jwala Mukhi (2.67 cm) and the maximum pedicel length was recorded by Manjari x AKC 86-39 (3.69 cm). The parental range was from 2.55 cm (LCA 305) to 3.30 cm (Manjari).

Incidence of wilt

Significant differences were observed in genotypes for wilt incidence (%) at vegetative, flowering and fruiting and final harvesting stages. At the end of vegetative stage, the range of bacterial wilt incidence was from 2.05 per cent (Ujjwala) to 19.55 per cent (Ujjwala x Jwala) and at the end of flowering and fruiting stage wilt percentage was maximum for Surektha (63.35%) and minimum for Ujjwala (5.70%). At the final harvest, Jwala recorded the highest wilt incidence

Table 9. Mean performance of parents and $F_2$ progenies for different morphological characters

| Genotypes | Plant height (cm) | Plant spread (cm) | Primary branches/ plant | Days to flowering | Days to first harvest | Fruits/ plant | Fruit yield/ plant (g) | Average fruit weight (g) | Fruit length (cm) | Seeds/ fruit | Fruit perimeter (cm) | Pedicel length (cm) | Incidence of wilt (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Veget-ative stage | Upto flower-ing and fruting stage | Upto final harvest |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Ujjwala | 37.75 | 32.90 | 8.10 | 44.40 | 75.45 | 56.45 | 89.75 | 1.86 | 5.73 | 64.05 | 3.19 | 3.29 | 2.05 | 5.70 | 8.15 |
| Manjari | 33.55 | 28.60 | 7.05 | 47.80 | 71.30 | 39.60 | 60.35 | 1.75 | 4.65 | 72.75 | 2.99 | 3.30 | 2.85 | 8.05 | 10.40 |
| DPLC-1 | 32.15 | 29.05 | 7.05 | 43.50 | 77.90 | 38.05 | 83.50 | 2.10 | 5.58 | 44.20 | 3.17 | 2.65 | 13.20 | 39.80 | 56.05 |
| AKC 86-39 | 33.30 | 32.95 | 7.10 | 50.70 | 76.50 | 47.70 | 84.85 | 2.18 | 6.13 | 48.25 | 3.18 | 2.85 | 7.75 | 40.75 | 62.00 |
| RHRC Clustering Erect | 35.65 | 30.30 | 8.30 | 49.85 | 83.70 | 37.80 | 74.80 | 2.08 | 6.20 | 43.50 | 3.28 | 2.93 | 16.25 | 49.95 | 74.95 |
| Jwala Sakhi | 41.15 | 37.80 | 6.90 | 35.10 | 61.05 | 32.60 | 112.65 | 3.80 | 7.05 | 31.75 | 5.01 | 2.90 | 5.95 | 31.70 | 47.65 |
| Jwala Mukhi | 38.85 | 31.30 | 6.70 | 38.85 | 66.25 | 27.65 | 94.45 | 3.73 | 6.68 | 35.90 | 5.14 | 2.73 | 8.25 | 36.90 | 53.35 |
| Jwala | 32.05 | 27.65 | 5.45 | 37.40 | 73.45 | 29.50 | 68.00 | 2.03 | 8.23 | 43.95 | 3.10 | 2.90 | 14.80 | 61.35 | 89.15 |
| Phule-5 | 44.75 | 35.15 | 8.40 | 37.50 | 66.55 | 53.45 | 110.70 | 3.05 | 8.04 | 39.05 | 3.45 | 2.93 | 4.20 | 41.05 | 55.15 |
| Surektha | 36.60 | 24.85 | 4.80 | 47.80 | 85.55 | 25.75 | 46.10 | 2.03 | 6.03 | 46.55 | 3.09 | 2.96 | 15.00 | 63.35 | 81.75 |
| LCA 305 | 42.50 | 36.25 | 8.40 | 51.30 | 84.65 | 63.25 | 93.80 | 2.36 | 6.08 | 37.80 | 3.34 | 2.55 | 6.95 | 45.60 | 67.15 |
| JCA 283 | 30.72 | 37.15 | 8.00 | 46.05 | 78.65 | 51.55 | 95.45 | 2.08 | 6.13 | 49.15 | 3.15 | 2.95 | 9.40 | 33.25 | 59.07 |
| Ujjwala x DPLC-1 | 33.73 | 31.30 | 5.37 | 40.70 | 75.60 | 42.30 | 77.25 | 2.05 | 6.46 | 43.85 | 3.05 | 3.50 | 16.10 | 54.65 | 74.45 |
| Ujjwala x AKC 86-39 | 43.83 | 39.15 | 4.67 | 38.75 | 69.85 | 57.25 | 114.35 | 2.78 | 6.41 | 56.65 | 3.31 | 3.47 | 7.05 | 43.95 | 63.40 |
| Ujjwala x RHRC Clustering Erect | 33.30 | 27.55 | 7.10 | 47.80 | 88.05 | 33.20 | 72.10 | 2.06 | 6.75 | 42.85 | 3.21 | 3.29 | 16.80 | 55.55 | 76.30 |
| Ujjwala x Jwala Sakhi | 51.93 | 49.25 | 8.60 | 29.70 | 60.85 | 71.90 | 202.75 | 4.09 | 7.78 | 37.03 | 4.29 | 2.87 | 7.45 | 11.00 | 15.80 |
| Ujjwala x Jwala Mukhi | 30.02 | 30.55 | 5.87 | 30.75 | 61.85 | 42.00 | 117.80 | 3.15 | 6.97 | 49.75 | 4.00 | 2.64 | 8.45 | 34.65 | 49.15 |

Contd.

