SCREENING OF CHILLI (*Capsicum annuum* L.) GENOTYPES FOR RESISTANCE TO BACTERIAL WILT AND MOSAIC

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **'Screening of chilli (*Capsicum annuum* L.) genotypes for resistance to bacterial wilt and mosaic'** 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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Dedicated to my beloved

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Introduction

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop grown throughout the country. The native home of chillies is considered to be tropical America. In India its introduction is believed to be through the Portuguese in the seventeenth century. At present chillies are indispensable and a common ingredient of Indian dietary. The fruits are known to impart pungency, colour, flavour and taste to food materials. The pungency is due to the crystalline volatile alkaloid called "Capsaicin" contained in the skin and the septa of the fruit. Nutritionally this is on par with tomato. It is a good source of vitamin A and C (282 IU and 58 to 225 mg per 100 g of fresh fruits respectively). Apart from a food adjunct it is used in pharmaceutical and cosmetic preparations. Besides its indigenous uses, chilli has very great export potential.

Estimated annual import of chilli in the world is one lakh tonnes, which is 22.22 per cent of total spice import in the world. As a leading producer, India has the production figure of 9.45 lakh tonnes from an area of 9.565 lakh hectares, and it is expected to reach 15 lakh tonnes by 2000 AD. India exports only 2.75 per cent to 7.50 per cent of its total production. Though chilli is grown throughout India, Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu account for about 75 per cent of total area and annual production in India.

Despite, favourable climatic conditions the cultivation of chilli in Kerala is threatened by many diseases and pests; the most damaging being bacterial wilt caused by *Ralstonia solanacearum* (Smith)Yubuuchi *et al.* The warm humid tropical climate and acidic soil conditions in Kerala are most congenial for the incidence of bacterial wilt. Crop losses up to 100 per cent occur due to this disease. None of the high yielding varieties are resistant to the disease. Chemical control measures have not been successful in controlling this disease. Breeding for resistance is the most effective means of controlling bacterial wilt in chilli. The research conducted in this direction in the Kerala Agricultural University has resulted in the identification of two chilli varieties, viz. Manjari and Ujwala 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.

Mosaic is yet another serious disease affecting chilli and is a constraint in chilli cultivation in Kerala. The seriousness of mosaic infection stems from the fact that there is no cure for the diseased plant, once it has become infected, and the infection can result in loss of all saleable produce from that plant. The mosaic viruses affecting the chilli are efficiently transmitted in nature by insects which, are often difficult to control. Further complication is added by the capability for significant pathogenic variation between strains of a given mosaic virus. So chilli cultivation is economical only when the lines are resistant to both mosaic and bacterial wilt.

At this juncture the present investigation is a holistic approach to enhance the productivity of chilli by developing wilt and mosaic resistant lines and hybrids.

The specific objectives of the present study are:

1. To identify chilli genotypes (long / medium long) with resistance to bacterial wilt.
2. To identify chilli genotypes possessing resistance to mosaic.
3. To incorporate mosaic resistance to bacterial wilt resistant chilli genotypes.

Review of Literature

REVIEW OF LITERATURE

Available literature relevant to the present investigations are reviewed and presented under the following heads.

2.1 Bacterial wilt

2.1.1 Bacterial wilt disease of chilli

Bacterial wilt caused by *Ralstonia solanacearum* (Smith) Yubuuchi *et al.* is one of the most destructive plant diseases in the warm humid regions of the world. The pathogen is known to attack a wide range of host plants. It attacks more than 200 plant species belonging to 33 families. Of these, family solanaceae has the largest number of hosts (Kelman, 1953). This disease limits the cultivation of chilli crop in the acidic soils of Kerala.

The disease was first reported from Italy in 1882 (Walkar, 1952). Smith (1896) described the disease, causal organism, and reported the occurrence of the disease in solanaceous crops. The disease is prevalent in the warmer parts of USA, Philippines, Indonesia, Srilanka and India causing considerable damage. In India,it assumes serious proportion in the West coast, Central and Deccan plateau of Karnataka, Kerala, Western Maharashtra, Madhya Pradesh, Orissa, Eastern plains of Assam, West Bengal and Bihar on tomato, potato, brinjal and chillies. (Rao, 1972; CPRI, 1974 and Shekhawat *et al.*, 1978).

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

2.1.1.1 Races of *Pseudomonas solanacearum*

P. solanacearum E.F.Smith is a complex species consisting of several races differing in many characters. Buddenhagen *et.al.* (1962) classified *P. solanacearum* isolates into three races on the basis of host range, pathogenicity and colony formation on TTC medium. Race I affects tomato, tobacco and other solanaceous crops. Race 2 infects triploid bananas. Race 3 is pathogenic to potato and few alternate hosts in tropics and subtropics. Hayward (1964) classified *P. solanacearum* into biotypes or biochemical types based on their ability to oxidise various carbon sources and on other bacteriological reactions and called them as biotype-I, biotype-II, biotype-III and biotype-IV.

Later, two new races were proposed; one from ornamental ginger in Philippines as race 4 (Aragaki and Quinon, 1965) and another from mulberry in China as race 5 (He *et al.*, 1983). In Kerala, Devi (1978) compared twenty six different isolates of *P. solanacearum* from chilli, brinjal and tomato and grouped them into 12 pathogroups. They come under race 1 and biotype III.

Cook and Sequeira (1988) used Restricted Fragment Length Polymorphism (RFLP) technique to study the relationship between biotypes I to IV of Hayward and races 1, 2 and 3 of Buddenhagen *et al.* (1962). The conclusion was that *P. solanacearum* could be divided into two distinct groups; Group I which includes strains of race 1. biotype-III and IV and Group II which includes strains of race 1, biotype-I and races 2 and 3. In addition they were able to distinguish strains of pathogen both by race and biotype. Race 3 strains produced a very distinct gel pattern which suggested that race 3 is a homogeneous group. Similarly, race 2 strains fell into

three distinct groups. These three groups represented strains from different geographical origin. In contrast, race 1 strains exhibited highly variable RFLP pattern suggesting that race 1 is highly heterogeneous.

In Himachal Pradesh Kumar *et al.* (1993) differentiated twelve isolates of *P. solanacearum* from tomato, potato, aubergine and bell pepper (*Capsicum*) into different biotypes I to IV of Hayward's classification. In this an isolate from chilli (*Capsicum*) that differed from others was tentatively identified as biotype-V.

2.1.1.2 Ecology and symptomatology of the Pathogen

2.1.1.2.1 Ecology

The ecology of the pathogen in naturally infested soil is poorly understood. Under natural conditions the pathogen was able to survive saprophytically in the soil for as long as six years (Chester, 1950). Buddenhagen and Kelman, (1964) inferred that the primary inoculum came from the soil but there was no conclusive evidence that the pathogen is an ubiquitous inhabitant in the soil.

Granda and Sequeria (1983) reported that long term survival of the pathogen was associated with localized or systematic infection of plants that did not express symptoms of bacterial wilt. Sequeria (1993) suggested that the bacterium appears to survive by continuously infecting the roots of susceptible or carrier plants or by colonising the rhizosphere of non host plants.

2.1.1.2.2 Symptomatology

The symptoms associated with bacterial wilt are very specific and distinct. The first and typical expression of disease is sudden wilting of lower leaves of the plants (Walker, 1952). The wilting is usually accompanied with yellowing of older leaves. Dwarfing and stunting of plants may also occur. The roots and the lower parts of the stem show a browning of vascular bundles and water soaked appearance in the roots. (Chupp and Sherf, 1960). A very distinct and characteristic indication of bacterial wilt is the appearance of bacterial ooze from the injured vascular regions. (Ashrafuzzaman and Islam, 1975).

2.1.1.3 Control of the pathogen

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.

Crop rotation is of little use. However, Sohi *et al.* (1981) reported that rotation with *Vigna sp.* followed by maize and cabbage or okra followed by *Vigna sp.* and maize gave effective control of *Pseudomonas solanacearum* in tomato.

2.1.2 Sources of Resistance

On an evalution of chilli cultivars Suryamukhi, Cluster, Jwala, G-4, and G-5 for yield and tolerance to bacterial wilt and fungal diseases, Rathaiah (1983), found Suryamukhi as tolerant to all the diseases with the highest mean yield of 61.08 q/ha followed by Cluster.

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 of *P. solanacearum*.Peter *et al.* (1984) studied the performance of four hot peppers, viz., Pant C-1, KAU Cluster and White Kandhari and Chuna along with six US cultivars for their reaction to nine isolates of *Pseudomonas solanacearum* (race 1 and 3). No pepper line tested was resistant to all the 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. The line Cholo was found most resistant with a disease incidence of 10 per cent after 60 days and 17245 fairly resistant with disease incidence of 46 per cent after 60 days. Total yield was also significantly higher in Cholo and 17245.

In a study conducted by Matos *et al.* (1990) six chilli genotypes were resistant and 41 lines were susceptible to bacterial wilt. Gopalakrishnan and Peter (1991) screened the accessions belonging to *Capsicum annuum*, *Capsicum frutescens* and *Capsicum chinense* for resistance to bacterial wilt in a wilt sick soil after artificial inoculation. Out of 146 accessions, two cluster fruited types belonging to *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 dry chilli yields of 31.2 and 42.0 g per plant and 61 and 13 g per plant respectively. Cluster fruited plants gave significantly better wilt resistance than solitary fruited types.

Jyothi *et al.* (1993) evaluated 29 chilli accessions in a wilt sick field during the rainy season. Cultivar Manjari was found resistant with the disease incidence of 20 per cent and two accessions were moderately resistant with the disease incidence of 20 to 40 per cent.

Among the 108 accessions of pepper screened for resistance at AVRDC, Taiwan (1993), MC-4, Cili Lang Kap Asnd PL 38475 had high level of tolerance to bacterial wilt. Out of seventy four sweet pepper and seven hot pepper genotypes tested for resistance, fourteen accessions showed resistance to bacteria and twelve were 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. (Matsunaga *et al.*, 1993).

Grimault and Prior (1994) inoculated the aubergine, capsicum and tomato cultivars with an aggressive strain of bacterium. Results suggested that tomato and aubergines have similar mechanisms of resistance to *P. solanacearum* and that capsicum was more tolerant towards high bacterial populations than aubergine and tomato.

Quezado and Lopes (1995) evaluated *Capsicum annuum* variety MC – 4 under greenhouse conditions for resistance to 20 Brazilian strains of *P. solanacearum.* Results showed that MC-4 was resistant to all the strains tested and Magda was susceptible to most strains.

To identify the accessions of related species of *Capsicum annuum* with resistance to bacterial wilt, Matsunaga and Monma (1995) examined a total of 84 accessions consisting of 23 *C. chinense*, 14 *C. frutescens*, 25 *C. baccatum* and two *C. pubescens*. Seven accessions viz. Rancho 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.

Gopalakrishnan (1996) reported that, the erect, cluster bearing cultivar Ujwala was resistant to bacterial wilt. There are 9 to 10 fruits per cluster, each fruit weighs 2.5 g, and is 6.2 cm long on an average. Fruits are highly pungent, with an oleoresin content of 24 % and a capsaicin content of 0.49%.

Jawfen and Berke (1997) evaluated 17 *Capsicum* accessions in a naturally infested field, and reported that PBC 066, PBC 204, PBC 1347 were resistant and suggested that the apparent resistance shown by these lines was actually tolerance, since though the pathogen was present, did not cause symptoms.

2.1.3 Factors affecting resistance

Resistance and susceptibility of the host to the pathogen is governed by defined metabolic, environmental and genetic factors.

Kuc (1964) stated that disease resistance is not an absolute or static condition and depends on many factors. Expression of the biochemical potential, determined by the genetic component of the organism is influenced by a multitude of factors including nutrition, growth regulators, temperature, moisture, daylength, stage of development and nature of tissue.

Low light intensity generally decreases resistance. It may also increase the resistance depending on the specific host pathogen combination. Long photoperiods generally result in higher levels of resistance (Bell 1981). He also observed that increasing the concentration of potassium and calcium increases most often the resistance while excess nitrogen decreases resistance. The phosphorus has variable effects.

At pH 3.5, a high wilt incidence was reported by Kelman and Cowling (1965). Shekhawat *et al.* (1978) reported that the bacterial wilt was more wide spread in heavy and acidic soils (pH 3.5 to 6.0) than in light and neutral (pH 6.5 to 7.9) to alkaline (pH 7.5 to 8.5) soils.

Bell (1981) reported that each plant part changes 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.

Insects and nematodes also play a role in the spread of the disease. Goth *et al.* (1983) observed that bacterial wilt resistance was broken down when root knot nematode larvae were added at the rate of 100 / 10 cm with bacterial isolates.

Schell *et al.* (1988) have cloned and characterised the gene P_{ch} A that is involved in the synthesis of polygalacturonase which is responsible for the break down 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 this induction involves mostly two additional PGS, P_{ch} B and P_{ch} C.

2.1.4 Mode of inheritance of resistance

Information on mode of inheritance and gene action of resistance of wilt would be useful in the choice of appropriate breeding programme. Monogenic recessive, monogenic dominant and polygenic inheritance of resistance to bacterial wilt has been reported earlier by different workers as detailed in Table 1.

Studies conducted in the Kerala Agricultural University, Vellanikkara revealed that resistant F_1s could be developed in chillies and brinjal by crossing resistant parents only, which indicates the recessive mode of inheritance of bacterial wilt resistance (KAU, 1989). Varghese (1991) studied the nature of inheritance of the resistance to bacterial wilt in brinjal and reported that it is inherited in a recessive and monogenic manner.

