CHAPTER-II

REVIEW OF LITERATURE

The reports available in literature pertaining to various aspects of the present studies have been reviewed under the following heads:

2.1 Genetics of resistance to bacterial wilt
2.2 Genetics of morphological and biochemical traits
2.3 Association of bacterial wilt resistance
2.4 Heterosis

2.1 GENETICS OF RESISTANCE TO BACTERIAL WILT

Bacterial wilt, a serious soil-borne disease, in capsicum caused by *Ralstonia solanacearum* E.F. Smith has become a serious problem in India (Gopalakrishnan and Peter, 1991). Yield losses up to 100 per cent have been reported in wilt prone areas of the world (Wang *et al*., 1997). In India, the disease is prevalent in Karnataka, Kerala, Maharashtra, Orissa and West Bengal causing heavy losses in yield (Kishun, 1987). It was first observed in Kangra valley in 1981 and gradually spread to other districts like Kullu, Mandi (Sood and Singh, 1993), Solan (Gupta *et al*., 1998), Bilaspur and Hamirpur (Sood *et al*., 2002). Now, it is an endemic disease in most of the districts and causes 80-100 per cent losses in heavily infested fields. Cultural practices and chemicals, if judiciously used, can reduce disease incidence and severity, but alone are expensive and ineffective. Thus, resistant varieties along with use of chemicals and cultural practices appear to be the most practical and durable solution. Wang *et al.* (1996)
suggested that growing of disease resistant varieties is the most effective control of bacterial wilt. In India, the breeding lines PBC-631 (from AVRDC, Taiwan) and IHR-546 (from IIHR, Bangalore) of *Capsicum annuum* L., were found to be highly resistant to bacterial wilt and have been recommended for inclusion in breeding programmes (Singh and Sood, 2003).

Thakur (1990), while studying the inheritance of disease resistance in *Capsicum annuum* L., used PI 257069 and PI 201234 as the resistant parents and California Wonder and Yolo Wonder as the susceptible parents. He found resistance to be digenic recessive in nature in all the four susceptible x resistant cross-combinations.

Genetic analysis of resistance of sweet pepper to bacterial wilt has recently been performed by Lafortune et al. (2005) in the doubled haploid (DH) progeny from a cross between a resistant parental line PM 687 and a susceptible cultivar Yolo Wonder for two consecutive years. Two to five genes with additive effects were estimated to control the resistance, indicating an oligogenic control as observed in tomato sources of resistance. They further stated that the similarity of the genetics of resistance to bacterial wilt in pepper and tomato and linkage with TMV resistance locus warrant the comparative mapping of the resistance quantitative trait loci in the genomes of the two species.

Nelson (1974) while working on tomato concluded that the level of bacterial wilt resistance varied from season to season and was associated with polygenes. Tikoo et al. (1974) reported genotype dependent gene action for resistance to bacterial wilt in tomato. IHR 663-12-3 proved to have a single dominant gene for resistance, but a few other genotypes were observed to have recessive genes.

Graham and Yap (1976) in an analysis of the $P_1$, $P_2$, $F_1$, $F_2$, $BC_1$ and $BC_2$ generations (six-generation model) of a cross between resistant ($V_4$) and a susceptible
genotype (Walter) of tomato observed dominance for resistance. Further, in a diallel study, they reported that resistance was mainly due to additive gene action. Gopinath and Madalageri (1986) in an analysis of bacterial wilt infection data from F₂ and BC₁ involving resistant and susceptible variety of brinjal revealed that resistance was controlled by single resistant gene for which the designation Rps was given. Tikoo et al. (1986) again reported that resistance to bacterial wilt in tomato was governed by recessive genes in CRA 66 Sel-A and a dominant gene in IHR 663-12-3.

Mahir et al. (1992) crossed local varieties of tomato having higher level of resistance with imported susceptible varieties and observed that the resistance was controlled by single dominant gene. Monma and Sakata (1992) in a six-generation study involving two bacterial wilt resistant (D-9 and Hawaii 7998) and a susceptible (TPD-5) line of tomato reported resistance to be partially recessive as there was incomplete dominance towards susceptibility. Peter et al. (1992) studied six generations of the cross CL-32-d-01-19GS’ (resistant) x Pusa Ruby (susceptible) and reported that the resistance was monogenic and incompletely dominant.

Grimault et al. (1995) used Hawaii 7998 (resistant) and Floradel (susceptible) genotypes of tomato for bacterial wilt resistance studies and observed it to be monogenic dominant in nature. Mohamed et al. (1997) reported bacterial wilt resistance as partially recessive since they could record incomplete dominance towards susceptibility. Monma et al. (1997) observed that the genetic mechanism of bacterial wilt resistance in tomato was complex with a duplicate form of epistasis.