Table 9. Continued

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala | 32.80 | 34.10 | 5.90 | 47.35 | 83.00 | 36.25 | 60.15 | 2.15 | 6.63 | 64.15 | 2.98 | 3.08 | 19.55 | 50.45 | 73.75 |
| Ujjwala x Phule-5 | 36.75 | 37.60 | 7.34 | 41.90 | 73.80 | 62.75 | 134.30 | 3.00 | 6.50 | 70.55 | 3.32 | 3.40 | 11.40 | 39.05 | 50.65 |
| Ujjwala x Surektha | 34.15 | 29.17 | 5.48 | 50.30 | 82.20 | 62.65 | 115.50 | 2.23 | 6.75 | 62.05 | 3.00 | 3.19 | 16.25 | 53.35 | 75.55 |
| Ujjwala x LCA 305 | 47.00 | 39.80 | 7.99 | 44.75 | 86.95 | 65.75 | 158.20 | 2.34 | 6.86 | 42.95 | 3.97 | 2.88 | 3.75 | 15.60 | 19.75 |
| Ujjwala x JCA 283 | 45.45 | 35.20 | 7.56 | 37.00 | 69.90 | 40.00 | 106.05 | 1.96 | 5.35 | 57.08 | 2.90 | 2.68 | 12.95 | 43.25 | 61.30 |
| Manjari x DPLC-1 | 34.25 | 31.65 | 6.90 | 36.67 | 67.20 | 36.80 | 67.15 | 2.46 | 5.24 | 71.65 | 2.88 | 2.89 | 9.35 | 47.95 | 64.20 |
| Manjari x AKC 86-39 | 40.25 | 35.15 | 5.99 | 38.98 | 67.95 | 53.85 | 140.10 | 2.48 | 6.13 | 68.15 | 3.42 | 3.69 | 16.00 | 47.45 | 66.20 |
| Manjari x RHRC Clustering Erect | 50.30 | 43.55 | 6.20 | 48.05 | 87.25 | 66.85 | 164.35 | 2.70 | 6.02 | 46.40 | 3.16 | 2.72 | 8.25 | 37.25 | 46.60 |
| Manjari x Jwala Sakhi | 37.65 | 29.70 | 5.65 | 36.75 | 64.75 | 36.35 | 91.00 | 3.18 | 6.41 | 62.70 | 3.65 | 3.41 | 8.60 | 29.05 | 44.20 |
| Manjari x Jwala Mukhi | 46.90 | 43.70 | 7.85 | 30.10 | 55.85 | 65.95 | 187.80 | 3.09 | 6.28 | 41.60 | 4.18 | 2.67 | 5.95 | 14.20 | 18.55 |
| Manjari x Jwala | 34.64 | 35.30 | 6.05 | 49.70 | 78.45 | 36.50 | 50.95 | 1.98 | 6.24 | 53.70 | 3.45 | 3.58 | 17.10 | 53.20 | 74.90 |
| Manjari x Phule-5 | 46.34 | 35.90 | 7.40 | 34.70 | 65.25 | 66.40 | 173.00 | 3.25 | 7.60 | 45.35 | 4.05 | 2.92 | 5.55 | 33.90 | 47.90 |
| Manjari x Surektha | 37.40 | 33.35 | 6.95 | 51.10 | 81.45 | 39.50 | 49.35 | 1.88 | 5.64 | 55.40 | 2.82 | 3.29 | 16.30 | 55.95 | 74.05 |
| Manjari x LCA 305 | 35.35 | 29.80 | 6.50 | 49.35 | 84.30 | 27.25 | 65.90 | 2.41 | 6.04 | 66.55 | 3.43 | 3.34 | 8.55 | 29.80 | 46.10 |
| Manjari x JCA 283 | 49.75 | 45.24 | 8.35 | 39.40 | 71.85 | 69.65 | 161.85 | 2.37 | 6.25 | 45.75 | 3.34 | 2.95 | 5.85 | 13.90 | 19.15 |
| SE | 2.44 | 2.81 | 0.72 | 1.80 | 2.39 | 6.30 | 9.86 | 0.17 | 0.30 | 3.68 | 0.23 | 0.17 | 2.81 | 3.81 | 16.59 |
| CD (0.05) | 4.97 | 5.75 | 1.47 | 3.67 | 4.88 | 12.85 | 20.12 | 0.35 | 0.61 | 7.51 | 0.46 | 0.34 | 5.75 | 7.79 | 33.85 |

(89.15%) and Ujjwala (8.15%) the lowest among parents and Ujjwala x RHRC Clustering Erect (76.30%) the highest and Ujjwala x Jwala Sakhi (15.80%) the lowest among $F_2$ progenies.

4.3.2 Selection for bacterial wilt resistance and green chilli characteristics

The $F_2$ populations were evaluated and scored for bacterial wilt resistance and green chilli characteristics like average fruit weight, fruit length, fruit perimeter, pedicel length and seed content and selection was made. The mean values and scores for the above characters are presented in Table 10.

The $F_2$ segregants of the following four crosses, Ujjwala x Jwala Sakhi, Ujjwala x LCA 305, Manjari x Jwala Mukhi and Manjari x JCA 283, were found resistant to bacterial wilt. They were evaluated for green chilli characteristics and fruit yield (Table 11).

Ujjwala x Jwala Sakhi recorded the highest yield (202.75 g) followed by Manjari x Jwala Mukhi (187.8 g), Manjari x JCA 283 (161.85 g) and Ujjwala x LCA 305 (158.2 g).

All the above $F_2$ progenies had green chilli characteristics like average fruit weight > 2 g, fruit length > 6 cm, fruit perimeter > 3 cm, pedical length < 3 cm and seed content of < 50/fruit.

Table 10. Evaluation of $F_2$ generation for bacterial wilt resistance and green chilli characteristics