Geetha and Peter (1993) reported that the F_1s in which only the resistant parents were involved were resistant and the hybrid, in which a susceptible genotype was one of the parents, was either susceptible or moderately resistant showing the recessive mode of inheritance of bacterial wilt resistance in brinjal.

Table. 1 Reaction of solanaceous crops / varieties / F_1 hybrids / species to bacterial wilt

Name of crop / varieties / F_1 hybrids / species	Gene action	Reported by
I. Brinjal		
1. *Solanum melongena*	Polygenic	Kelman (1953)
2. *S. melongena* var. Insanum	Monogenic dominant	Swaminathan and Sreenivasan (1971)
3. *S. melongena*	Monogenic dominant	Vijayagopal and Sethumadhavan (1974)
4. *S. melongena*	Polygenic	Kuriyama (1975)
5. *S. melongena*	Monogenic dominant	Gopimony (1983)
6. *S. melongena*	Monogenic dominant	Narayanan (1984)
7. WCGR-112-8 x Pusa Kranti	Monogenic dominant	Gopinath and Madalageri (1986)
II Chilli		
1. *C. annuum*	Recessive	Dutta and Kishun (1982)
2. *C. annuum*	Recessive	Manjunath and Dutta (1987)
III Tomato		
1. *Lycopersicon pimpinellifolium* PI-127805 A	Recessive	Abeygunawardena and Sriwardena (1963)
2. *L. esculentum* PI-126408	Additive	Ferrer (1976)
3. CRA 66 Sel A	Multiple recessive	Tikoo *et al.*, (1983)
4. *L. esculentum*	Complimentary and hypostatic	Sreelathakumari (1983)
5. *L. esculentum*	Epistasis	Bosch *et al.*, (1985)
7. LE 79	Monogenic and incomplete dominant	Rajan and Peter (1986)
8. CRA 66 Sel A	Polygenic control	Nirmaladevi (1987)
8. D-9	Partially recessive	Monma and Sakata (1993)
9. *L. esculentum*	Recessive	Kumar (1995)

2.2 Chilli mosaic

2.2.1 Mosaic disease of chilli

The first report on mosaic diseases of pepper in India was by Mcrae (1924) and Kulkarni (1924) from the erstwhile Bombay province. Later, several viruses causing mosaic on bell pepper and chilli have been reported by a number of scientists from time to time.

Out of the eighteen viruses reported to occur naturally on pepper throughout the world, only ten have been reported from India, viz. tobacco leaf curl virus (Vasudeva, 1954). Indian chilli mosaic virus (Jha and Raychaudhuri, 1956). Potato virus X (Ramakrishnan, 1959) tobacco mosaic virus (Kandaswamy *et al.*, 1963) Cucumber mosaic virus (Anjaneyulu and Apparao, 1967), potato virus Y (Jeyarajan and Ramakrishnan,1969) tobacco ring spot virus, pepper veinal mottle virus, pepper vein banding virus (Rao, 1976) and tobacco etch virus (Bidari, 1982).

Viruses cause a lot of physiological imbalances and growth abnormalities in pepper ultimately leading to a drastic reduction in the yield of marketable fruits. According to Jeyarajan and Ramakrishnan (1971), PVY lowered chlorophyll a, chlorophyll b and total chlorophyll contents of pepper leaves. Potassium, calcium, magnesium and moisture contents were also low in the infected leaves.

Aillaud (1971) reported that *Capsicum annuum* plants inoculated with CMV developed abnormal flowers in addition to the characteristic symptoms. Sciumbato (1973) observed an yield reduction of 97 per cent in bell pepper and 61 per cent in chilli due to CMV inoculation.

Joshi and Dubey (1976) noticed more number of stomata per unit area, in CMV infected pepper plants as compared to healthy ones, thus allowing more moisture to pass out in the diseased plants. They further reported that the growth of *Capsicum* plants were affected adversely by a mild and a severe strain of CMV, particularly by the latter. Less moisture content and more dry matter content were found in diseased plants as compared to healthy ones.

Rao (1976) reported that when *Capsicum* plants were inoculated with PVY at varying intervals of 15 to 90 days after sowing, the maximum adverse effect was noticed in the youngest plants which became severely stunted and produced no yield. There was no noticeable effect on the growth of the plants which were inoculated when 90 days old.

Lalman and Tewari (1977) studied the effect of CMV on productivity of *C. annuum* and found that gross production rate and severity of infection were inversely proportional. The gross production rate in infected plants were reduced by both mild and severe strains.

Tobias *et al.* (1978) reported reduction in growth, yield and fruit size of pepper varieties due to seven viruses including CMV, the extent of reduction varying with varieties. According to Cordrey and Bergman (1979), CMV, infected plants of Yolo Wonder showed reduced contents of P, K, Mg, Fe, and Cu in the basal leaves. Chauhan *et al.* (1981) reported variable degrees of pollen sterility in pepper plants due to CMV infection.

The yield reduction ranged between 26.50 per cent to 56.00 per cent due to PVY inoculation among five varieties of bell pepper (Villalon, 1981). Tanzi *et al.* (1986) reported that when susceptible and resistant cultivars of *Capsicum annuum* were inoculated with TMV-pep, both showed reductions in flowering, fruiting and early yield compared with uninoculated control. The reductions being significantly greater in supposedly resistant variety.

Mosaic disease of *Capsicum* was widespread in commercially cultivated fields in Karantaka, with disease incidence ranging from 11.8 to 94.8 % with an average of 53%. Average disease incidence was lower in rainfed crops (50.1%) than irrigated crops (58.3%) (Bidari and Reddy, 1991).

George *et al.* (1993) noticed that potato Y poty virus and cucumber mosaic cucumovirus were the most important viruses affecting *Capsicum annuum* in and around Bangalore region.

Bidari and Reddy (1994) observed that among several groups of mosaic viruses distributed in chilli growing areas of Karnataka, pepper vein banding virus (PVBV, 19.1%) was most prevalent followed by cucumber mosaic cucumovirus (CMV, 13.2%)

The effect of chilli mosaic virus on yield of chilli plants with respect to plant age was determined by Singh *et al.* (1996). The results showed reduction in number, weight and length of chilli fruits and weight of seeds. The percentage loss in yield was higher in early inoculated plants than in late inoculated.

2.2.2 Source of resistance

Preliminary investigations related to the virus resistance of pepper can supposedly be traced back to the resistance of *Capsicum frutescens* cv. Tabasco and *C. annuum* cv. Midninum Blanco to TMV (Holmes, 1937). Thereafter a good number of sources of resistance to different viruses have been located by various scientists.

As early as 1959 Cook and Anderson reported a line of *C. annuum* P11 showing resistance to PVY, TEV and TMV. In a varietal screening trial Cook (1962) found two accessions of *C. annuum* viz. PI 264281 and SC 46252 resistant to PVY. After conducting mechanical and insect inoculation tests of varieties of *C. annuum* and *C. frutescens* with 22 isolates of PVY Horvath (1967) found one cultivar Markgarther as immune to PVY. Nagai (1968) tested 45 varieties of bell pepper and 46 varieties of chilli for resistance to three strains of PVY and found chilli accessions P 11, SA 112, I 30771 and I 30772 as immune to all the 3 strains. According to the studies conducted by Jeyarajan and Ramakrishnan (1969), out of 22 varieties of chilli tested X 91 – 6 – 5, A-158. Warangal, S-32, Pandurana, CA – 733 – 1 – 1 – 1 – 1, A – 123, Gollaprodu, CA – 766 – 1 – 3, A– 125, A – 126, CA – 452 – 1, A – 160, Rosagulla and C – 60 A did not develop symptoms on PVY infection.

Singh (1973) screened 105 varieties and five species of chilli against chilli mosaic under field conditions and found the varieties, Puri Red, Puri Orange, C – 2, Kondiverum and Suryamukhi as resistant.

In a screening trial involving 68 lines of five species of *Capsicum*, Saccardo (1974) observed that eight lines of *C. annuum*, ten lines of *C. frutescens*, one line each

of *C. microcarpum*, *C. pendulum* and *C. chinense* were resisitant to CMV. Lovisolo and Cont (1976) reported resistance to CMV in Capsicum varieties Piment, Sucette and Antibios.

Cook (1977) reported a multiple virus resistant variety VR-2 with resistance to PVY, TEV and TMV developed at the University of Florida. Another multiple virus resistant variety Delray Bell displaying resistance to PVY, TEV and tolerance to pepper mottle virus was described by Cook *et al.* (1977).

According to Pochard (1977a) no complete resistance to CMV has been discovered in peppers. He believed that a higher, more durable resistance will require a combination, in a single genotype, of three kinds of resistance which he designated as Ra (ability to escape infection if the inoculum dose is low), Rb (hypersensitive resistance which localizes the virus through necrosis of the invaded tissue) and Rc (non-necrotic resistance expressed in a slow rate of virus multiplication). However, various workers had located sources of different levels of resistance to the isolates of CMV.

Tewari and Anand (1977) reported a mosaic resistant variety, Jwala developed as a hybrid derivative of cross between NP-46-A and Puri Red. Some perennial chilli types with small pungent fruits in Tarai region of Uttar Pradesh were found to be immune to viruses. Selections from crosses between a perennial local type and variety NP-46-A had been released under the names Pant C-1 and Pant C-2 which were resistant to viruses (Mathai *et al.*, 1977).

Konai and Nariani (1980) evaluated 33 lines of five species of *Capsicum* against cmv, pvx, tmv and TLCV. The variety Pant C-1 and Pant C-2 were tolerant to all the viruses, while *C. frutescens* accession EC 31352 was tolerant to cmv and pvx. In a screening trial involving 48 lines of pepper Rao *et al.* (1980) found two lines DH-16 A, and DH-30-4 as resistant to tmv and cmv.

Marchoux *et al.* (1983) developed a line Philomere 1 with high level of resistance to cmv using *C. baccatum* as the source of reistance. Nagai (1984) observed the resistance to TMV and CMV in *C. annuum* cv P1.

Miladinovic *et al.* (1985) obtained several sublines from progenies of (*C. annuum* x *C. chinense*) x *C. pendulum* of which subline 12 displayed high level of reistance to CMV.

According to Sharma and Singh (1985) the chilli genotypes Pant C-1, S118-2, Lorai, Loungi and Perennial were resistant or tolerant to TMV and CMV. Singh and Kaur (1986) reported a multiple virus resistant red pepper variety Punjab Lal, developed using Perennial as one of the parents which had genetic resistance to CMV, TMV, and TLCV.

The virology research programme at the Texas Agricultural Experiment Station at Waslco resulted in the release of multiple virus resistant pepper cultivars viz. Tambel 1, Tambel 2, Tam mild chile 1, Tam mild chile 2, Tam mild Jalapeno1, and Hidalgo which had genetic resistance to PVY, TEV, PMV and TMV (Villalon, 1986).

In a screening trial involving F3 progenies of PI 280419, Nicklow and Comas-Haezebrouck (1987) observed that seven lines were resistant to Massachusettus strain of virus but they were susceptible to California strain.

Sangar *et al.* (1988) tested ten varieties of *Capsicum annuum* under natural field conditions and found that the varieties JCA 248, JCA 218, Pant C-1, NP 46 A, Pusa Jwala and JCA 196 were resistant to leaf curl virus. JCA 31 A, Selection 3, JCA 154 and Pandurana exhibited different degrees of susceptibility. All varieties showed some symptoms of TMV. The varieties JCA 248, JCA 218 and PantC-1 were the least affected.

Miladinovic *et al.* (1989) developed several sub lines using *C. frutescens* variety Tobasco and a *Capsicum* species from Columbia of which sub lines MV 4/ 88, MV 6/ 88, and MV 9 / 88 were found resistant to CMV and TMV. Bral *et al.* (1989) evaluated 33 lines under field conditions and found that six lines exhibited resistance to mosaic.

After screening 120 genotypes belonging to eight species of *Capsicum* for resistance to potato virus Y and cucumber mosaic virus, George (1989) reported that five *Capsicum annuum* accessions viz. IHR-243, IHR-328-9, IHR-384, IHR-1049 and

Pant C-1, and one *C. chinense* accession IHR-1252 showed resistance to both potato virus Y and cucumber mosaic virus, two *C. annuum* accessions IHR-993, and IHR-994, one *C. frutescens* accession IHR-1243 and one *C. pubescens* accession exhibited resistance to potato virus Y alone and one *C.pubescens* accession IHR-1267 displayed resistance to cucumber mosaic virus alone.

AVRDC (1990) screened about 291 *Capsicum annuum* lines for resistance to CMV, Pepper Veinal Mottle Poty Virus, (pvmv) Chilli Veinal Mottle Virus (cvmv) and reported that VC 16, HNA 832 and Szechuan were resistant to PVMV. VC, 35, 37, 40 and 41 to CVMV, and Kunja Koa Ryong San to CMV. Among the 82 lines tested, Punjab Lal, Perennial, Gauhathi Black were resistant to mosaic (Chowfla and Sharma, 1990) Out of a total of 48 varieties of *Capsicum* screened by Singh *et al.* (1990) for resistance to mosaic, only four lines were resistant.

Tewari (1991) reported that *Capsicum frutescens* cv. Pusa Sadabahar was tolerant to cucumber mosaic cucumo virus, tobacco mosaic tobamo virus and tobacco leaf curl geminivirus.