Vidyasagar (1998) in a six-generation study involving two bacterial wilt resistant viz., BWR-5 and BT-18 and a susceptible genotype Solan Gola of tomato observed resistance to be dominant in nature as the plant survival in resistant (R) x susceptible (S)
F₁s were above 97 per cent, 103 days after transplanting. The F₂, BCP₁ and BCP₂ data of the cross BWR-5 x Solan Gola suggested the involvement of two interacting genes possibly dominant and recessive epistasis. However, the same was not true with the F₂ and BCP₂ data of the cross BT-18 x Solan Gola.

Chaudhary and Sharma (1999) crossed bacterial wilt resistant varieties of brinjal (Arka Keshav and Arka Neelkanth) with susceptible variety (Pusa Purple Long) to study the inheritance of disease resistance. Segregation studies of F₂ progenies of both the crosses indicated the presence of single dominant gene controlling resistance to bacterial wilt and they further advocated to incorporate resistance into susceptible varieties through back cross pedigree method.

Oliveira et al. (1999) studied the genetic nature of bacterial wilt (Ralstonia solanacearum) resistance of tomato in crosses using resistant (Hawaii 7998, Rotam 4 and Yoshimatsu 4-11) and susceptible (L390 and TSW 10) parents in the presence of bacterial isolates of biovars I and III. The resistance was found to be oligogenic or polygenic, depending on the genotype-isolate combination. The resistance index of the F₁ in most crosses was higher than the midparent value suggesting that resistance in tomato is partially dominant, as there was incomplete dominance towards resistance.

Chaudhary (2000) carried out an investigation to determine the mode of inheritance of bacterial wilt (R. solanacearum) resistance in brinjal. The variable segregation patterns ranging from monogenic dominant and recessive to inhibitory type in different cross-combinations indicated that resistance to bacterial wilt is conditioned by polygenes. Gopalakrishnan et al. (2002) in their inheritance studies involving the F₁, F₂, BC₁, and BC₂ generations of a cross between the resistant variety Soorya and the
susceptible variety Pusa Kranti of brinjal revealed monogenic and incompletely dominant inheritance of susceptibility over resistance.

The mode of inheritance of bacterial wilt (*Ralstonia solanacearum*) resistance in four tomato crosses (Hawaii-7998 x Solan Gola, Hawaii-7998 x Roma, BT-18 x Solan Gola and TBL-4 x Solan Gola) was studied by Sharma and Verma (2004). The results of their study clearly indicated the involvement of more than one interacting gene, and the role of additive and dominance components and their interactions in the expression of bacterial wilt resistance in tomato. Whereas, Thakur *et al.* (2004) reported dominance of bacterial wilt susceptibility over resistance in tomato. The F₂ segregation into 3 (S) : 1 (R) ratio indicated the monogenic recessive nature of resistance.

2.2 **Genetics of morphological and biochemical traits**

The information on the genetics of quantitative and qualitative traits is of immense importance to the plant breeder for deciding the breeding strategy to be followed. To understand the type of gene action, various mating designs have been developed by various workers. Commonly used approaches of diallel and line x tester provide information about the population as a whole and do not provide any information about the individual parent/cross. Generation mean study enables the gene action to be analysed cross-wise and provide precise information on additive x additive [i] (fixable), additive x dominance [j] and dominance x dominance [l] (non-fixable) interactions, the relative magnitude of which indicates the future breeding strategy. Studies with regard to estimation of different components of genetic variance through generation means have been carried out by various workers in a variety of crops, but such information is too limited in sweet pepper. Nevertheless, literature on various morphological and
biochemical traits based on the studies being carried out through other techniques viz., diallel, line x tester, triple test cross, etc. in addition to generation means technique in Capsicum have been reviewed as under:

Popova et al. (1970), while studying the inheritance of several biochemical characteristics in F₁ peppers, observed no heterotic effects for dry matter, sugars, vitamin C (ascorbic acid) and carotene, and reported the inheritance of these characteristics to be intermediate in nature.

Chung et al. (1979) in crosses of Yolo Wonder with Tatong and Funong’s Tender Twig of capsicum reported over dominance for fruit width, flesh weight and days to first flower in the cross with Tatong and number of branches, stalk length, plant height and days to first flower showed overdominance in the cross with Funong’s Tender Twig. Epistasis was significant for all the characters except fruit width in the first cross and total number of flowers in the second cross.