| $F_2$ progenies | % of wilt | Score | Average fruit weight (g) | Score | Fruit length (cm) | Score | Fruit perimeter (cm) | Score | Pedicel length (cm) | Score | Seeds/ fruit | Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ujjwala x DPLC-1 | 74.45 | S | 2.05 | 1 | 6.46 | 1 | 3.05 | 1 | 3.50 | 0 | 43.85 | 1 |
| Ujjwala x AKC 86-39 | 63.40 | S | 2.78 | 1 | 6.41 | 1 | 3.31 | 1 | 3.47 | 0 | 56.65 | 0 |
| Ujjwala x RHRC Cluster Erect | 76.30 | S | 2.06 | 1 | 6.75 | 1 | 3.21 | 1 | 3.29 | 0 | 42.85 | 1 |
| Ujjwala x Jwala Sakhi | 15.80 | R | 4.09 | 1 | 7.78 | 1 | 4.29 | 1 | 2.87 | 1 | 37.03 | 1 |
| Ujjwala x Jwala Mukhi | 49.15 | MS | 3.15 | 1 | 6.97 | 1 | 4.00 | 1 | 2.64 | 1 | 49.75 | 1 |
| Ujjwala x Jwala | 73.75 | S | 2.15 | 1 | 6.63 | 1 | 2.98 | 0 | 3.08 | 0 | 64.15 | 0 |
| Ujjwala x Phule-5 | 50.65 | MS | 3.00 | 1 | 6.50 | 1 | 3.32 | 1 | 3.40 | 0 | 70.55 | 0 |
| Ujjwala x Surektha | 75.55 | S | 2.23 | 1 | 6.75 | 1 | 3.00 | 1 | 3.19 | 0 | 62.05 | 0 |
| Ujjwala x LCA 305 | 19.75 | R | 2.34 | 1 | 6.86 | 1 | 3.97 | 1 | 2.88 | 1 | 42.95 | 1 |
| Ujjwala x JCA 283 | 61.30 | S | 1.96 | 0 | 5.35 | 0 | 2.90 | 0 | 2.68 | 1 | 57.88 | 0 |
| Manjari x DPLC-1 | 64.20 | S | 2.46 | 1 | 5.24 | 0 | 2.88 | 0 | 2.89 | 1 | 71.65 | 0 |
| Manjari x AKC 86-39 | 66.20 | S | 2.48 | 1 | 6.13 | 1 | 3.42 | 1 | 3.69 | 0 | 68.15 | 0 |
| Manjari x RHRC Clustering Erect | 46.60 | MS | 2.70 | 1 | 6.02 | 1 | 3.16 | 1 | 2.72 | 1 | 46.40 | 1 |
| Manjari x Jwala Sakhi | 44.20 | MS | 3.18 | 1 | 6.41 | 1 | 3.65 | 1 | 3.41 | 0 | 62.70 | 0 |
| Manjari x Jwala Mukhi | 18.55 | R | 3.09 | 1 | 6.28 | 1 | 4.18 | 1 | 2.67 | 1 | 41.60 | 1 |
| Manjari x Jwala | 74.90 | S | 1.98 | 0 | 6.24 | 1 | 3.45 | 1 | 3.58 | 0 | 53.70 | 0 |
| Manjari x Phule-5 | 47.90 | MS | 3.25 | 1 | 7.60 | 1 | 4.05 | 1 | 2.92 | 1 | 45.35 | 1 |
| Manjari x Surektha | 74.05 | S | 1.88 | 0 | 5.64 | 0 | 2.82 | 1 | 3.29 | 0 | 55.40 | 0 |
| Manjari x LCA 305 | 46.10 | MS | 2.41 | 1 | 6.04 | 1 | 3.43 | 1 | 3.34 | 0 | 66.55 | 0 |
| Manjari x JCA 283 | 19.15 | R | 2.37 | 1 | 6.25 | 1 | 3.34 | 1 | 2.95 | 1 | 45.75 | 1 |

Score for Bacterial wilt resistance

R - Resistant (< 20% wilted plants)
MR - Moderately resistant (20-40% wilted plants)
MS - Moderately susceptible (40-60% wilted plants)
S - Susceptible (> 60% wilted plants

Scores for green chilli characteristics

| 1. Average fruit weight | Scores | 4. Pedicel length | Scores |
|---|---|---|---|
| > 2 g | 1 | < 3 cm | 1 |
| < 2 g | 0 | > 3 cm | 0 |
| 2. Fruit length | | 5. Seeds/fruit | |
| > 6 cm | 1 | < 50 | 1 |
| < 6 cm | 0 | > 50 | 0 |
| 3. Fruit perimeter | | | |
| > 3 cm | 1 | | |
| < 3 cm | 0 | | |

Table 11. Characters of bacterial wilt resistant and green chilli types of $F_2$ segregants

| $F_2$ progenies | % of wilt | Average fruit weight (g) | Fruit length (cm) | Fruit perimeter (cm) | Pedicel length (cm) | Seeds/ fruit | Fruit yield (g) |
|---|---|---|---|---|---|---|---|
| Ujjwala x Jwala Sakhi | 15.80 | 4.09 | 7.78 | 4.29 | 2.87 | 37.03 | 202.75 |
| Manjari x Jwala Mukhi | 18.55 | 3.09 | 6.28 | 4.18 | 2.67 | 41.60 | 187.80 |
| Manjari x JCA 283 | 19.15 | 2.37 | 6.25 | 3.34 | 2.95 | 45.75 | 161.85 |
| Ujjwala x LCA 305 | 19.75 | 2.34 | 6.86 | 3.97 | 2.88 | 42.95 | 158.20 |

Plate 9. Promising $F_2$ segregants having green chilli characteristics and resistance to bacterial wilt

(a) $F_2$ segregant of Ujjwala x Jwala Sakhi

(b) $F_2$ segregant of Manjari x Jwala Mukhi


CA-219
X
JWALA SAKHI
($F_2$)


MANJARI
X
JWALA MUKHI
($F_2$)

Plate 9. Promising $F_2$ segregants having green chilli characteristics and resistance to bacterial wilt

(c) $F_2$ segregant of Manjari x JCA 283


ANJARI
X
JCA 283
(F2)

# Discussion

# DISCUSSION

Chilli is an important spice cum vegetable crop grown throughout India. The fruits impart pungency, colour, aroma and taste to the food materials. The cultivation of chilli is threatened by many diseases and pests. Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith is the main problem for chilli cultivation in Kerala. The varieties released from Kerala Agricultural University viz., Manjari and Ujjwala are resistant to this disease. However, both these varieties are not acceptable for green chilli purpose as they are highly pungent and are more seeded types. The present investigation was taken up at this juncture to incorporate bacterial wilt resistance in the popular green chilli cultivars.

Further, $F_1$ hybrids have a great role in boosting up yield in chilli. An $F_1$ hybrid in chilli resistant to bacterial wilt having green chilli characteristics will be a boon to chilli growers in the State. The results of the present findings are discussed here:

## 5.1 Evaluation of $F_1$ hybrids and parents

### 5.1.1 Evaluation for bacterial wilt resistance

Twenty $F_1$ hybrids and twelve parents were evaluated for their reaction to bacterial wilt incidence. All the $F_1$ hybrids were found to be susceptible or moderately susceptible to bacterial wilt with an incidence of above 40 per cent. This could be expected as no dominant source of resistance to bacterial wilt was used in the study.