According to Bansal *et al.* (1992) out of the 25 genotypes tested Perennial, Punjab Lal, Indonesian Selection and MS 13 were free from CMV. The lines CA 586, ELS 1, ELS 2, Jawahar 218, JCS 1, KCI 159, Laichi 4-4, MF 41-1-2, Pant C-1, Surajmani, TC 2 and 851201 were moderately resistant. Hameed *et al.* (1993) noticed resistance to TMV in three lines viz., Anaheim, TMR – 23, Schi – 3 out of the eight lines tested under both glass house and field conditions. Hundal *et al.* (1995) reported that the variety Punjab Surkh was tolerant to mosaic virus, resistant to leaf curl virus and moderately resistant to die back disease.

Forty six accessions of chilli were evaluated for resistance to cucumber mosaic cucumovirus (CMV) and Potato Y Poty Virus (PVY) by Dhawan *et al.* (1996) and found that eight genotypes viz., HC 1, HC 15, HC 22, HC 28, HC 69, HC 226, Pusa Sadabahar and Virus Free - 1 were highly resistant. Arora *et al.* (1996) evaluated two varieties named Hissar Vijay and Hissar Shakthi and reported that both the varieties were resistant to mosaic virus and leaf curl virus and gave a high early and total yield. The studies conducted by Ariyaratne *et al.* (1996) revealed that the genotypes

Agronomico 10C-5. Delray Bell, VR 4, Jaioro and PI 152225 were resistant to many TEV isolates tested.

Lane *et al.* (1997) reported that *C. annuum* variety Dempsey, originated from a three way cross between PI 163192, PI 64281 and Jupiter was found resistant to strains of potato Y potyvirus and pepper mottle potyvirus. These plant introductions contributed genes for resistance to tobacco etch potyvirus. Piccirillo *et al.*, (1997) studied the response of *C. baccatum*, *C. chinense*, *C. chacoense*, *C. frutescens*, *C. praetermissum*, and a series of lines and hybrids of *C. annuum* to cucumber mosaic virus, tobacco mosaic virus, and found that all the genotypes tested were susceptible.

2.2.3 Genetics and inheritance of resistance

Cook (1960) demonstrated monogenic recessive resistance in *C. annuum* PI 264281 (P 11) and SC 46252 (P34) to N^{YR} strain of PVY. The genes in P11 and P34 were allelic and apparently identical with et^a, a gene which conferred resistance to TEV. He later discovered a single PVY – N immune plant in Yolo Wonder which was the progenitor of Yolo Y. This plant possessed a single recessive gene which he designated as Y^a. This gene proved to be allelic with et^a (Cook, 1961). In another study he found that the resistance to the strains N and N^{YR} was monogenically controlled and in each case the respective dominant alleles conferred susceptibility and the homozygous recessive conferred resistance (Cook, 1963).

According to Barrior *et al.* (1971), the resistance to CMV in pepper cultivar LP-I was conditioned by a single recessive gene. Zitter and Cook (1973) reported that a single recessive gene control the resistance to PVY and TEV and tolerance to PMV in cv. Avelar. This allele designated as et^{av} had a higher potency than et^a which protected only against PVY – N^{YR} and TEV – C.

The results of a series of experiments conducted by Pahlen (1975) pointed towards a polygenic inheritance of PVY in pepper. The genes had an additive effect, as demonstrated by the high level of resistance obtained from crosses of partially resistant varieties. Pochard (1977b) in a detailed study recognised difference in inheritance patterns of genotypes to different pathotypes of PVY. The resistance to the pathotype C in varieties Alger's Sweet, Avelar, Ikeda, Jalapeno were recessive. Singh and Takur

(1977) also reported that resistance to CMV is governed by a single recessive gene for which they proposed a symbol 'cm'.

Studies by Pochard (1977b) revealed that the resistance to CMV was polygenically inherited. In another experiment, he pointed out the existence of a major dominant gene controlling resistance to CMV for which he assigned the symbol 'Riv'. (Pochard, 1982).

Investigations by Singh and Chenulu (1985) revealed that resistance to PVY in *C. angulosum* accession EC 97758 and *C. microcarpum* was monogenic recessive and controlled by a single pair of identical recessive genes. The moderate resistance to PVY in *C. annuum* CV NP 36, *C. frutescens* accession 76-208 and *C. pubescens* was also monogenically recessive but was inherited independently of the genes responsible for resistance or susceptibility.

Kostova and Todorov (1986) reported that the resistance in *C. chinense* from PI 315008 was controlled by a gene not allelic to L3, Betti *et al.* (1986) reported that the L3 resistance gene is not completely dominant. Shifriss and Cohen (1986) suggested that, many genes for small fruits are linked with the resistance to CMV.

Contrary to the previous view that the genes conferring resistance to cucumber mosaic virus (CMV) in *Capsicum annuum* are linked to those governing fruit size. Shifriss and Cohen (1987) reported that fruit weight and size were probably controlled by numerous genes not necessarily linked with other traits such as resistance to CMV.

Choi *et al.* (1988) reported that Long Red Cayenne appeared to possess a pair of recessive resistance genes. Gillorteg *et al.* (1988) noticed that the resistance in Perennial was under polygenic control.

George (1989) reported that resistance to potato virus Y in five *C. annuum* accessions was controlled by a single recessive gene.

The studies by George and Anand (1991) revealed that resistance to cucumber mosaic virus in four accessions of *C. annuum* was governed by a single dominant gene.

Bal *et al.* (1995) studied the genetic control of virus resistance against chilli mosaic using the progenies of Punjab Lal (multiple disease resistant) Ludhiana Local selection (susceptible) and Punjab Lal x Hungarian Sweet Yellow. Genetic analysis indicated that susceptibility to mosaic was dominant and resistance was controlled by monogenic recessive genes. They suggested conventional backcrossing for transferring resistant genes to commercial varieties.

Yanshuzhan *et al.* (1996) reported that, resistance in chilli showed incomplete dominance and was controlled by additive and dominant genes. He also suggested that multiple selection method could be used in bringing resistance to CMV, and highly resistant parents should be used to obtain the F1. Deom *et al.* (1997) reported that the resistance to Tobacco Etch Virus in *C. annuum* cv. Dempsey was conferred by the recessive gene et^a

2.2.4 Vectors, factors affecting resistance

Doolittle and Walker (1923) mechanically transmitted CMV from cucumber to chilli. Doolittle and Walker (1925) found that *Aphis gossypii* readily transmitted the virus to chilli in the field. In Bulgaria, Kovachevsky (1940) reported that the virus was transmitted in the field by the aphids *Myzus persicae* and *Aphis gossypii.* Simons (1955) found that the southern cucumber mosaic virus was transmitted in descending order of efficiency by the three vectors *Aphis gossypii*, *Myzus persicae* and *Aphis rumicis.* Transmission efficiency varied with the aphid species and the host plant species. Some virus strains were readily transmitted than others (Simons, 1955).

Dubey and Joshi (1974) found that a single aphid (*Aphis gossypii*) can transmit the virus but transmission was high with five aphids per plant. Maximum transmission occurred with a pre - acquisition fasting period of four hours, acquisition feeding of two minutes and inoculation feeding of 30 minutes. The insect lost its ability to transmit the virus within one hour of removal from diseased plants.

Conti *et al.* (1979) found that CMV was transmitted by seven of aphid species tested by them. Fegla *et al.* (1981) reported that the disease spread was positively correlated with the total number of flying aphids. Gahukur and Nariani (1982) found

that the isolates of CMV were transmitted in non persistent manner by *Aphis gossypii*, *Myzus persicae* and *A. craccivora*.

In Israel, Eastop (1985) reported that *Aphis citricola* and other *Aphis* spp. were responsible for more than 50 per cent of the total transmission of CMV. Peaks of CMV infection of bait plants coincided with peak population of these aphids caught in suction traps.

Luo *et al.* (1989) reported that among 2399 flying aphids trapped in pepper field, 23 transmitted cucmber mosaic cucumovirus to the test seedlings of pepper. *Myzus persicae*, *Lipaphis erysimi*, and *Rhopalosiphum padi* were the most efficient vectors of the virus in pepper fields. The peak period of virus transmission by alate aphids occurred from 20th May to 10th June.

Brown and Poulos (1990) noticed that, golden mosaic disease of chilli and tomato caused by previously uncharacterised geminivirus, designated as serrano golden mosaic virus was transmitted by *Bemisia tabacii*.

2.2.4.1 Studies on indicator plants

The reactions expressed by the various indicator plants when subjected to artificial inoculation with mosaic viruses are given in Table 2.

Table 2. The reaction of indicator plants to mosaic

Indicator plants	**Nature of infection**	**Reference**
Chenopodium amaranticolor	Necrotic local lesions	Gahukar and Nariani (1982)
C. murale	Necrotic local lesions	-do-
C. album	Necrotic local lesions	-do-
Nicotiana glutinosa	Chlorotic spots, systematic mosaic, leaf distortion and stunting	-do-
N. tabacum var. white Burley	Chlorotic ring spots, systemic mosaic	-do-

Materials and Methods

MATERIALS AND METHODS

The present investigation was undertaken in the vegetable research farm of the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara during the period from 1996 to 1998. The experimental plot is located at an altitude of 22.5 m above MSL, and between 10° 32′ N latitude and 76° 16′ E longitude. The area enjoys a typical warm humid tropical climate. The experimental site has a sandy loam soil with pH of 5.0. The soil is highly infested with *Ralstonia solanacearum* resulting in high rate of crop damage when solanaceous vegetables are grown.

The study consisted of the following experiments

1. Evaluation of chilli genotypes for resistance to bacterial wilt
2. Evaluation of chilli genotypes for mosaic resistance
3. Hybridization between selected genotypes

3.1 Evaluation of chilli genotypes for resistance to bacterial wilt

3.1.1 Experimental materials

Chilli germplasm maintained in the Department of Olericulture, College of Horticulture, Vellanikkara; collections made from other state agricultural universities and abroad formed the basic experimental material for cataloguing and screening under field conditions. The source of the chilli accessions are given in Table 3.

3.1.2. Experimental methods

Fifty three accessions were grown in a randomised block design with two replications in the bacterial wilt sick soil. Twenty-five days old seedlings were transplanted in furrows at a spacing of 45 x 45 cm accommodating 16 plants / accession / replication. Spot planting with a well known bacterial wilt susceptible variety Pusa Jwala was done to study the host reaction to the bacteria. The bacterial wilt incidence was confirmed through ooze test. All cultural and management practices adopted were as per the Package of Practices Recommendations (KAU, 1996).

The number of plants wilted at weekly intervals was recorded and percentage of wilt incidence was worked out. Then the accessions were grouped according to Mew and Ho (1976) as follows.

Table 3. Source of 53 chilli accessions

Sl.No.	Accession Number	Cultivar	Source
1	2	3	4
1	CA 33	Manjari	KAU, Vellanikkara
2	CA 53	Pant C 1	Pantnagar, UP
3	CA 67	CO 1	TNAU, Coimbatore
4	CA 87	G 4	Tamil Nadu
5	CA 94	K 2	Tamil Nadu
6	CA 153	CA 960	Tamil Nadu
7	CA 186	CO 2	TNAU, Coimbatore
8	CA 219	Ujwala	KAU, Vellanikkara
9	CA 337	Punjab Lal	PAU, Ludhiana
10	CA 451	Jwalamukhi	KAU, Vellanikkara
11	CA 452	Jwalasakhi	KAU, Vellanikkara
12	CA 517	IIHR 819	IIHR, Banglore
13	CA 591	Bayadagi Kaddi	UAS, Dharwad
14	CA 644	Pusa Sadabahar	IARI, New Delhi
15	CA 695	LCA 334	Lam, Guntur, A.P
16	CA 696	CH 1	Ludhiana, Punjab
17	CA 698	Local	Tamil Nadu
18	CA 699	Local	Tamil Nadu
19	CA 701	Phule C 5	M P K V V, Rahuri
20	CA 702	RHRC 16-5	M P K V V, Rahuri
21	CA 703	Hisar Vijay	HAU Hissar
22	CA 710	PBC 717	AVRDC, China
23	CA 714	PBC 473	AVRDC, China
24	CA 715	PBC 385	AVRDC, China
25	CA 716	PBC 066	AVRDC, China
26	CA 725	Punjab Guchhedar	PAU, Ludhiana
27	CA 727	Punjab Surkh	PAU, Ludhiana
28	CA 728	S 20 - 1	PAU, Ludhiana
29	CA 729	Laichi	PAU, Ludhiana

(Contd.....)

Table 3. (Contd....)

1	2	3	4
30	CA 730	Lorai	PAU, Ludhiana
31	CA 731	Perennial	PAU, Ludhiana
32	CA 733	Suryamukhi	PDVR, Varanasi
33	CA 734	Arka Lohit	IIHR, Banglore
34	CA 737	PBC 148	AVRDC, China
35	CA 738	PBC 204	AVRDC, China
36	CA 739	PBC 375	AVRDC, China
37	CA 740	PBC 384	AVRDC, China
38	CA 744	PBC 518	AVRDC, China
39	CA 745	PBC 535	AVRDC, China
40	CA 746	PBC 716	AVRDC, China
41	CA 747	Ramanathapuram Local	TNAU, Coimbatore
42	CA 748	Vilathikulam Local	TNAU, Coimbatore
43	CA 750	Coimbatore Local	TNAU, Coimbatore
44	CA 751	Nagkanya	Ankur seeds, Nagpur
45	CA 752	Local	Tamil Nadu
46	CA 753	Maecheri	Tamil Nadu
47	CA 754	Local	Tamil Nadu
48	CA 755	Bayadagi Dabbi	UAS, Dharwad
49	CA 756	Dyavanur Kaddi	UAS, Dharwad
50	CA 757	ARCH 228	Ankur seeds, Nagpur
51	CA 758	CO 3	TNAU, Coimbatore
52	CA 759	PKM 1	TNAU, Coimbatore
53	CA 760	LCA 235	PDVR, Varanasi

R - Resistant (<20 % wilted plants)

MR - Moderately Resistant (20 – 40 % wilted plants)

MS - Moderately Susceptible (40 – 60 % wilted plants)

S - Susceptible (> 60 % wilted plants)

3.1.3. Observations

Observations on the following characters were recorded.

i) Plant height (cm)

ii) Plant spread (cm)

iii) Days to first flower

iv) Days to first harvest

v) Fruit length (cm)

vi) Fruit girth (cm)

vii) Pedicel length (cm)

viii) Number of fruits per plant

ix) Average fruit weight (g)

x) Fruit yield per plant (g)

xi) Driage (%)

xii) Number of harvests

xiii) Total duration (days)

xiv) Pest and disease incidence

3.1.4. Genetic cataloguing of chilli germ plasm

The chilli crop raised for the evaluation of bacterial wilt resistance was catalogued.