Subramanya and Ozaki (1980) reported that long pedicel was partially dominant over short and polygenic in inheritance. F₂ populations exhibited a continuous range of phenotypes. At least 3 loci determined this trait. Thakur et al. (1980) reported that fruit size was influenced by additive gene action, number of days to flowering by dominance, and height, fruit number per plant and total yield by over-dominance in a diallel cross involving six varieties of capsicum. Both additive and non-additive effects influenced early yield.

Milkova (1981) in an analysis of data on plant height, fruit (shape) index, pericarp thickness and pedicel length including yield concluded that these characters were controlled by small number of genes.
Prudek (1981) on the basis of data recorded in the parents, F₁s and F₂s of a five-variety diallel, made recommendations for the production of heterotic hybrid sweet peppers. He reported that systems of genetic control were not always the same in the F₂ as in the F₁. In the F₁, fruit yield was controlled mainly by overdominance effects in an additive genetic system, though incomplete dominance made a contribution in the F₂. In both generations, incomplete dominance contributed to the control of mean fruit weight and pericarp vigour.

Ahmed et al. (1982) studied six generations of two crosses (Elephant Trunk x Perennial and Kalocsi E15 x Perennial). They reported both additive and dominance genetic effects to be important for number of days to fruiting and height, whereas only additive gene effects were important for seed number and fruit weight.

Thakur et al. (1987), while studying the genetics of fruit characters (average fruit weight, fruit index and flesh thickness) of sweet pepper through generation mean analysis, reported the governance of both additive and non-additive gene action and received similar indication from epistatic effects. They suggested the utilization of heterosis breeding to be more feasible option for all the traits; however, they also suggested recurrent selection to be equally suitable for improvement of average fruit weight.

Kaul and Sharma (1988) observed predominance of additive genetic variance for the characters viz., fruit length, fruit diameter, number of fruits per plant and fruit yield per plant of bell pepper. Whereas, Miranda et al. (1988) reported non-additive gene action to be more important than additive gene action for total yield per plant, early yield and plant height in capsicum. There was a predominance of additive variance for total number of fruits per plant. Overdominance was observed for total yield per plant, early
yield and plant height, whereas incomplete dominance was noticed for total number of fruits per plant.

Joshi (1989) studied genetics of yield per plant and five yield-related traits viz., plant height, number of branches per plant, fruit length, fruit circumference and number of fruits per plant in three crosses of HC-210, Ruby King and California Wonder with Elephant Trunk of capsicum. He reported epistasis to be important in all the traits studied, and assumed that breeding methods that exploit non-additive gene action, such as reciprocal recurrent selection, would be rewarding for the improvement of these traits.

Blank and Maluf (1997) evaluated two $F_1$s of sweet pepper in green house and reported that early flowering, increased plant height, and high yield were controlled by dominant alleles and high fruit weight by recessive alleles.

Murthy and Deshpande (1997), while studying the six generations of four crosses of chilli, observed all the three types of gene action i.e. interaction components to be involved in the inheritance of yield attributes. They reported that this could be due to differences in magnitude of the gene effects and genetic background of the crosses and further suggested the exploitation of heterosis breeding, pedigree breeding and selection of desirable transgressive segregants for varietal improvement.

Bal and Singh (1999) reported preponderance of additive gene effects for fruit length and breadth in chilli. They also reported the duplicate type of gene action in majority of the crosses, which will reduce the net gain occurring from heterozygosity due to cancellation of the dominance and epistatic effects and further suggested to adopt recurrent selection for the improvement of fruit length and breadth.

Echeverri et al. (1999) carried out genetic analysis of yield, number of fruits per plant, fruit size (fruit weight, locule weight, and fruit length and width) and days to
flowering using hybrids between ten sweet pepper cultivars (LPUNAL, Yolo Wonder, Keystone Resistant Giant, Pimentao Amarelo, Morviones, Avelar, California Wonder, Roque 8-B, Red Pepper, and L-363-46-672) crossed in a diallel fashion. Dominance gene effects were very important for expression of yield per plant and days to flowering, and less important for fruits per plant, mean fruit weight, and fruit width. Overdominance was observed for days to flowering.

Chaim and Paran (2000) studied the inheritance of ten quantitative traits related to plant and fruit development in an intraspecific cross between a bell-type (*Capsicum annuum* var. *annuum* (Grossum group) cv. Maor) and a small-fruited pungent chilli line (*C. annuum* var. *annuum* (Longum group) cv. Perennial). Most of the genetic variation associated with traits that affect the size of the fruit and its shape was found to be additive in nature.