Among the parents, lowest wilt incidence was observed in Ujjwala (8.59%) followed by Manjari (11.67%) which were classified as resistant as per Mew and Ho (1976). Resistance of Ujjwala and Manjari to bacterial wilt disease has

already been reported by Gopalakrishnan and Peter (1991). Out of ten male parents, five were moderately susceptible and the others were susceptible.

### 5.1.2 Evaluation of chilli for green chilli characteristics

Genotypes with an average fruit weight of more than 2 g, fruit length of more than 6 cm, fruit perimeter of more than 3 cm, seeds per fruit less than 50 and pedicel length of less than 3 cm were grouped under green chilli types.

All the $F_1$ hybrids showed an average fruit weight of more than 2 g and fruit perimeter of more than 3 cm. Ujjwala x Jwala Sakhi showed the highest mean performance for both the above characteristics. This is because of the fact that one of the parent Jwala Sakhi had the highest values for both the characters. In addition sca effect of the same cross was highest for average fruit weight. Fruit length was maximum in the $F_1$ hybrid Manjari x Phule-5 followed by Ujjwala x Jwala Sakhi. Minimum number of seeds per fruit was observed in the $F_1$ hybrid Ujjwala x DPLC-1. Pedicel length was minimum in Manjari x Jwala Mukhi followed by Ujjwala x LCA 305 and Ujjwala x Jwala Sakhi. Among the parents, LCA 305 followed by Jwala and Jwala Sakhi recorded the lower values for pedicel length.

$F_1$ hybrids Manjari x Phule-5, Ujjwala x LCA 305, Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi and Ujjwala x DPLC-1 were having all the green chilli characteristics.

## 5.2 Mean performance, combining ability, gene action and heterosis

In heterosis breeding programme, selection of best parents based on informations on gene action and knowledge of combining ability leads to fruitful

result in the isolation of promising $F_1$ hybrids for further exploitation. Analysis of combining ability provides guidelines for early assessment of the relative breeding potential of parent materials. It also helps the breeder in identifying the best combiners which may be hybridized either to exploit heterosis or to build up favourable fixable genes.

In the present line x tester analysis, there were 20 crosses along with 2 lines and 10 testers. The significance of variance due to both gca and sca indicated the role of both additive and non-additive gene action for the control of the above characters. The mean squares for the genotypes were significant for all the vegetative and reproductive characters indicating the presence of adequate variability which could be exploited by selection. Significant heterosis was also observed for yield and its components.

Plant height

Highly significant positive gca effect in LCA 305 (6.18) shows that LCA 305 is a good general combiner for increased plant height. This parent showed highest mean performance also. Significant relative heterosis, heterobeltiosis and standard heterosis was reported for plant height. Heterobeltiosis and relative heterosis was high in the crosses, Manjari x RHRC Clustering Erect, followed by Ujjwala x LCA 305. High standard heterosis was observed in Ujjwala x LCA 305 which was the tallest among the hybrids. This combination had high sca effect indicating that it is the best specific combiner.

Plant height is usually indicative of its vegetative vigour which influences the productivity. Heterosis for plant height was reported earlier by

Murthy and Lakshmi (1983), Krishnakumari (1984), Uzo (1984) and Thomas and Peter (1988). Non-additive gene action was predominant. Predominance of non-additive gene effect and absence of non-interacting crosses for yield indicates towards utilization of heterosis to obtain better production (Thakur, 1987).

Plant spread

Manjari x Phule-5 and Ujjwala x Jwala Sakhi were good specific combiners. Significant heterosis was also observed for plant spread. The $F_1$ hybrid, Manjari x Jwala Mukhi recorded the highest heterobeltiosis and relative heterosis. Standard heterosis was maximum in Ujjwala x LCA 305 followed by Manjari x LCA 305. The parents LCA 305 and Jwala Mukhi were good general combiners also. Predominance of non-additive gene action over additive was observed.

Primary branches/plant

Manjari x RHRC Clustering Erect (14.2) and Manjari x Phule-5 (13.0) produced more number of primary branches/plant which were higher than their respective parents. Ujjwala x Jwala Sakhi and Ujjwala x Surektha were the best specific combiners. Significant heterosis was observed for the trait. The $F_1$ hybrid Manjari x RHRC Clustering Erect exhibited the highest relative heterosis, standard heterosis and heterobeltiosis. It could be seen that one of the parents of the above cross, RHRC Clustering Erect had high gca effect. Heterosis for primary branches/ plant was earlier reported by Bhagyalakshmi *et al.* (1991) in chilli.

Days to flowering

Jwala Mukhi (-9.18) and Jwala Sakhi (-8.83) were good general

combiners for earliness since they showed high negative gca values. The crosses involving the above parents, Ujjwala x Jwala Mukhi and Manjari x Jwala Sakhi were the earliest to flower (29.5 days after planting). They were earlier than their respective parents. Additive gene action was predominant which shows that this character can be improved by appropriate selection method.

Number of days taken by a variety to put forth the first flower is generally indicative of its earliness. Out of twenty hybrids, fourteen exhibited significant and negative standard heterosis. Both heterobeltiosis and relative heterosis were the highest and negative in Manjari x AKC 86-39. Highest negative value of standard heterosis was recorded in two hybrids, Ujjwala x Jwala Mukhi and Manjari x Jwala Sakhi followed by Manjari x AKC 86-39 (-35.51%). Heterosis for days to flowering was reported by Krishnakumari (1984) and Thomas and Peter (1988).

Days to first harvest

The parents Jwala Sakhi and Jwala Mukhi showed high negative gca effect for days to first harvest. The hybrids involving any one of these parents were the earliest matured hybrids viz. Manjari x Jwala Sakhi (52.72 days) followed by Manjari x Jwala Mukhi (58.50 days). They were earlier than their respective parents. Gene action for days to first harvest was additive as shown by high $\sigma^2_A$ value.

Significant and negative heterobeltiosis, relative heterosis and standard heterosis were exhibited by many of the $F_1$ hybrids. Crosses Manjari x AKC 86-39 recorded the highest negative value of heterobeltiosis followed by Manjari x Jwala

Sakhi. The same cross Manjari x Jwala Sakhi showed highest amount of relative heterosis and standard heterosis. The present results concur with the findings of Wang *et al.* (1986) and Chen (1985) in chilli.