3.1.4.1 Observations recorded

The chilli accessions were catalogued as per the descriptor for *Capsicum* by IBPGR.

3.1.4.1.1 Morphological characters

Growth habit - Erect / Intermediate / Prostrate

Stem colour - Green / Green with purple stripes / Purple

Leaf shape - Deltoid / Ovate / Lanceolate

Leaf colour - Light green / Green / Dark green / Light purple Purple / Variegated

Leaf pubescence - Sparse / Intermediate / Dense

Corolla colour - White / Light yellow / Yellow / Purple with white base White with purple base / Purple.

Number of flowers - One / Two / Three or more.

Flower postion - Pendant / Intermediate / Erect.

Anthocyanin spots or stripes on fruit - Present / Absent

Fruit colour at ripe stage - White / Lemon yellow / Pale orange yellow / Orange Red / Purple.

3.1.4.1.2 Quantitative characters

i) Plant height (cm)
ii) Plant spread (cm)
iii) Days to first flower
iv) Days to first harvest
v) Fruit length (cm)
vi) Fruit girth (cm)
vii) Pedicel length (cm)
viii) Number of fruits per plant
ix) Average fruit weight (g)
x) Fruit yield per plant
xi) Driage (%)
xii) Number of harvests
xiii) Total duration

3.1.5 Statistical analysis

The data were subjected to analysis of variance as described by Panse and Sukhatme (1978) for a randomized block design.

Variability for different quantitative characters were estimated as suggested by Burton (1952). The formula used in the estimation of variability at genotypic and phenotypic levels is as follows.

a) Genotypic coefficient of variation (GCV)

$$\frac{\text{Genotypic standard deviation}}{\text{Mean of the character}} \times 100$$

b) Phenotypic coefficient of variation (PCV)

$$\frac{\text{Phenotypic standard deviation}}{\text{Mean of the character}} \times 100$$

c) Standard error of the mean.

$$\frac{\text{Environmental standard deviation}}{\sqrt{(\text{Replications})}}$$

$$\text{Environmental variance} = \frac{\text{Mean square due to genotype} - \text{mean square due to error}}{\text{Replications}}$$

Phenotypic variance = Genotypic variance + error variance

d) Heritability in the broad sense was estimated by the formula suggested by Burton and Devane (1953)

$$h^2(b) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

e) Genetic advance at five percent intensity of selection was calculated using the formula of Johnson *et al.* (1955)

$GA = h^2 \times \sigma p \times i$

Where, h^2 = heritability

p = Phenotypic standard deviation

i = coefficient of intensity of selection (2:06 at p= 0.05)

e) Genetic advance (%) = $\frac{\text{genetic advance}}{\text{mean of the character}} \times 100$

3.1.5.1 Path coefficient analysis

In path coefficient analysis the correlation among cause and effect was partitioned into direct and indirect effects of causal factors on effect factor. All the twelve characters were considered for path coefficient analysis.

Plate 1. Inoculated plants kept under insect proof condition

Plate 2. Variability in chilli

3.1.5.2 Genetic divergence

The genetic divergence was calculated according to the method suggested by Mahalanobis (1928). Clustering of genotypes was done using Tocher's method (Rao 1952).

3.2. Evaluation of chilli genotypes for mosaic resistance

3.2.1 Experimental materials

All the chilli accessions screened for bacterial wilt resistance were utilized for the evaluation of mosaic resistance. For this the plants were raised in sterilized soil in pots under insect proof conditions. The soil was sterilised using formaldehyde solution (40 % formaldehyde diluted with water at 1:30 ratio) and sowing was carried out fifteen days after sterilisation.

3.2.2. Experimental methods

3.2.2.1. Preparation of inoculum

The young leaves showing mosaic symptoms were washed thoroughly in running tap water and wiped between the folds of blotting paper. They were then macerated using sterilised mortar and pestle using (1 ml) of 0.05 M phosphate buffer (pH 7.2) and 0.5 per cent sodium sulphite per gram of leaf tissue. The resultant pulp was squeezed through double layer of muslin cloth. The extract thus obtained was used as standard inoculum.

3.2.2.2. Method of inoculation

Four weeks old seedlings were selected for the mechanical inoculation. The leaves to be inoculated were marked and dusted with 600 mesh carborundum powder. A wad of sterilised, absorbent cotton pad saturated with the inoculum was gently rubbed over the surface of the dusted leaves for three to four times. Then the inoculated leaves were washed immediately to remove the excess of inoculum with a fine jet of distilled water from a squeeze bottle. Inoculation and establishment of the viruses were done under insect proof conditions (Plate 1). The inoculated seedlings were observed critically for symptom expression. The number of seedlings screened per accession was twenty.

3.2.2.3 Scoring procedure

Plants were scored for leaf symptom expression 30 days after inoculation using a 1 to 3 scale as follows.

Score

No symptoms (Resistant) - 1

Local lesions on inoculated leaves and mosaic symptoms on uninoculated leaves (Moderate infection) - 2

Severe local and systemic necrotic symptoms and leaf distortion (Susceptible) - 3

(George 1989)

The plants which did not show symptoms were reinoculated with the virus and scored again twenty days after inoculation.

3.2.2.4 Virus resistance confirmation studies

Confirmation of resistance was done using the following three methods viz., inoculation on indicator plants, graft transmission and back inoculation.

3.2.2.5 Inoculation on indicator plants

The accessions which have shown resistance after two inoculations were subjected to virus resistance confirmation studies by inoculating on indicator plants. Here *Chenopodium amaranticolor* was used as indicator plant and inoculation was done at 4 to 5 leaf stage. For this the inoculum was prepared from supposedly resistant plants and inoculated plants were kept under insect proof conditions for symptom development. The plants from which the inoculum failed to develop symptoms on indicator plants were regarded as resistant and utilized for further investigations

3.2.2.6 Back inoculation

Seedlings not showing any mosaic symptoms even after two inoculations were indexed back on healthy seedlings of the susceptible variety. This was done mechanically on 4 to 10 weeks old seedlings of susceptible variety raised in pots under insect proof conditions. Inoculated seedlings were observed for symptom expression.

3.2.2.7 Graft transmission

The method of grafting followed was wedge grafting. The root stock used were susceptible variety (CA 754) showing the symptoms of mosaic. The scion used was the top of 30 days old seedlings of supposedly resistant plants. The grafted plants were kept under insect proof condition and noted for disease reaction.

The accessions which exhibited resistance in all these studies were identified as sources of stable and extreme resistance and utilized for the breeding programme.

3.3 Hybridisation between selected genotypes

Accession found resistant to bacterial wilt but susceptible to mosaic was used as female parent and accessions rated as resistant to mosaic and susceptible to bacterial wilt were used as male parents. The parents selected based on this criteria were CA 714 (female) and CA 703 and CA 644 (male). The selected parents were grown under open field conditions and emasculation of flower buds was done on the previous day of flower opening and then the flowers covered with butter paper cover. Similarly the male flowers were also protected to avoid the chances of contamination. Pollination was done in the next day morning. F_1 seeds were extracted from red ripe fruits. Later F_1 progenies were evaluated for their reaction to bacterial wilt and mosaic.

Results

RESULTS

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

4.1 Evaluation of chilli genotypes for resistance to bacterial wilt

4.2 Evaluation of chilli genotypes for mosaic resistance

4.3 Development and evaluation of F_1 hybrids for bacterial wilt and mosaic resistance

4.1 Evaluation of chilli genotypes for resistance to bacterial wilt

Fifty three chilli accessions were grown in a bacterial wilt sick field. The percentage of wilt incidence at vegetative, flowering, fruiting and the harvesting stages were observed. The genotypes were classified into resistant, moderately resistant, moderately susceptible and susceptible as per Mew and Ho (1976). The results are presented in Table 4.

The chilli accessions showed different levels of resistance to bacterial wilt. Fifteen accessions were found resistant to the wilt incidence below 20 per cent. Minimum wilt incidence was noticed in the accession CA 745 (PBC 535) (8.34 %) followed by CA 731 (Perennial) (8.40 %), CA 219 (Ujwala) (8.53 %), CA 738 (PBC 204) (8.54 %), CA 337 (Punjab Lal) (8.59 %), CA 715 (PBC 385) (8.69 %), CA 739 (PBC 375) (9.19 %), CA 517 (IIHR 819) (9.40 %), CA 714 (PBC 473) (9.76 %), CA 740 (PBC 384) (10.84 %), CA 716(PBC 066) (11.27 %), CA 33 (Manjari) (12.04 %), CA 744 (PBC 518) (13.78 %), CA 53 (Pant C-1) (17.86 %) and CA 746 (PBC 716) (18.91 %). Sixteen accessions were moderately resistant with wilt incidence ranged between 20 and 40 per cent. Among the sixteen accessions, following four accessions namely CA 725, CA 754, CA 756 and CA 591 have shown only 22.22 per cent of wilt. Thirteen accessions were rated as moderately susceptible with disease incidence varied between 40 and 60 per cent. Remaining nine accessions were found to be highly susceptible with more than 60 per cent wilt incidence

Based on fruit length the above mentioned fifteen resistant accessions were classified into short, medium long and long as per Smith *et al.* (1987). Nine accessions namely CA 337, CA 53, CA 731, CA 33, CA 219, CA 517, CA 738, CA 739 and CA 746 were found short with fruit length between 5 and 7.5 cm. The accession CA 745 had

Table 4. Evaluation of 53 chilli accessions for bacterial wilt resistance during Sept. 1997 to Jan. 1998

Accession number	Incidence of bacterial wilt (%)			Score
	Vegetative stage	Upto flowering and fruiting	Upto final harvest (Total)	
1	2	3	4	5
CA 33	3.74	8.48	12.04	R
CA 53	6.54	13.76	17.89	R
CA 67	10.00	14.81	25.92	MR
CA 87	40.00	60.42	68.80	S
CA 94	4.44	15.55	28.88	MR
CA 153	44.44	66.66	88.88	S
CA 186	9.40	25.92	37.03	MR
CA 219	1.63	5.77	8.53	R
CA 337	2.00	5.74	8.59	R
CA 451	8.84	32.80	45.72	MS
CA 452	8.34	33.25	47.37	MS
CA 517	3.50	5.78	9.40	R
CA 591	11.11	15.76	22.22	MR
CA 644	13.34	39.81	61.84	S
CA 695	11.10	20.00	33.00	MR
CA 696	11.10	33.33	44.44	MS
CA 698	4.44	11.10	24.44	MR
CA 699	25.00	50.00	50.00	MS
CA 701	25.00	38.00	63.00	S
CA 702	29.25	45.00	69.72	S
CA 703	30.00	41.11	67.40	S
CA 710	8.33	27.24	38.64	MR
CA 714	2.54	6.32	9.76	R
CA 715	2.30	5.84	8.69	R
CA 716	3.49	8.41	11.27	R
CA 725	2.46	11.11	22.20	MR
CA 727	10.00	33.52	48.00	MS
CA 728	10.28	18.51	25.92	MR
CA 729	11.11	33.33	44.44	MS

(Contd...)

Table 4. (Contd.....)

1	2	3	4	5
CA 730	10.20	22.22	22.22	MR
CA 731	3.50	4.76	8.40	R
CA 733	14.76	33.33	44.44	MS
CA 734	30.50	48.46	70.56	S
CA 737	8.59	27.54	38.84	MR
CA 738	2.46	5.37	8.54	R
CA 739	2.82	6.42	9.19	R
CA 740	3.27	6.82	10.84	R
CA 744	5.94	7.61	13.78	R
CA 745	2.41	5.72	8.34	R
CA 746	6.73	11.57	18.91	R
CA 747	14.81	25.92	37.03	MR
CA 748	16.66	50.00	66.66	S
CA 750	14.81	33.33	44.44	MS
CA 751	17.77	22.22	42.22	MS
CA 752	11.11	28.66	51.11	MS
CA 753	11.11	22.22	44.44	MS
CA 754	20.37	31.11	53.33	MS
CA 755	11.67	20.00	37.77	MR
CA 756	11.11	11.11	22.22	MR
CA 757	10.24	20.00	22.22	MR
CA 758	13.46	22.22	33.33	MR
CA 759	29.47	48.32	65.92	S
CA 760	11.11	33.33	48.14	MS

R - Resistant (< 20 % wilt)

MR - Moderately resistant (20 - 40 % of wilt)

MS - Moderately susceptible (40 - 60 % of wilt)

S - Susceptible (>60 % of wilt)

medium long fruits measuring 7.5 and 10 cm. Remaining five accessions CA 714, CA 715, CA 716, CA 740 and CA 744 were rated as long with the fruit length between 10 and 15 cm.