Patel *et al.* (2006) advocated that green fruit yield of chilli is the outcome of the interplay of various yield contributing components and in general preponderance of inter and intra allelic interaction with marginal influence of additive gene effect was evidenced for green fruit yield and most of the component traits *viz.*, number of fruits per plant, average fruit length, average fruit girth and average fruit weight.

Sood and Kaul (2006a) reported both additive and non-additive genetic systems in 15 F₁s (developed through diallel mating design) of bell pepper and suggested to practice selection in later generations, when the non-additive effects have diminished.

### 3.3 ASSOCIATION OF BACTERIAL WILT RESISTANCE

The importance of biochemical study of defense reaction in the physiology of disease resistance is widely accepted. On infection many physiological changes take place in the
host leading to the resistant or susceptible reaction. It is a well established fact that certain biochemical constituents which are present in the resistant host earlier to infection or induced after the invasion of the pathogen act either as toxicants or inhibit growth, development and multiplication of pathogen. Changes in amino acids, sugars and phenols due to bacterial infections have been reported by many workers (Chand, 1968; Chand and Walker, 1968)

Bhullar et al. (1972) studied the role of phenols in resistance to anthracnose (*Capsicum capsici*) and reported that resistant varieties had a higher amount of phenols than susceptible varieties. Narain and Mohapatra (1973) reported that the degree of resistance to *Colletotrichum capsici* on leaves were positively associated with phenol content of leaves.

Thind et al. (1981) observed increased total phenols in resistant chilli genotypes and decreased in susceptible genotypes on infection with *Xanthomonas vesicatoria*. Tyagi and Chauhan (1982) found higher sugar content in the leaves of susceptible varieties than the resistant ones and the increased sugar content in susceptible varieties stimulated the spore germination of *Alternaria solani*. The involvement of phenolic compounds and related enzymes in disease resistance mechanisms have been reported to occur in many other field crops also (Manibhushanrao et al., 1988). Singh and Singh (1989) opined that increase in phenol content in resistant varieties was associated with increased activity of enzymes leading to the formation of quinones and other oxidation products and resulted in the reduction of multiplication of pathogens.

Azad (1991) reported maximum percentage of reducing (1.3 %), non-reducing (0.8 %) and total (2.1 %) sugars in susceptible varieties, while minimum percentage of reducing (0.95 %), non-reducing (0.64 %) and total (1.6 %) sugars in resistant varieties
of chilli fruits during infection with *Colletotrichum capsici*. Saraswathi and Shivashankar (1998) reported positive, but non-significant correlation between phenol content and bacterial wilt resistance.

Nawalagatti *et al.* (1999) also observed higher total chlorophyll, phenols and lower sugars in resistant over the susceptible genotypes of chilli studied for their reaction to murda complex. Hegde and Anahosur (2001), while screening chilli genotypes against fruit rot under natural conditions, observed that resistant genotypes exhibited higher capsaicin, ascorbic acid and lower total sugars than susceptible ones.

Gopalakrishnan *et al.* (2002) in inheritance studies involving the F₁, F₂, BC₁, and BC₂ generations of a cross between the resistant variety Soorya and the susceptible variety Pusa Kranti of brinjal revealed that roots of resistant variety Soorya had high contents of total phenol (0.36%) and ortho dihydroxy phenol (0.02%), which could prevent the entry and further multiplication of bacteria in the resistant variety. In contrast, the content of total phenol and ortho dihydroxy phenol in the roots of susceptible variety, Pusa Kranti was 0.22 % and 0.001%, respectively.

Kumar *et al.* (2002) studied biochemical assay of resistance to bacterial wilt in tomato involving total phenols, ortho dihydroxy phenols and ascorbic acid using six bacterial wilt resistant genotypes (*viz.*, Sakthi, Mukthi, LE 382-1, LE 214, LE 415 and LE 421) and one susceptible genotype, Pusa Ruby. The total phenol, ortho dihydroxy phenol and ascorbic acid in the bacterial wilt-resistant genotypes were higher than susceptible cultivar Pusa Ruby in roots, shoots and whole plant at various growth stages. The presence of phenols and ascorbic acid at higher concentration in roots and stem at early stages in the field establishment was significant in checking the multiplication of *Ralstonia solanacearum* thereby imparting host resistance.
Sheela and Mathew (2002) reported changes in activities of the enzymes polyphenol oxidase (PPO) and peroxidase in resistant (LE 79-5) and susceptible (Pusa Ruby) genotypes of tomato after infection by *R. solanacearum*. The PPO activity was initially higher in the roots of resistant cultivar LE 79-5, but after infection more activity was noticed in Pusa Ruby. A decrease in PPO activity was noticed in LE 79-5 and an increase in Pusa Ruby after infection by *R. solanacearum*. In stems, the PPO activity increased in both genotypes after infection. Peroxidase activity also increased following infection in both root and stem of LE 79-5 and Pusa Ruby.