Fruits/plant

Among the $F_1$ hybrids maximum fruits/plant was produced by Manjari x Phule-5 (110.10 fruits) followed by Ujjwala x LCA 305 (104.10 fruits). LCA 305 and Phule-5 were good general combiners as shown by high gca values. Non-additive gene action was found to be predominant.

Both heterobeltiosis and relative heterosis were the highest in Manjari x RHRC Clustering Erect followed by Manjari x Jwala Mukhi. Standard heterosis was significant in all the twenty hybrids except Ujjwala x RHRC Clustering Erect, with the highest being in Manjari x Phule-5. Heterosis for number of fruits is an important aspect in crop improvement and productivity. Heterosis for total fruits/plant was reported by Uzo (1984), Depestre and Espinosa (1988) and Kordus (1991).

Fruit yield/plant

Manjari x Phule-5 and Ujjwala x LCA 305 recorded the highest yield/plant. This may be because of the fact that Phule-5 and LCA 305 were good general combiners for fruit yield/plant having significant positive gca effect.

Manjari x RHRC Clustering Erect (148.99%) showed the highest value for heterobeltiosis followed by Manjari x Phule-5 (146.27%). Except three, all other hybrids showed significant relative and standard heterosis with the highest value for

Manjari x Phule-5. Heterosis for total yield/plant has already been reported by Thakur (1987), Thomas and Peter (1988), Kordus (1991) and Ram and Lal (1992).

Average fruit weight

Among the parents, Jwala Sakhi showed highest mean performance for average fruit weight. The same parent also had the highest gca effect followed by Phule-5. The crosses involving any one of the above parents were recorded high average fruit weight viz. Ujjwala x Jwala Sakhi and Manjari x Phule-5. The cross Ujjwala x Jwala Sakhi also showed high positive sca effect. Gene action was non additive.

Ujjwala x LCA 305 had the highest heterobeltiosis. All the hybrids were significantly superior to their respective mid parents and standard parents. Relative heterosis was the highest in Manjari x Phule-5 followed by Ujjwala x LCA 305, while high value of standard heterosis was noticed in Ujjwala x Jwala Sakhi followed by Manjari x Phule-5. Thomas and Peter (1988) also observed heterosis for average fruit weight in bell pepper and chilli.

Fruit length

Fruit length was maximum in the $F_1$ hybrid Manjari x Phule-5 followed by Ujjwala x Jwala Sakhi. This can be expected because Phule-5 and Jwala Sakhi were good general combiners for fruit length. The cross Manjari x Phule 5 recorded highest sca value also. Additive gene action was predominant for average fruit weight.

Except one hybrid, all others showed significant heterobeltiosis and except two, others showed significant relative heterosis. Heterobeltiosis was maximum in the $F_1$ hybrid Ujjwala x JCA 283 followed by Ujjwala x LCA 305. Both relative and standard heterosis were higher in Manjari x Phule-5. Heterosis for fruit length was earlier reported by Thomas and Peter (1988).

Fruit perimeter

Highest mean performance and gca values were recorded for Jwala Sakhi and Jwala Mukhi. The crosses involving the above parents like Ujjwala x Jwala Sakhi, Manjari x Jwala Sakhi and Manjari x Jwala Mukhi also gave good performance. All the twenty hybrids showed significant relative heterosis and standard heterosis. The crosses Manjari x Phule-5 followed by Ujjwala x LCA 305 recorded the highest heterobeltiosis and relative heterosis. Standard heterosis was maximum in Ujjwala x Jwala sakhi followed by Manjari x Jwala Sakhi.

Seeds/Fruit

Best general combiners for less number of seeds/fruit were Jwala Mukhi and Phule-5, since they recorded maximum negative gca value. Largest value for heterobeltiosis was observed in Ujjwala x AKC 86-39 and standard heterosis was observed in Ujjwala x DPLC-1. Relative heterosis was maximum in Manjari x Jwala Mukhi followed by Ujjwala x DPLC-1.

Pedicel length

Best cross for reduced pedicel length was Manjari x Jwala Mukhi involving the best general combiner, Jwala Mukhi. All the twenty hybrids exhibited

significant values for heterobeltiosis, relative heterosis and standard heterosis with the highest being in Manjari x Jwala Mukhi.

The present study reveals that parents showing higher mean performance for a particular character are generally good general combiners for that character. It was also observed that when parents possessing high gca effect were crossed, the $F_1$ hybrids gave good performance. The variation in the gca effect of parents can be attributed to genetic as well as geographic diversity in the materials. High sca effect observed for different characters may be helpful for sorting out outstanding parents with favourable alleles for the different components of yield.

## 5.3 Evaluation of $F_2$ progenies for bacterial wilt resistance and green chilli characteristics

The $F_2$ populations were evaluated and scored for bacterial wilt resistance and green chilli characteristics like average fruit weight, fruit length, fruit perimeter, pedicel length and seed content. The $F_2$ segregants of Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi, Manjari x JCA 283 and Ujjwala x LCA 305 were found resistant to bacterial wilt with a wilt incidence of less than 20 per cent and they were having green chilli characteristics.

Analysis of variance for yield and it's components were performed. Plant height, plant spread and primary branches per plant have a direct bearing on total yield. The $F_2$ segregants of Ujjwala x Jwala Sakhi recorded the highest value for plant height, plant spread and primary branches per plant indicating that it is the most vigorous one. Progenies recorded higher values than the parents. Manjari x JCA 283 recorded the second highest value for plant spread and primary branches/plant.

The earliness can be evaluated from the factors like days to flowering and days to first harvest. $F_2$ progenies of Ujjwala x Jwala Sakhi were the earliest to flower followed by Manjari x Jwala Mukhi. $F_2$ progenies of Manjari x Jwala Mukhi were the earliest for first harvest followed by Ujjwala x Jwala Sakhi. Among the parents the earliest one was Jwala Sakhi.

Number of fruits per plant was maximum for Ujjwala x Jwala Sakhi followed by Manjari x JCA 283. Fruits per plant is being influenced by vegetative characters like plant height, plant spread and primary branches per plant which were also highest for the same hybrids.