4.1.1 Genetic cataloguing in chilli

Fifty three accessions of chilli utilised in the resistance studies were genetically catalogued based on the descriptor (Plate 2). Vegetative and inflorescence characters were recorded and accessions were catalogued (Table 5).

The accessions were erect / intermediate / prostrate in their growth habit. The stem colour varied from green to purple. The leaf shape was ovate / lanceolate / deltoid. The leaf colour was light green / green / dark green / purple. The leaves were free from pubescence. Flower colour varied from white to purple. Number of flowers per axil, flower position, anthocyanin spots or stripes on fruit, fruit colour at mature stage varied with accessions.

4.1.2 Genetic variability in chilli

The analysis of variance of 53 accessions of chilli showed significant difference between the accessions for all the characters (Appendix I). The population mean, range, genotypic coefficient of variance, phenotypic coefficient of variance, heritability, genetic advance and genetic gain for all the 13 characters are given in Table 6.

Plant height

Plant height ranged from 40.20 cm to 90.65 cm. The accession CA 728 had the maximum plant height whereas CA 695 had the minimum. The gcv and pcv were 20.64 and 20.66 respectively. The heritability was 0.99. The genetic advance and genetic gain were 23.99 and 42.49 % respectively.

Plant spread

Plant spread ranged from 29.15 cm to 45.85 cm. The maximum plant spread was recorded by CA 702 and the minimum was by CA 699. The heritability observed was 0.99. The gcv and pcv were 13.56 and 13.59 respectively. The genetic advance was 9.10 and genetic gain was 27.84 per cent.

Table 5. Morphological description of 53 chilli accessions

Sl. No.	Accession number	Growth habit	Stem colour	Leaf shape	Leaf colour	Leaf pubescence	Corolla colour	Number of flowers per axil	Flower position	Anthocyanin spots of stripes on fruits	Fruit colour at mature stage
1	2	3	4	5	6	7	8	9	10	11	12
1	CA 33	Intermediate	Green	Lanceolate	Green	Sparse	White	Seven	Erect	Absent	Red
2	CA 53	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Erect	Absent	Red
3	CA 67	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
4	CA 87	Erect	Green	Lanceolate	Dark green	Sparse	White	One	Pendant	Absent	Red
5	CA 94	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
6	CA 153	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
7	CA 186	Erect	Green	Lanceolate	Green	Sparse	White	One	Intermediate	Absent	Red
8	CA 219	Erect	Green	Lanceolate	Green	Sparse	White	Nine	Erect	Absent	Red
9	CA 337	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Erect	Absent	Red
10	CA 451	Intermediate	Green	Ovate	Light green	Sparse	White	One	Pendant	Absent	Red
11	CA 452	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
12	CA 517	Intermediate	Green	Ovate	Light green	Sparse	White	One	Intermediate	Absent	Red
13	CA 591	Erect	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
14	CA 644	Intermediate	Green	Ovate	Green	Sparse	White	Ten	Erect	Absent	Red
15	CA 695	Erect	Green	Ovate	Dark green	Sparse	White	One	Intermediate	Absent	Red
16	CA 696	Intermediate	Green	Ovate	Green	Sparse	White	One	Intermediate	Absent	Red
17	CA 698	Erect	Green	Ovate	Dark green	Sparse	White	One	Pendant	Absent	Red
18	CA 699	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
19	CA 701	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
20	CA 702	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
21	CA 703	Erect	Green	Deltoid	Dark green	Sparse	White	Ten	Erect	Present	Red
22	CA 710	Erect	Green	Ovate	Green	Sparse	White	Eight	Erect	Absent	Red
23	CA 714	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
24	CA 715	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
25	CA 716	Intermediate	Green	Ovate	Dark green	Sparse	White	One	Pendant	Absent	Red

(Contd.....)

Table 5 (Contd.....)

1	2	3	4	5	6	7	8	9	10	11	12
26	CA 725	Intermediate	Green	Lanceolate	Green	Sparse	White	Eight	Erect	Absent	Red
27	CA 727	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
28	CA 728	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
29	CA 729	Erect	Green	Ovate	Green	Sparse	White	Eight	Erect	Absent	Red
30	CA 730	Intermediate	Purple	Ovate	Purple	Sparse	Purple	One	Erect	Present	Brownish red
31	CA 731	Erect	Green	Ovate	Green	Sparse	White	One	Erect	Absent	Red
32	CA 733	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
33	CA 734	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
34	CA 737	Intermediate	Green	Ovate	Green	Sparse	White	One	Erect	Absent	Red
35	CA 738	Erect	Green	Deltoid	Green	Sparse	White	One	Pendant	Absent	Red
36	CA 739	Erect	Green	Lanceolate	Dark green	Sparse	White	One	Pendant	Absent	Red
37	CA 740	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
38	CA 744	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
39	CA 745	Prostrate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
40	CA 746	Erect	Green	Ovate	Green	Sparse	White	One	Erect	Absent	Red
41	CA 747	Intermediate	Green	Ovate	Dark green	Sparse	White	One	Pendant	Absent	Red
42	CA 748	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
43	CA 750	Intermediate	Green	Ovate	Green	Sparse	White	One	Intermediate	Absent	Red
44	CA 751	Erect	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
45	CA 752	Erect	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
46	CA 753	Erect	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
47	CA 754	Erect	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
48	CA 754	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
49	CA 755	Erect	Green	Ovate	Dark green	Sparse	White	One	Pendant	Absent	Red
50	CA 756	Erect	Green	Ovate	Dark green	Sparse	White	One	Pendant	Absent	Red
51	CA 758	Intermediate	Green	Lanceolate	Green	Sparse	White	One	Pendant	Absent	Red
52	CA 759	Intermediate	Green	Ovate	Green	Sparse	White	One	Pendant	Absent	Red
53	CA 760	Erect	Green	Lanceolate	Green	Sparse	White	One	Intermediate	Absent	Red

Table 6. Range, Mean, gcv, pcv, heritability, genetic advance and genetic gain for different characters in chilli

Characters	Range	Mean ± SE	gcv	pcv	Heritability	Genetic advance	Genetic gain
Plant height (cm)	40.20 to 90.65	56.45 ± 0.40	20.64	20.66	0.99	23.99	42.49
Plant spread (cm)	29.15 to 45.85	32.69 ± 0.33	13.56	13.59	0.99	9.10	27.84
Days to first flower	59.00 to 83.00	68.05 ± 1.18	7.29	7.50	0.95	9.95	14.62
Days to first harvest	95.00 to 120.50	104.42 ± 1.60	4.75	4.99	0.91	9.71	9.29
Fruit length (cm)	2.70 to 12.82	6.50 ± 0.04	31.87	31.88	1.00	4.27	65.69
Fruit girth (cm)	2.24 to 5.49	3.17 ± 0.03	21.01	21.03	0.99	1.37	43.19
Pedicel length (cm)	1.19 to 3.57	2.48 ± 0.09	19.07	19.44	0.96	0.96	38.71
Number of fruits per plant	31.00 to 108.50	61.09 ± 1.85	20.81	21.03	0.98	25.91	42.41
Average fruit weight (g)	1.26 to 6.27	2.84 ± 0.04	34.33	34.37	0.99	2.01	70.77
Fruit yield per plant (g)	84.40 to 352.75	129.33 ± 2.87	29.28	29.36	0.99	77.78	60.14
Driage (%)	18.68 to 22.93	20.90 ± 0.18	5.85	5.91	0.98	2.49	11.91
Number of harvests	7.50 to 12.00	9.66 ± 0.60	9.76	11.60	0.71	1.63	16.87
Total duration (days)	166.50 to 210.00	190.74 ± 2.14	4.45	4.59	0.94	16.93	8.87

Days to first flower

The genotype CA 715 was the earliest to flower. It took 59 days whereas CA 698 took 83 days to produce the first flower. Heritability was 0.95. The gcv and pcv were 7.29 and 7.50 respectively. The genetic gain was 14.62 per cent.

Days to first harvest

The days to first harvest ranged from 95.00 (CA 715) to 120.50 (CA 698). The gcv and pcv were 4.75 and 4.99. The heritability value was 0.91. The genetic gain and genetic advance were 9.71 and 9.29 % respectively.

Fruit length

Length of the fruits ranged from 2.70 cm to 12.82 cm. The longest fruits were produced by CA 755 and the shortest fruits were produced by CA 731. The heritability value was maximum (1.00). The gcv and pcv were 31.87 and 31.88 respectively. The genetic advance was 4.27 and the genetic gain was 65.69.

Fruit girth

The fruit girth ranged from 2.24 cm to 5.49 cm. The genotype CA 728 recorded the maximum fruit girth and CA 591 recorded the minimum. The gcv and pcv values were 21.01 and 21.03. The heritability was 0.99. The genetic advance and genetic gain were 1.37 and 43.19 per cent respectively.

Pedicel length

The pedicel length ranged from 1.19 (CA 737) to 3.57 (CA 716. The pcv was 19.44 and gcv was 19.07. The heritability observed was 0.96. The genetic advance was 0.96 and the genetic gain was 38.71 per cent.

Number of fruits per plant

The number of fruits per plant ranged from 31.00 to 108.50. The genotype CA 731 produced highest number of fruits, whereas the genotype CA 696 produced least number of fruits. The gcv and pcv were 20.81 and 21.03 respectively. The heritability value was 0.98. The genetic advance and genetic gain were 25.91 and 42.41 per cent respectively.

Plate 3. CA 728 - The highest yielding chilli accession

Average fruit weight

Average fruit weight varied significantly between the accessions. It ranged from 1.26 (CA 737) to 6.27 (CA 728). The gcv and pcv values were 34.33 and 34.37. The heritability was 0.99. The genetic gain was 70.77.

Fruit yield per plant

The accessions differed significantly with respect to this character. It ranged from 84.40 (CA 737) to 352.75 (CA 728) (Plate 3). The heritability was observed as 0.99. The gcv and pcv values were 29.28 and 29.36 respectively. The genetic advance and genetic gain were 77.78 and 60.14 per cent.

Driage

The driage ranged from 18.68 to 22.93 per cent. CA 731 had maximum driage percentage of 22.93 per cent whereas CA 695 had the minimum.The gcv and pcv values were 5.85 and 5.91. The heritability was 0.98. The genetic advance and genetic gain were 2.49 and 11.91 respectively.

Number of harvests

Number of harvests ranged from 7.50 (CA 517) to 12 (CA 731). The heritability value was low 0.71. The gcv and pcv values were 9.76 and 11.60 respectively. The genetic advance was 1.63 and the genetic gain was 16.87.

Total duration

Total duration ranged from 166.50 (CA 758) to 210 (CA 94). The gcv and pcv were 4.45 and 4.59. The heritability was observed as 0.94. The genetic advance and genetic gain were 16.93 and 8.87 respectively.

4.1.3 Genetic divergence among 53 genotypes of chilli

The 53 genotypes of chilli were grouped into seven clusters (Table 7). Cluster V had the largest number of genotypes (19) followed by cluster I (8). Cluster III and VI had 6 genotypes each. There were six genotypes in cluster VII, four in cluster II. Cluster IV had four genotypes. Means of variables for seven clusters is given in the Table 8.

Table 7. Clustering pattern in 53 genotypes of chilli

Cluster No.	No. of genotypes in each cluster	Genotypes
I	8	CA 53, CA 186, CA 337, CA 703, CA 715, CA 729, CA 731, CA 734
II	4	CA 696, CA 727, CA 730, CA 733
III	6	CA 451, CA 452, CA 714, CA 715, CA 716, CA 728
IV	4	CA 591, CA 702, CA 755, CA 756
V	19	CA 33, CA 67, CA 153, CA 219, CA 644, CA 695, CA 738, CA 739, CA 740, CA 746, CA 747, CA 748, CA 750, CA 753, CA 754, CA 757, CA 758, CA 759, CA 760
VI	6	CA 87, CA 94, CA 698, CA 699, CA 701, CA 752
VII	6	CA 517, CA 725, CA 737, CA 744, CA 745, CA 751

Table 8. Means of variables for seven clusters in chillies

Cluster No.	Plant height (cm)	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (g)	Driage (%)	Number of harvests	Total duration (days)
I	50.30	29.24	64.71	100.67	4.64	2.83	2.15	73.67	2.25	126.14	21.58	10.50	190.04
II	58.56	33.70	62.00	98.60	5.18	3.37	1.99	44.90	3.07	103.60	19.60	8.70	186.90
III	63.63	34.01	67.21	103.36	9.37	3.87	2.92	42.50	4.73	177.81	21.03	9.00	189.43
IV	81.05	40.45	65.75	103.25	8.50	2.78	2.63	59.75	2.77	145.80	20.96	11.25	203.88
V	52.27	30.78	68.39	104.87	6.45	3.32	2.67	64.16	2.70	124.56	20.51	9.39	188.16
VI	61.19	31.53	77.14	114.14	7.32	2.94	2.76	60.07	2.62	112.57	20.66	10.00	200.86
VII	49.94	39.50	70.67	106.08	5.89	2.95	1.99	63.50	2.47	124.09	21.97	9.00	184.50

The genotypes included in cluster I were CA 703, CA 710, CA 734, CA 337, CA 53, CA 186, CA 729 and CA 731. The mean plant height of the genotypes was 50.30 cm and had maximum number of fruits per plant (73.67) with an average fruit weight of 2.25 g. They had a mean fruit yield of 126.14 g per plant. They have short fruits measuring 4.64 cm. They were resistant / moderately resistant / susceptible to bacterial wilt. Their reaction to mosaic ranged from resistance to susceptibility.