### 2.4 Heterosis

The discovery of heterosis has been recognized as one of the major landmarks in the annals of plant breeding and its utilization in breeding hybrid varieties of both cross-pollinated and self-pollinated crops has amply demonstrated its usefulness. The term heterosis signifies the increased or decreased vigour of the hybrids (obtained by crossing two genetically dissimilar individuals) over the better parent (heterobeltiosis) or over the standard check (standard, economic heterosis) or over average performance of parents (relative/ average heterosis).

In *Capsicum annuum* L., the early findings on heterosis as measured by F$_1$ values exceeding the mean of parents for characters, such as early maturity, plant height, fruit size and productivity both in terms of fruit and total weight have been reported by many workers (Deshpande, 1933; Pal, 1945; Martin, 1949; Angeli, 1957; Marinkov, 1960; Carlson, 1962 and Popova, 1962).

Betlach (1967) reported heterosis for increased number of fruits per plant and yield per plant, but he couldn’t find heterosis for average fruit weight. He also reported
no marked differences between parents and F₁ progeny for ascorbic acid, dry matter and total sugar content. Marfutina (1970) observed 8.30-8.95 per cent higher dry matter and 33-48 per cent higher total sugars in F₁s than the standard check. Joshi (1986) reported superiority of Bullnose x HC20 (146.79%), HC209 x Ruby King (22.90%) and Yolo Wonder x Bullnose (23.20%) in total yield over the best variety, HC201. He further stated that heterosis for yield resulted from combined heterosis for plant height, number of primary branches, fruit size, average fruit weight, early yield and number of fruits per plant.

Thakur (1987), while studying eight parent diallel cross in capsicum, suggested utilization of heterosis to improve yield. Eleven crosses out of 28 exceeded the mid parental value and also the better parent in yield, but only six out yielded the best parent, Russian Yellow.

Kaul and Sharma (1988) in a line (12) x tester (2) analysis recorded 34.0, 33.1 and 25.0 per cent heterosis in Sweet Banana x California Wonder, Osh Region x California Wonder and HC201 x California Wonder, respectively, over the better parent for fruit yield per plant.

Echeverri et al. (1998) evaluated hybrids between ten sweet pepper cultivars and reported the highest relative heterosis and heterobeltiosis (155.87 and 138.69%) for fruit yield per plant where parent LPUNAL was involved.

Ahmed and Hurra (2000) derived information on heterosis from data on ten quantitative traits recorded in 11 parents (8 lines and 3 testers) and their 24 F₁ hybrids grown at Srinagar during 1997. They suggested that the hybrids KSPS-461 x Oskash, KSPS-461 x KSPS-2, KSPS-461 x California Wonder, KSPS-13 x California Wonder and HC-201 x KSPS-2 revealing the most significant desirable heterosis for yield and yield-
contributing characters can be successfully exploited under temperate growing conditions in India.

Chaim and Paran (2000) reported heterosis and transgressive segregation for days to first ripened fruit, plant height and pedicel length in an intraspecific cross between a bell-type and a small-fruited pungent chilli line.

Mamedov and Pyshnaja (2001) studied heterosis in 15 F₁ hybrids (derived from six parental) of sweet pepper for yield and yield components. The number of crosses that exhibited significant desirable heterosis over better parent were 15 for early yield, 15 for total yield, 7 for fruit weight, 12 for fruit number per plant, 9 for fruit length, 4 for fruit girth and 8 for pericarp thickness.

Pandey et al. (2002) evaluated heterosis for fruit yield per plant, fruit number per plant, and ascorbic acid content in sweet pepper. The highest average heterosis was recorded for fruit yield. Yolo Wonder x CW-51 exhibited the highest heterosis over the best parent (51.78%), significant positive heterosis for fruit number (98.45%) and ascorbic acid content (14.21%).

Gomide et al. (2003) also observed heterosis among experimental hybrids for total yield and mean fruit weight. Heterosis values relative to the standard cultivar Magali-R-F1 ranged from 7.50 to 49.89 per cent for early yield; 0.45 to 28.55 per cent for total yield; and 3.07 to 47.37 per cent for mean fruit weight.

Sood and Kaul (2006b) also reported heterosis for earliness, average fruit weight, number of fruits per plant and yield in intraspecific crosses of bell pepper and attributed the appearance of heterosis for fruit yield to increased number of fruits, fruit weight, harvest duration and the combined heterosis of other contributing traits.