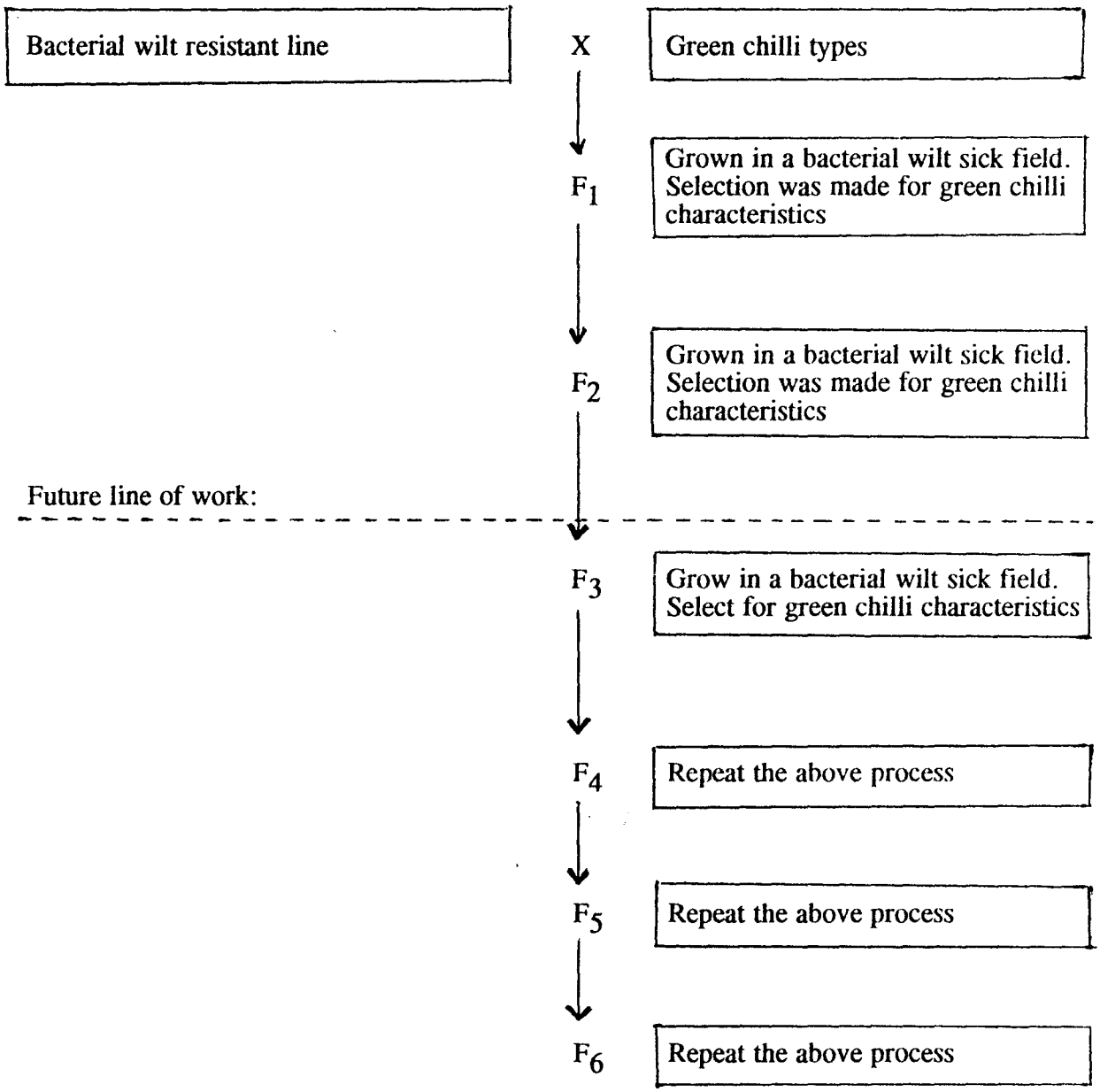
Yield per plant, which is one of the important considerations in any breeding programme is mainly determined by the number of fruits per plant and average fruit weight. High values for average fruit weight was recorded for the $F_2$ progenies Ujjwala x Jwala Sakhi and Manjari x Phule-5. The same hybrids Ujjwala x Jwala Sakhi and Manjari x Phule-5 were the top performers for yield also.

Fruit length and fruit girth are two important fruit characters which were maximum in the segregant Ujjwala x Jwala Sakhi. Minimum pedicel length was noticed in Ujjwala x Jwala Mukhi and minimum seeds per fruit in Ujjwala x Jwala Sakhi.

From the foregoing discussion, it can be concluded that when we consider the factors of bacterial wilt resistance and green chilli characteristics, the $F_2$ progenies with outstanding performance were Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi, Manjari x JCA 283 and Ujjwala x LCA 305. They can be further

improved by advancing generations up to $F_6$ for evolving green chilli varieties resistant to bacterial wilt. The breeding technology adopted in the study is schematically represented below.

Schematic representation of breeding technology




By $F_6$ generation, uniformity can be obtained

# Summary

## SUMMARY

The present investigation on 'Incorporation of bacterial wilt resistance in green chilli (*Capsicum annuum*) was conducted at the vegetable research farm of the Department of Olericulture, College of Horticulture, Vellanikkara during October, 1993 - May, 1995.

Ten popular green chilli varieties (susceptible to bacterial wilt) were crossed with two bacterial wilt resistant varieties viz. Manjari and Ujjwala in a line x tester fashion to develop twenty $F_1$ hybrids. The $F_1$ hybrids along with their parents were evaluated for bacterial wilt resistance in a bacteril wilt sick field. All the $F_1$ hybrids were susceptible/moderately susceptible to bacterial wilt with a wilt incidence of above 40 per cent.

The $F_1$ hybrids along with their parents were evaluated for green chilli characteristics. The $F_1$ hybrids Manjari x Phule-5, Ujjwala x LCA 305, Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi and Ujjwala x DPLC-1 were grouped under green chilli types.

Superior hybrids for various growth parameters were identified. Ujjwala x Jwala Sakhi (4.22 g/fruit) recorded highest value for average fruit weight, Manjari x Phule-5 (8.46 cm) for fruit length, Ujjwala x Jwala Sakhi (4.75 cm) for fruit perimeter, Ujjwala x DPLC-1 (33.60/ fruit) for minimum seeds/fruit and Manjari x Jwala Mukhi (2.71 cm) for minimum pedicel length.