The genotypes of cluster II were CA 696, CA 727, CA 733 and CA 730. They had a mean plant height of 58.56 cm. They were early flowering types (62.00 days) with an average fruit weight of 3.07 g. They had minimum driage (19.60 %). All the genotypes except CA 730 were moderately susceptible to bacterial wilt. They showed resistance / moderate infection / susceptibility to mosaic.

The genotypes CA 714, CA 715, CA 716, CA 728, CA 451 and CA 452 were included in the cluster III. They had maximum fruit length of 9.37 cm. with an average fruit weight of 4.73 g. They had maximum fruit yield per plant (177.81 g). They were resistant / moderately resistant / moderately susceptible to bacterial wilt. They were moderately resistant / susceptible to mosaic. The genotypes CA 702, CA 755, CA 756, and CA 591 having maximum plant height and plant spread of 81.05 cm and 40.45 cm respectively were included in cluster IV. They had average yield of 145.80 g per plant. They had maximum number of harvests (11.25). Except CA 702 all the three genotypes were moderately resistant to bacterial wilt. Their reaction to mosaic was moderate infection or susceptible.

Cluster V included the following genotypes CA 695, CA 753, CA 153, CA 754, CA 757, CA 747, CA 748, CA 750, CA 758, CA 67, CA 759, CA 760, CA 33, CA 219, CA 644, CA 738, CA 739, CA 740 and CA 746. The mean plant height of the genotypes was 52.27 cm with a mean plant spread of 30.78 cm. They had an average fruit length of 6.45 cm. The mean fruit yield per plant was 124.56 g. The reaction to bacterial wilt and mosaic ranged from resistance to susceptibility.

The genotypes included in the cluster VI were CA 94, CA 698 CA 699, CA 701, CA 87 and CA 752. They had a mean plant height of 61.19 cm. Average number of fruits per plant was 60.07 with a mean fruit weight of 2.62 g. The reaction to bacterial wilt was moderately resistant / moderately susceptible / susceptible. All the genotypes were

susceptible to mosaic. The genotypes CA 725, CA 751, CA 517, CA 737, CA 744 and CA 745 were included in the cluster VII. The genotypes belonging to this cluster recorded the minimum plant height 49.94 cm. The genotypes in this cluster recorded the maximum driage (21.97 %). They were resistant / moderately resistant / moderately susceptible to bacterial wilt. Their reaction to mosaic ranged from resistance to susceptibility.

The average distance of cluster members from cluster centroids was maximum for cluster III (3.543) and minimum for cluster II (2.018). The average distance of cluster I, cluster IV, cluster V, cluster VI and cluster VII from cluster centroids were 2.378, 2.865, 2.401, 2.332 and 2.420 respectively (Table 9). The intercluster distance was highest between cluster I (0.000) and cluster III (5.453) followed by that between cluster I and IV (5.138) and the minimum was between cluster VI and VII (Table 10).

4.1.4 *Correlation studies*

The genotypic and phenotypic correlation of various yield components with yield was worked out and presented (Table 11 and 12). The characters having significant correlation with yield were plant height, days to first flower, days to first harvest, fruit length, pedicel length and total duration. The fruit girth was insignificant and negatively correlated with yield. Total duration had the highest positive and significant correlation with yield (0.576). The next high positive and significant correlation with yield was exhibited by plant height (0.509) followed by fruit length (0.250). In all the characters studied, genotypic correlation coefficients were found to be high.

4.1.5 Inter correlation among different characters

Plant height was found to have significant positive correlation with plant spread, fruit length, pedicel length, average fruit weight, driage, total duration and yield (rg = 0.26, 0.44, 0.19, 0.34, 0.36, 0.27 and 0.509 respectively). Plant height was significantly and negatively correlated with number of fruits per plant (rg = -0.29). Plant spread was positively and significantly correlated with fruit length (rg = 0.27) and significantly and negatively correlated with number of fruits per plant (rg = -0.21).

Days to first flower was having significant positive correlation with days to first harvest, fruit length and pedicel length (rg = 0.96, 0.20 and 0.18 respectively). Days to

Table 9. Average distances of cluster numbers from cluster centroids

Cluster	I	II	II	IV	V	VI	VII
	2.378	2.018	3.543	2.865	2.401	2.332	2.420

Table 10. Distance between cluster centroids for seven clusters in chillies

Cluster	I	II	II	IV	V	VI	VII
I	0.000						
II	3.827	0.000					
III	5.453	4.346	0.000				
IV	4.816	5.138	4.663	0.000			
V	2.561	3.168	3.751	4.469	0.000		
VI	4.621	5.421	4.905	4.421	3.199	0.000	
VII	3.419	3.813	4.810	4.777	2.897	4.154	0.000

Table 11. Phenotypic correlation coefficients among yield and its components in chilli.

Characters	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Driage (%)	Number of harvests	Total duration (days)	Yield per plant (g)
Plant height (cm)	0.259**	0.052	0.108	0.440**	0.167	0.192*	-0.292**	0.343**	0.364**	-0.035	0.230**	0.493**
Plant spread (cm)		0.100	0.051	0.269**	0.104	-0.154	-0.212*	0.133	0.161	0.129	0.024	0.113
Days to first flower			0.946**	0.194*	0.025	0.182*	0.122	-0.094	-0.055	0.086	0.083	0.193*
Days to first harvest				0.229*	0.048	0.228*	0.094	-0.029	-0.006	0.079	0.017	0.225*
Fruit length (cm)					0.222*	0.518**	-0.387**	0.571**	0518**	-0.022	-0.057	0.250**
Fruit girth (cm)						0.041	-0.239**	0.639**	0.529**	-0.085	-0.224*	-0.038
Pedicel length (cm)							-0.236**	0.322**	0.171	-0.074	-0.030	0.205*
Number of fruits per plant								-0.592**	-0.062	0.248**	0.329**	0.033
Average fruit weight (g)									0.733	-0.210*	-0.280**	0.008
Driage (%)										-0.010	0.022	0.087
Number of harvests											0.028	0.039
Total duration (days)												0.533**

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

Table 12. Genotypic correlation coefficients among yield and its components in chilli

Characters	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Driage (%)	Number of harvests	Total duration (days)	Yield per plant (g)
Plant height (cm)	0.260**	0.055	0.144	0.440**	0.167	0.197*	-0.295**	0.343**	0.366**	-0.037	0.274**	0.509**
Plant spread (cm)		0.101	0.052	0.270**	0.105	-0.160	-0.214*	0.133	0.163	0.133	0.026	0.117
Days to first flower			0.960**	0.200*	0.026	0.186*	0.130	-0.098	-0.055	0.095	0.090	0.208*
Days to first harvest				0.241**	0.051	0.246**	0.101	0.031	-0.006	0.088	0.022	0.253**
Fruit length (cm)					0.222*	0.528**	-0.392**	0.571**	0.519**	-0.022	-0.067	0.259**
Fruit girth (cm)						0.042	-0.242**	0.639**	0.532**	-0.086	-0.264**	-0.039
Pedicel length (cm)							-0.243**	0.329**	0.177*	-0.065	-0.036	0.221*
Number of fruits per plant								-0.599**	-0.072	0.247**	0.406**	0.035
Average fruit weight (g)									0.736**	-0.213*	-0.336**	0.009
Driage (%)										-0.014	-0.026	0.089
Number of harvests											0.053	0.043
Total duration (days)												0.576**

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

first harvest had significant positive correlation with fruit length (rg = 0.24) and pedicel length (rg = 0.24).

Fruit length was found to have significant positive correlation with fruit girth, pedicel length, average fruit weight and driage (rg = 0.22, 0.52, 0.57 and 0.51 respectively). Fruit length was significantly and negatively correlated with number of fruits per plant (rg = -0.39).

Fruit girth was significantly and positively correlated with average fruit weight (rg = 0.63) and driage (rg = 0.53). Fruit girth was having significant negative correlation with number of fruits per plant (rg = -0.24) and total duration (rg = -0.26). Pedicel length was found to have significant positive correlation with average fruits per plant (rg = 0.32) driage (rg = 0.177) and negatively correlated with number of fruits per plant (rg = -0.24).

Number of fruits per plant was significant and positively correlated with number of harvests, (rg = 0.24) and total duration (rg = 0.40). It was negatively correlated with average fruits per plant (rg = -0.59). There was significant positive correlation between average fruit weight and driage (rg = 0.73). Average fruit weight was negatively correlated with number of harvests (rg = -0.21) and total duration (rg = -0.33).

4.1.6 Path coefficient analysis

The direct and indirect contribution of the component characters on yield can be found out by partitioning the correlation between yield and component characters in to direct and indirect effects (Table 13). All the 12 characters were considered for path coefficient analysis.

Average fruit weight exhibited the highest positive direct effect on fruit yield (0.977) followed by number of fruits per plant (0.593), fruit length (0.203) plant height (0.146), number of harvests (0.090), plant spread (0.062), driage (0.049) and fruit girth (0.005). Total duration exhibited the highest negative direct effect (-0.095) followed by pedicel length (-0.086), days to first flower (-0.063) and days to first harvest (-0.005).

The direct effect of days to first flower on yield was negative (-0.063) but the positive correlation with the yield was due to the indirect effect through number of fruits per plant (0.077) and fruit length (0.041). The direct effect of pedicel length on yield was

Table 13. Direct and indirect effects of yield components on fruit yield in chillies (Genotypic path)

Characters	Plant height (cm)	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Driage (%)	Number of harvest	Total duration (days)	Correlation with yield
Plant height (cm)	**0.146**	0.016	-0.003	-0.001	0.089	0.001	-0.017	0.175	0.335	-0.002	0.025	-0.048	0.509
Plant spread (cm)	0.038	**0.062**	-0.006	0.000	0.055	0.001	0.014	-0.127	0.130	0.006	0.002	-0.011	0.117
Days to first flower	0.008	0.006	**-0.063**	-0.005	0.041	0.000	-0.016	0.077	-0.096	0.005	0.008	-0.020	0.208
Days to first harvest	0.017	0.003	-0.061	**-0.005**	0.049	0.000	-0.021	0.060	-0.030	0.004	0.002	-0.024	0.253
Fruit length (cm)	0.064	0.017	-0.013	-0.001	**0.203**	0.001	-0.045	-0.232	0.558	-0.001	-0.006	-0.025	0.259
Fruit girth (cm)	0.024	0.007	-0.002	0.000	0.045	**0.005**	-0.004	-0.144	0.624	-0.004	-0.024	0.004	-0.039
pedicel length (cm)	0.029	-0.010	-0.012	-0.001	0.107	0.000	**-0.086**	-0.144	0.322	-0.003	-0.003	-0.021	0.221
Number of fruits per plant	-0.043	-0.013	-0.008	0.000	-0.079	-0.001	0.021	**0.593**	-0.585	0.012	0.036	-0.003	0.035
Average fruit weight (g)	0.050	0.008	0.006	0.000	0.116	0.003	-0.028	-0.356	**0.977**	-0.010	-0.030	-0.001	0.009
Driage (%)	-0.005	0.008	-0.006	0.000	-0.004	0.000	0.006	0.147	-0.208	**0.049**	0.005	-0.004	0.089
Number of harvests	0.040	0.002	-0.006	0.000	-0.014	-0.001	0.003	0.241	-0.328	0.003	**0.090**	-0.055	0.043
Total duration (days)	0.074	0.007	-0.013	-0.001	0.052	0.000	-0.019	0.021	0.008	0.002	0.052	**-0.095**	0.576

The diagonal values in bold indicate direct effects
Residual 0.1755

Plate 4a. Symptoms of chilli mosaic

Plate 4b. Symptoms of chilli mosaic

negative (-0.086) but the correlation with yield was significant and positive due to the indirect effect through average fruit weight (0.322) and fruit length (0.107). The direct and indirect effects of these characters are presented in Table 14 and Fig. 1. The residual effect was relatively small indicating the sufficiency of the independent characters included in the regression.

4.1.7 Step down regression analysis

The step down regression analysis was employed to identify the best set of characters that could predict the dependent character. All the characters were used for this analysis and the results are presented in Table 15.

Though 79.85 per cent of variation in the dependent character was explained by 12 characters it could be observed that 79.68 per cent of variation in the dependent character was contributed by the five characters viz; plant height, fruit length, pedicel length, number of fruits per plant, average fruit weight. Thus these five characters could be considered as the best for predicting the yield per plant.

4.2 Evaluation of chilli genotypes for mosaic resistance

Fifty three chilli genotypes were tested for resistance to mosaic. The results are presented in the Table 16. Susceptible ones showed the symptoms within seven to ten days after inoculation, as slight vein clearing of expanding leaves followed by mosaic mottling. Margin of the leaves were slightly bent upwards (Plate 4a and 4b). New leaves developed an irregular and discontinuous green vein banding symptom. Some of the leaves developed dark green raised blisters all over the surface veins and veinlets became wavy resulting in upward curling and crinkling of leaves. Some leaves showed irregular expansion of lamina along with green blisters. The internodes were shortened giving the plant a stunted appearance.

Out of 53 genotypes tested only nine viz. CA 703 (Hisar Vijay), CA 337 (Punjab Lal), CA 731 (Perennial), CA 730 (Lorai), CA 644 (Pusa Sadabahar), CA 737 (PBC 148), CA 738 (PBC 204), CA 739 (PBC 375) and CA 744 (PBC 518) showed highest degree of resistance to mosaic as evidenced by the mean disease score of 1.00. Twelve genotypes namely CA 696 (CH-1), CA 710 (PBC 717), CA 715 (PBC 385), CA 734 (Arka Lohit), CA 725 (Punjab Guchedar), CA 53 (Pant C- 1), CA 733 (Suryamukhi), CA 33(Manjari),

Table 14. Results of path analysis of all the independent variables

Variables	Characters	Direct effect		Total indirect effect		Indirect effect	
		Effect	Rank	Effect	Rank	Effect	Variable
X_1	Plant height	0.146	IV	0.570	II	0.335	X_9
X_2	Plant spread	0.062	IX	0.102	XI	0.130	X_9
X_3	Days to first flower	-0.063	VIII	0.008	XI	-0.096	X_9
X_4	Days to first harvest	-0.005	XI	-0.001	XII	-0.061	X_3
X_5	Fruit length	0.203	III	0.317	IV	0.558	X_9
X_6	Fruit girth	0.005	XI	0.526	III	0.624	X_9
X_7	Pedicel length	-0.086	VII	0.264	V	0.322	X_9
X_8	Number of fruits per plant	0.593	II	-0.663	I	-0.585	X_9
X_9	Average fruit weight	0.977	I	0.242	VI	-0.356	X_8
X_{10}	Driage	0.049	X	0.061	X	0.147	X_8
X_{11}	Number of harvests	0.090	VI	-0.115	VIII	-0.328	X_9
X_{12}	Total duration	-0.095	V	0.183	VII	0.074	X_1

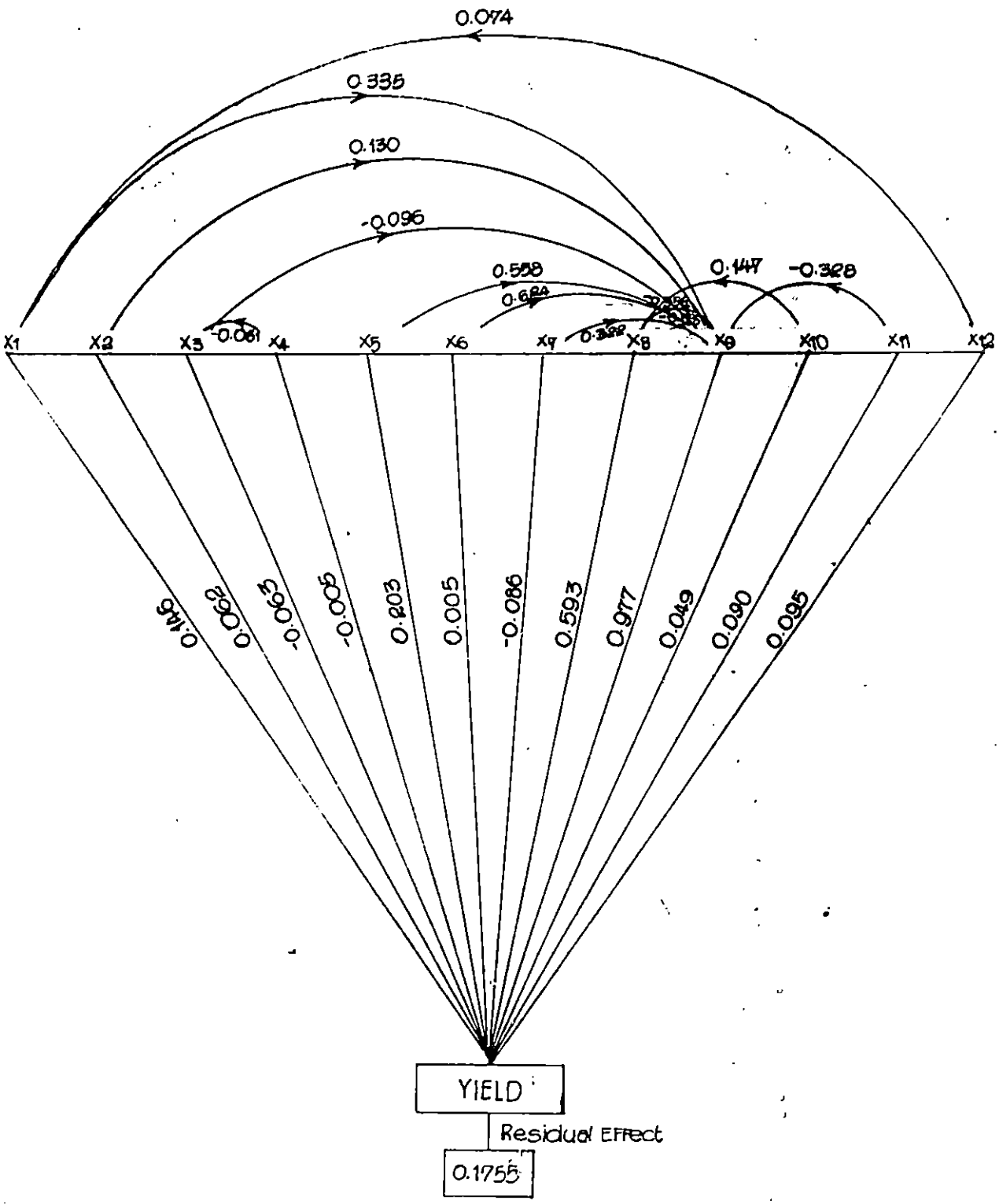

Fig. 1 Path Diagram Showing direct and indirect effect of Selected independent variables on yield.

Table 15. Results of step down regression analysis

Variable	Independent variable	Partial regression coefficient 'b'	Standard error of 'b'	t' value of b
1	Plant height (cm)	0.144	0.152	3.081
5	Fruit length (cm)	0.205	1.073	3.507
7	Pedicel length (cm)	-0.133	3.814	2.737
8	Numbers of fruits per plant	0.599	0.153	11.584
9	Average fruit weight (g)	0.963	2.243	16.656

$R^2 = 0.7968$

Intercept constant = - 110.22

Table 16. Reaction of 53 chilli genotypes to mosaic

Sl.No.	Accession Number	Mean disease score	Sl.No.	Accession Number	Mean disease score
1	2	3	1	2	3
1	CA 33	1.25	28	CA 728	2.20
2	CA 53	2.00	29	CA 729	2.50
3	CA 67	2.45	30	CA 730	1.00
4	CA 87	2.50	31	CA 731	1.00
5	CA 94	2.80	32	CA 733	2.00
6	CA 153	2.10	33	CA 734	1.64
7	CA 186	2.80	34	CA 737	1.00
8	CA 219	1.20	35	CA 738	1.00
9	CA 337	1.00	36	CA 739	1.00
10	CA 451	2.60	37	CA 740	1.05
11	CA 452	2.55	38	CA 744	1.00
12	CA 517	2.50	39	CA 745	1.10
13	CA 591	2.32	40	CA 746	1.20
14	CA 644	1.00	41	CA 747	2.90
15	CA 695	2.50	42	CA 748	2.68
16	CA 696	2.00	43	CA 750	3.00
17	CA 698	2.55	44	CA 751	2.80
18	CA 699	2.45	45	CA 752	2.62
19	CA 701	3.00	46	CA 753	2.75
20	CA 702	2.25	47	CA 754	3.00
21	CA 703	1.00	48	CA 755	2.80
22	CA 710	1.40	49	CA 756	2.25
23	CA 714	2.23	50	CA 757	2.47
24	CA 715	1.35	51	CA 758	2.20
25	CA 716	2.32	52	CA 759	2.40
26	CA 725	2.00	53	CA 760	2.20
27	CA 727	2.05			

Score: 1 Completely resistant, >1 to 2 moderate infection, >2 to 3 susceptible

Plate 5. CA 744 - Accession having resistance to both bacterial wilt and mosaic

Plate 6. CA 337 - Accession having resistance to both bacterial wilt and mosaic

CA 219 (Ujwala), CA 740 (PBC 384), CA 745 (PBC 535) and CA 746 (PBC 716) showed moderate infection with disease score between 1 and 2. Remaining thirty two genotypes were susceptible to mosaic with a disease score of above 2.

4.2.1 Combined Resistance

Among the 53 accessions screened for bacterial wilt and mosaic resistance five accessions viz., CA 337, CA 731, CA 738, CA 739 and CA 744 were found to possess the resistance to both the diseases (Plate 5 and 6). Two accessions viz., CA 337 and CA 731 were from Punjab Agricultural University, Ludhiana and the remaining three were obtained from AVRDC Taiwan. They were having average fruit yield of 135.50 g, 101.85 g, 131.70 g, 159.70 g and 151.50 g per plant respectively (Appendix II). This is on par with the yield of our popular varieties viz., Jwalamukhi, Jwalasakhi, Ujwala and Manjari.

4.2.2 Confirmation of virus resistance

These studies were confined to the genotypes which were found to be resistant to mosaic during preliminary screening.

4.2.2.1 Back inoculation

The experiment was conducted to determine whether the resistance shown by the nine genotypes was tolerance or symptomless carrier type or true resistance.

In the case of CA 703, CA 337, CA 731, CA 730, CA 644, CA 737, CA 738, CA 739 and CA 744 which were isolated as sources of resistance in the initial screening, back inoculation failed to index back, the mosaic virus. But all the seedlings, back inoculated from the symptomatic plants of susceptible genotypes produced characteristic mosaic symptoms.

4.2.2.2 Reaction on indicator plants

The indicator plant *Chenopodium amaranticolor* when inoculated with the sap of resistant accessions, failed to express the symptoms. But the indicator plants when inoculated with the sap of susceptible genotypes produced the characteristic necrotic lesions.

4.2.2.3 Grafting

Studies on grafting revealed that when the scions of resistant genotypes were grafted on infected stocks of susceptible variety they did not show any mosaic symptoms even 15 days after grafting. The branches developed later were also perfectly healthy.

4.3 Development and evaluation of F_1 hybrids for bacterial wilt and mosaic resistance

The F_1 hybrids CA 714 x CA 703 and CA 714 x CA 644 were evaluated in the bacterial wilt sick soil and was found completely susceptible. None of the hybrids survived wilt incidence. The F_1 hybrids showed susceptibility to mosaic while subjected to artificial inoculation of virus by macerating the leaves with carborandum powder (Table 17).

Table 17. Reaction of parents and F_1 hybrids to bacterial wilt and mosaic

(a) Cross: CA 714 x CA 703

Parents / F_1	Bacterial wilt		Mosaic	
	Number of plants		Number of plants	
	Resistant	Susceptible	Resistant	Susceptible
CA 714	20	0	0	20
CA 703	0	20	20	0
F_1	0	27	0	25

(b) Cross: CA 714 x CA 644

Parents / F_1	Bacterial wilt		Mosaic	
	Number of plants		Number of plants	
	Resistant	Susceptible	Resistant	Susceptible
CA 714	20	0	0	20
CA 644	0	20	20	0
F_1	0	32	0	30

Discussion

DISCUSSION

Chilli is an important spice cum vegetable crop grown throughout the country. It is an important constituent of many foods and known to impart pungency, colour, and flavour. Cultivation of chilli is threatened by many diseases and pests. In the warm humid tropical climatic conditions as prevailing in Kerala and in the coastal areas bacterial wilt caused by *Ralstonia solanacearum* (Smith) Yubuuchi *et al.* is a serious problem. None of the high yielding varieties is resistant to the disease. Chemical control measures are also not effective.

Mosaic is yet another serious disease affecting chilli resulting in considerable loss to chilli crop in Kerala. Chilli cultivation is economical only when the varieties used are resistant to both mosaic and bacterial wilt. At this juncture the present investigation is a holistic approach to enhance the productivity of chilli by developing wilt and mosaic resistant lines and hybrids.

5.1 Evaluation for bacterial wilt resistance

In the field evaluation where 53 accessions were tested the bacterial wilt incidence ranged from 8.34 to 88.88 per cent. The accessions CA 87 and CA 153 were severely affected by this dreadful disease (68.80 % and 88.88 % respectively).

Fifteen accessions including CA 745, CA 731, CA 219, CA 738, CA 337, CA 715, CA 739, CA 517, CA 714, CA 740, CA 716, CA 33, CA 744, CA 53 and CA 746 were found to be resistant to wilt. The check variety Pusa Jwala completely succumbed to bacterial wilt at the vegetative stage itself.

The resistance of Ujwala (CA 219) and Manjari (CA 33) to bacterial wilt was already reported by Gopalakrishnan and Peter (1991), Jyothi *et al.*, (1993) and Gopalakrishnan (1996). Peter (1984) reported the resistance of Pant C-1 (CA 53) to bacterial wilt over the four hot pepper varieties tested. The resistance of AVRDC lines viz., PBC 535 (CA 745), PBC 204 (CA 738), PBC 384 (CA 740), PBC 385 (CA 715) was also identified by Jawfen and Berke (1997).

5.1.1 Genetic cataloguing of chilli germplasm

Success of any crop improvement programme primarily depends on the extent of genetic variation and diversity in a crop. This is all the more true in the case of chilli, which is mostly a cross pollinated crop. To assess the extent of variation, fifty three chilli accessions collected from the various parts of the country and out side India were evaluated in a wilt sick soil during September 1997 to January 1998. The accessions showed significant variations for plant height, plant spread, days to first flower, days to first harvest, fruit length, fruit girth, pedicel length, number of fruits per plant, average fruit weight, fruit yield per plant, driage, number of harvests and total duration. The large variation observed in the population was a result of natural out crossing. The studies conducted by Rani *et al.* (1996a), Bhatt and Shan (1996), Ghildiyal *et al.* (1996) also revealed a wide range of variability for most of the characters in chilli indicating great scope for improvement.

The genotypic coefficient of variation (gcv) was high for fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant, suggesting that variability in these characters was due to genetic constitution. The results confirmed the earlier findings of Natarajan *et al.* (1993) and Rani *et al.* (1996a). In general the genotypic coefficient of variation was lower than phenotypic coefficient of variation (pcv) implying the possible role of environment on these traits.