Line x tester analysis was performed for the estimation of combining ability and heterosis. The $F_1$ hybrids having highest mean performance for yield and

its components were Ujjwala x LCA 305 for plant height and plant spread (62.90 and 49.90 cm respectively), Manjari x RHRC Clustering Erect for primary branches/plant (14.20), Manjari x Jwala Sakhi and Ujjwala x Jwala Mukhi for minimum days to flowering (29.50 days after planting), Manjari x Jwala Sakhi for minimum days to first harvest (52.72 days after planting) and Manjari x Phule-5 for fruits/plant (110.10 fruits) and fruit yield/plant (318.30 g).

Good general combiners for different characters were identified. They were LCA 305 (for plant height, plant spread and fruits/plant), Jwala Mukhi (for days to flowering, seeds/fruit and pedicel length), Jwala Sakhi (for days to first harvest, average fruit weight and fruit perimeter) and Phule-5 (for yield/plant and fruit length).

Good specific combiners were Ujjwala x LCA 305 (plant height and days to flowering), Ujjwala x Jwala Sakhi (for primary branches/plant, average fruit weight and pedicel length), Manjari x RHRC Clustering Erect (for fruits/plant and yield/plant), Manjari x Phule-5 (for plant spread and fruit length) and Manjari x Surektha (for seeds/ fruit).

Standard heterosis, relative heterosis and heterobeltiosis were estimated. For plant height, heterobeltiosis and relative heterosis were highest in Manjari x RHRC Clustering Erect (46.83 and 51.74% respectively) followed by Ujjwala x LCA 305 (39.47 and 46.19% respectively). For plant spread, Manjari x Jwala Mukhi recorded the highest heterobeltiosis (45.38%) and relative heterosis (45.62%). Manjari x RHRC Clustering Erect showed highest relative heterosis (67.06%), standard heterosis (77.50%) and heterobeltiosis (57.78%) for primary branches/plant. Manjari x AKC 86-39 recorded the highest negative heterobeltiosis

for days to flowering and days to first harvest (-35.50% and -17.24% respectively). For fruits/plant and fruit yield/plant, Manjari x Phule-5 exhibited highest standard heterosis (109.12% and 266.07% respectively). Manjari x RHRC Clustering Erect showed highest heterobeltiosis (85.57%) and relative heterosis (101.76%) for fruits/plant. Manjari x Phule-5 recorded the highest relative heterosis for average fruit weight (57.43%), fruit length (32.29%) and fruit perimeter (32.82%). Ujjwala x Jwala Sakhi showed the high value of standard heterosis for average fruit weight (143.90%) and fruit perimeter (55.73%). For pedicel length, heterobeltiosis, relative heterosis and standard heterosis were highest and negative in Manjari x Jwala Mukhi (-7.82%, -8.98% and -9.97% respectively) and for seeds/fruit, relative heterosis was maximum and negative in Manjari x Jwala Mukhi (-34.36%) and standard heterosis in Ujjwala x DPLC-1 (-55.20%).

Additive gene action was predominant for days to flowering, days to first harvest, fruit length and fruit perimeter. Non-additive gene action was predominant for plant height, plant spread, primary branches/plant, fruits/plant, fruit yield/plant, average fruit weight, seeds/fruit and pedicel length.

The $F_2$ segregants were evaluated for bacterial wilt resistance, green chilli characteristics and other yield attributes. $F_2$ segregants resistant to bacterial wilt having green chilli characteristics were selected for further improvement. They were Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi, Manjari x JCA 283 and Ujjwala x LCA 305. These segregants can be utilised for evolving green chilli types resistant to bacterial wilt.

The $F_2$ segregants of Ujjwala x Jwala Sakhi showed highest mean performance for plant height (51.93 cm), plant spread (49.25 cm), primary

branches/plant (8.60), fruit/plant (71.90 fruits), fruit yield/plant (202.75 g), days to flowering (29.70 days), average fruit weight (4.09 g), fruit length (7.78 cm), fruit perimeter (4.29 cm) and seeds/fruit (37.03 seeds). $F_2$ segregants of Manjari x Jwala Mukhi were the earliest to first green chilli harvest (55.85 days) and minimum pedicel length was noticed in Ujjwala x Jwala Mukhi (2.64 cm).

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*Originals not seen

# Appendices

APPENDIX-1

ANOVA for line x tester analysis for yield and its components

| Source | df | Mean squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant height | Plant spread | Primary branches per plant | Days to flower-ing | Days to first harvest | Fruits/ plant | Yield/ plant | Average fruit weight | Fruit length | Fruit perimeter | Seeds/ fruit | Pedicel length |
| Genotypes | 31 | 108.72** | 91.69** | 7.66** | 73.84** | 163.58** | 682.91** | 6580.07** | 0.934** | 1.78** | 0.70** | 244.09** | 0.1039** |
| Parents | 11 | 24.95* | 29.66* | 2.34* | 31.87** | 83.55** | 386.01** | 488.63** | 1.14** | 2.75** | 1.02** | 259.10** | 0.042** |
| Hybrids | 19 | 78.88** | 55.14** | 6.68** | 92.75** | 211.93** | 506.90** | 6299.68** | 0.7838** | 1.25** | 0.5214** | 241.56** | 0.1107** |
| Parent vs Hybrids | 1 | 1597.18** | 1230.21** | 84.85** | 176.45** | 125.22** | 7293.00** | 78913.4** | 1.49** | 1.21** | 0.6136** | 127.23** | 0.6636** |
| Lines | 1 | 81.56* | 0.3164 | 9.60** | 76.21** | 189.21** | 0.4187 | 482.70 | 0.029 | 2.57** | 0.219 | 684.48** | 0.066** |
| Testers | 9 | 73.57** | 82.02** | 5.87** | 167.26** | 397.56** | 523.42** | 7982.44** | 1.41** | 1.80** | 0.9537** | 101.45** | 0.091** |
| Line x testers | 9 | 83.89** | 34.34* | 7.17** | 20.07** | 28.84* | 546.65** | 5263.24** | 0.2459** | 0.551** | 0.1227 | 332.45** | 0.1356** |
| Error | 31 | 11.26 | 13.14 | 0.9838 | 3.95 | 10.27 | 49.38 | 157.57 | 0.027 | 0.078 | 0.0661 | 15.51 | 0.0079 |

** Significant at 1% level

* Significant at 5% level

APPENDIX-2

General analysis of variance for characters in the $F_2$ generation of chilli

| Source of variation | df | Mean square | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | % of wilt | | |
| | | Plant height | Plant spread | Primary branches/plant | Days to flowering | Days to first harvest | Fruits/ plant | Fruit yield/ plant | Average fruit weight | Fruit length | Seeds/fruit | Fruit perimeter | Pedicel length | Vegetative stage | Upto flowering & fruiting | Upto final harvest |
| Replication | 1 | 11.18 | 0.036 | 0.07 | 17.83 | 0.001 | 216.83 | 816.53 | 0.02 | 0.02 | 94.33 | 0.008 | 0.105 | 5.063 | 0.246 | 25.750 |
| Treatment | 31 | 78.54** | 63.09** | 2.51** | 88.04** | 160.05** | 413.26** | 3570.08** | 0.77** | 1.21** | 269.00** | 0.669** | 0.192** | 48.108** | 499.79** | 730.894** |
| Error | 31 | 5.946 | 7.94 | 0.52 | 3.24 | 5.73 | 39.65 | 97.27 | 0.03 | 0.09 | 13.54 | 0.051 | 0.028 | 7.924 | 14.57 | 275.32 |

**Significant at 1% level

APPENDIX-3
Meteorological data during the cropping period

| Month | Temperature (°C) | | Mean relative humidity (%) | Total rainfall (mm) | Number of rainy days | Mean sunshine hours |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | | | | |
| 1991 | | | | | | |
| October | 30.7 | 23.4 | 83 | 519.0 | 16 | 4.8 |
| November | 31.5 | 23.6 | 73 | 74.6 | 4 | 5.8 |
| December | 31.6 | 23.1 | 66 | 18.0 | 2 | 7.5 |
| 1994 | | | | | | |
| January | 32.9 | 22.6 | 58 | 19.4 | 1 | 9.1 |
| February | 34.8 | 23.1 | 59 | 1.7 | 0 | 8.7 |
| March | 36.2 | 23.7 | 59 | 21.0 | 1 | 9.3 |
| April | 34.9 | 24.4 | 74 | 165.2 | 10 | 8.0 |
| May | 33.6 | 24.7 | 75 | 124.2 | 7 | 8.0 |
| June | 28.9 | 22.9 | 90 | 955.1 | 27 | 2.1 |
| July | 28.6 | 22.4 | 91 | 1002.1 | 29 | 1.4 |
| August | 30.0 | 22.8 | 85 | 509.2 | 20 | 3.0 |
| September | 31.8 | 23.2 | 78 | 240.5 | 8 | 7.3 |
| October | 32.3 | 22.7 | 80 | 350.2 | 20 | 6.7 |
| November | 31.8 | 23.3 | 68 | 125.3 | 5 | 8.1 |
| December | 32.2 | 22.2 | 58 | 0 | 0 | 10.6 |
| 1995 | | | | | | |
| January | 32.9 | 22.4 | 59 | 0 | 0 | 9.6 |
| February | 35.4 | 23.4 | 60 | 0.5 | 0 | 10.6 |
| March | 37.6 | 23.8 | 60 | 2.8 | 0 | 9.3 |

# INCORPORATION OF BACTERIAL WILT RESISTANCE IN GREEN CHILLI (*Capsicum annuum* L.)

By

**SEENA, P. G.**

## ABSTRACT OF A THESIS

submitted in partial fulfilment of the
requirement for the degree of

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## ABSTRACT

The present investigation on 'Incorporation of bacterial wilt resistance in green chilli (*Capsicum annuum* L.)' was conducted at the College of Horticulture, Vellanikkara, Thrissur during October, 1993-May, 1995. Ten popular green chilli varieties susceptible to bacterial wilt were crossed with two bacterial wilt resistant varieties viz. Manjari and Ujjwala, to develop twenty $F_1$ hybrids. They were grown in a wilt sick field for evaluating bacterial wilt resistance and green chilli characteristics. All the $F_1$ hybrids were susceptible/ moderately susceptible to bacterial wilt. The $F_1$ hybrids Manjari x Phule-5, Ujjwala x LCA 305, Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi and Ujjwala x DPLC-1 were grouped under green chilli types.

Line x tester analysis was performed to derive informations on general and specific combining ability effects, gene action and heterosis. Good general combiners were LCA 305 for plant height, plant spread and fruits/plant, Jwala Sakhi for days to first harvest, average fruit weight and fruit perimeter and Phule-5 for fruit yield/plant and fruit length. Good specific combiners were Ujjwala x LCA 305 for plant height and days to flowering, Manjari x Phule-5 for plant spread and fruit length, Manjari x RHRC Clustering Erect for fruits/plant and fruit yield/plant and Ujjwala x Jwala Sakhi for primary branches/plant and average fruit weight.

Significant heterosis was observed for all the characters studied viz., plant height, plant spread, primary branches/plant, days to flowering, days to first harvest, fruits/plant, fruit yield/plant, average fruit weight, fruit length, fruit perimeter, seeds/fruit and pedicel length. Manjari x Phule-5 exhibited highest

standard heterosis for fruits/plant and fruit yield/plant and relative heterosis for average fruit weight, fruit length and fruit perimeter. Ujjwala x Jwala Sakhi showed high standard heterosis for average fruit weight and fruit perimeter. Manjari x RHRC Clustering Erect exhibited maximum heterobeltiosis and relative heterosis for plant height followed by Ujjwala x LCA 305. Manjari x Jwala Mukhi recorded highest negative value of relative heterosis for seeds/fruit and pedicel length.

$F_2$ segregants were evaluated for bacterial wilt resistance, green chilli characteristics and other yield attributes. The $F_2$ segregant Ujjwala x Jwala Sakhi recorded the highest mean performance for all the characters studied except days to first harvest and pedicel length.

Considering bacterial wilt resistance and green chilli characteristics, the $F_2$ segregants Ujjwala x Jwala Sakhi, Manjari x Jwala Mukhi, Manjari x JCA 283 and Ujjwala x LCA 305 were found promising which can be further selected for evolving green chillies resistant to bacterial wilt.