Heritability was high for almost all the characters and it ranged between 0.71 to 1.00. The heritability estimates indicate high heritable portion of variability and the efficiency of selection for these characters. Similar results were reported by Elangovan *et al.* (1981).

The genetic gain for fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant, showed that these characters are governed by additive genes. The genetic gain was low for days to first flower, days to first harvest, driage and total duration indicating that expression of these characters were conditioned by non additive genes. These findings are in accordance with that of Bhagyalakshmi *et al.* (1990) and Rani *et al.* (1996 a).

Heritability with genetic gain was of more precise value, than the former alone in predicting the effect of selection. The heritability estimates were high and coupled with high genetic gain for fruit length. Fruit girth, number of fruits per plant, average fruit weight, and fruit yield per plant revealed the role of additive gene action in the expression of these characters which could therefore, be considered as reliable indices for selection. These results are in agreement with the earlier findings of Rani *et al.* (1996 a). High heritability with moderate genetic gain noticed for plant spread, days to first flower and number of harvests implied equal importance of additive and non additive gene action. Days to first harvest, driage, and total duration were found to have high heritability and low genetic gain revealing the non additive gene effect.

5.1.2 Correlation studies

A thorough knowledge of the relationship between yield and its component characters makes crop improvement more effective.

The results of the present study showed that genotypic correlation coefficients were higher than phenotypic correlation coefficients (Table 11 and 12). This might be due to the masking effect of environment in the total expression of the genotypes resulting in reduced phenotypic association. This is in line with the report of Nandpuri *et al.* (1970).

In the present investigations yield was significantly and positively correlated with plant height, days to first flower, days to first harvest, fruit length, pedicel length, and total duration at both phenotypic and genotypic levels. The results indicated that these traits had certain inherent relationship with yield and suggested their importance in determining fruit yield. This is in concurrence with the findings of Bhagyalakshmi *et al.* (1990), Thakur (1993) and Rani *et al.* (1996b)

Plant height expressed significant and positive association with yield which is in confirmation with the results obtained by Arya (1978) and Kaul and Sharma (1989). The component characters exhibited significant inter-relationship among themselves and indicated the likely consequences of selection for simultaneous improvement of desirable characters.

Similar *interse* association of yield contributing traits in chilli was also reported earlier by Vijayalakshmi *et al.* (1988), Bhagyalakshmi *et al.* (1990), Singh and Rajput (1992) and Thakur (1993).

5.1.3 Path coefficient analysis and step down regression analysis

The path coefficient analysis was worked out to get an insight into the direct and indirect effects of different characters on yield. The residual effect of 0.1755 revealed that 79.85 per cent of yield was contributed by the characters studied and thus indicated the adequacy of the characters. The average fruit weight and number of fruits exercised maximum direct effects on yield per plant indicating that these are the main contributors to yield. These results are in agreement with those of Kaul and Sharma (1989). The results suggested that due emphasis should be given to the genotypes having high average fruit weight and more number of fruits per plant in the selection process. Fruit length, plant height, fruit girth and plant spread also exerted considerable direct effect on yield revealing the scope for considering these characters in selection. The indirect effect of plant height through number of fruits per plant and average fruit weight, plant spread through average fruit weight; fruit length through average fruit weight; driage through number of fruits per plant were positive and high, which indicated that selection for any of these characters would indirectly improve the yield through associated characters.

5.2 Evaluation of genotypes for mosaic resistance

Screening of genotypes resistant to mosaic under artificial epiphytotic conditions exhibited that the nine accessions viz., CA 703, CA 337, CA 730, CA 731, CA 644, CA 737, CA 738, CA 739 and CA 744 were free from mosaic, indicating that the genotypes were either symptomless carriers or resistant ones. But as their sap failed to produce local lesions on *Chenopodium amaranticolor* these genotypes were rated as resistant. Holmes (1954) reported that resistance may be absolute constituting natural immunity or it may involve a tendency to escape infection despite artificial infection and thus genotypes may be considered as highly resistant.

Resistance of Punjab Lal and Perennial to mosaic has already been reported by Bansal *et al.* (1992). Resistance of lines Lorai and Perennial was confirmed by Sharma and Singh (1985). The resistance of accessions namely CA 737, CA 738, CA 739 and

Plate 7. CA 714 - Bacterial wilt resistant parent

Plate 8. CA 644 - Mosaic resistant parent

CA 744 also confirmed (personal communication). The chilli lines showing resistance to mosaic were originated from different geographical regions. It is possible that each of this line carry different genes for virus resistance. However, complementation studies among these resistance lines is required to determine whether such lines carry different genes for resistance. If that is the case, the gene for resistance can be combined in one line to obtain a more durable resistance.

A set of twelve accessions showed moderate infection under artificial inoculation. They were CA 696, CA 710, CA 715, CA 734, CA 725, CA 53, CA 733, CA 33, CA 219, CA 740, CA 745 and CA 746. Pant C 1 was rated as moderately resistant by Bansal *et al.* (1992). Dhawan *et al.* (1996) reported Hisar Vijay as a multiple disease resistant variety. Singh (1973) and Rathaiah (1983) found the chilli line Suryamukhi as tolerant to all diseases including mosaic. Holmes (1954) has made revelation that the genotypes have a sufficient degree of tolerance which may be either due to partial suppression of viral multiplication or suppression of systemic spread or both.

Among the 53 accessions screened for bacterial wilt and mosaic resistance five accessions viz., CA 337, CA 731, CA 738, CA 739 and CA 744 were found to possess the resistance to both the diseases. So these accessions as such can be recommended for cultivation under disease prone conditions of Kerala.

5.3 Development and evaluation of F_1 hybrids for bacterial wilt and mosaic resistance

The F_1 hybrids were developed using CA 714 a line with resistance to bacterial wilt but susceptible to mosaic (Plate 7) and CA 703 and CA 644 both resistant to mosaic but susceptible to bacterial wilt (Plate 8). The susceptibility of the F_1 hybrids to both bacterial wilt and mosaic showed the inability of the parents to transfer the genes which impart the resistance. This points to the fact that all the three parents used in the hybridization programme possess recessive genes for resistance. Earlier Dutta and Kishun (1982) and Manjunath and Dutta (1987) identified the recessive nature of genes towards bacterial wilt resistance in chilli. Cook and Anderson (1959), Zitter and Cook (1973), Bal *et al.* (1995) and George (1998) also reported that the resistance to mosaic was controlled by a single homozygous recessive gene.

All the F_1 progenies were found susceptible to both the diseases, as the resistance is controlled by recessive genes which could not be expressed in a heterozygous condition. Under such circumstances, in order to transfer resistance to the both diseases to a single agronomically superior variety, the F_1s should be backcrossed separately to both the parents. To start with, the bacterial wilt resistant parent will be taken as the donor parent and backcrossing will be done with the agronomically superior parent. With the repeated alternate backcrossing and selfing up to BC_5 to BC_6 generation recessive resistant gene will be tranferred to the agronomically superior variety. As the next step the mosaic resistant parent will be crossed as the donor with the newly developed wilt resistant parent. With the repeated alternate backcrossing and selfing the recessive mosaic resistant gene will be transferred to the newly developed bacterial wilt resistant parent. Thus both the disease resistant genes will be brought together in a single agronomically superior variety.

Summary

SUMMARY

The present investigation on "Screening of chilli (*Capsicum annuum* L.) genotypes for resistance to bacterial wilt and mosaic" was conducted at the vegetable research farm of the Department of Olericulture, College of Horticulture, Vellanikkara during 1997-'98.

Fifty three chilli accessions collected from India and abroad were evaluated in the wilt sick soil during September 1997 to January 1998. The chilli accessions showed different levels of resistance to bacterial wilt. Fifteen accessions were found resistant with the wilt incidence below 20 per cent. The minimum wilt incidence was noticed in CA 745 (PBC 535). Sixteen accessions were moderately resistant with the wilt incidence between 20 and 40 per cent. Thirteen accession were moderately susceptible with the wilt incidence between 40 and 60 per cent. Nine accessions were regarded as susceptible with the wilt incidence above 60 per cent. The accession CA 153 (CA 960) recorded the highest wilt incidence of 88.88%. Based on fruit length, the 15 resistant accessions were classified into short, medium long and long as per Smith *et al.* (1987). Nine accessions viz., CA 337, CA 53, CA 731, CA 33, CA 219, CA 517, CA 738, CA 739 and CA 746 were rated as short fruited with the fruit length between 5 and 7.5 cm. The accession CA 745 was found to be medium long with the fruit length between 7.5 and 10 cm. Remaining five accessions namely CA 714, CA 715, CA 716, CA 740 and CA 744 were observed as long fruited with fruit length between 10 and 15 cm.

The chilli crop raised for the evaluation of bacterial wilt resistance was catalogued as per IBPGR descriptor list for *Capsicum*. The accessions showed significant differences for most of the characters studied viz., plant height, plant spread, days to first flower, days to first harvest, fruit length, fruit girth, pedicel length, number of fruits per plant, average fruit weight, fruit yield per plant, driage, number of harvests and total duration.

The earliest flowering genotype was CA 715 (59 days). The genotype CA 728 is highly promising which recorded the highest average fruit weight (6.78 g), maximum fruit yield per plant (352.75 g) and maximum plant height (90.65 cm). The longest fruits were produced by CA 755 (12.82 cm). The accession CA 731 produced the shortest fruits, maximum number of fruits per plant (108.50) and maximum driage (22.93 %). The

accession CA 94 recorded the longest duration and continued to yield up to 210 days and CA 758 recorded the shortest duration of 166.50 days.

The 53 accessions of chilli were grouped into seven clusters. Inter-cluster distance was higher than intra-cluster distance indicating homogeneity within the clusters and heterogeneity between clusters. Therefore it is possible to exploit heterosis in chilli.

The genotypic and phenotypic coefficient of variation was maximum for the character, fruit yield per plant (29.28, 29.36 respectively) and minimum for total duration (4.5 and 4.59 respectively). Heritability was high for almost all the characters. High heritability along with high genetic gain was observed for fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant. Days to first harvest, driage and total duration were found to have high heritability but low genetic gain.

The characters having significant positive correlation with yield were plant height, days to first flower, days to first harvest, fruit length, pedicel length and total duration. The fruit girth was non-significant and negatively correlated with yield. The highest positive correlation with yield was expressed by the total duration (0.576). Average fruit weight exhibited the highest positive direct effect on fruit yield followed by number of fruits per plant and fruit length.

All the chilli accessions screened for bacterial wilt resistance were utilized for evaluation of mosaic resistance. Out of 53 accessions tested only nine showed resistance with the disease score of one. Another twelve accessions showed moderate infection with the disease score between 1 and 2. Remaining 32 accessions were found susceptible with the disease score between 2 and 3.

The resistance of the above said nine accessions were confirmed by the following three confirmation studies namely inoculation on the indicator plant, graft transmission and back inoculation. Among the 53 accessions screened for bacterial wilt and mosaic resistance, five accessions namely CA 337, CA 731, CA 738, CA 739 and CA 744 were found to possess resistance to both the diseases. So these accessions as such can be recommended for cultivation under disease prone areas of Kerala. The F_1s developed using the resistant parents were found susceptible to both bacterial wilt and mosaic.

References

REFERENCES

Abeygunawardena, D.V.M. and Siriwardena, A.A.P. 1963. Studies on resistance in tomato to bacterial wilt. *Trop. Agric.* **119**: 55-66

Aillaud, G.1971. Study of floral malformations observed on *Capsicum annuum* L., after inoculation with cucumber virus-1. *Annalos de Universite de Province Sciences*, 46:39-47

Allen, C., Simon, L., Atkinson, M. and Sequeria, L. 1993. Analysis of polygalucturonase as component of bacterial wilt disease. *Proc. ACIAR* **45**: 238-244

Anjaneyulu, A. and Apparao, A. 1967. Natural occurrence of cucumber mosaic virus on chilli. *Indian Phytopath.* **20**: 380 – 381

Aragaki, M and Quinon, V.L. 1965. Bacterial wilt of ornamental ginger(*Hedychium* spp.) caused by *Pseudomonas solanacearum. Pl. Disease Rep.* **49**: 378-379

Ariyaratne, I., Hobbs, H.A., Valverde, R.A., Black, L.L. and Dufresne, N.J. 1996. Resistance of *Capsicum* spp. genotypes to Tobacco Etch Poty virus isolates from Western Hemisphere. *Pl. Disease* **80**: 1251-1261

Arora, S.K., Pandita, M.L., Pratap, P.S., Malik, Y.S., Mehra, R., Dhawan, P. and Gandhi, S.K. 1996. Hissar Vijay and Hissar Shakthi, two new varieties of chilli. *Haryana agric. Univ. J. Res.* **26**: 227-235

Arya, P.S. 1978. Correlation and regression studies in peppers. (*Capsicum* spp L.). *Madras agric. J.* **65**: 771-774

Ashrafuzzaman, H. and Islam, T. 1975. Bacterial wilt in tomato-a review. *Bangladesh Hort.* **3**: 37-44

AVRDC. 1990. *Progress Report.* Asian vegetable Research and Development Centre, Taiwan p.54-56

AVRDC. 1993. *Progress Report.* Asian Vegetable Research and Development Centre, Taiwan p.123-128

Bal, S.S., Singh, J. and Dhanju, K.C. 1995. Genetics of resistance to mosaic and leaf curl viruses in Chilli. *Indian J. Virol.* **11**: 77-79

Bansal, R.D., Aulakh, R.K. and Hundal, J.S. 1992. Reaction of different genotypes of pepper (*Capsicum annuum* L.) to cucumber mosaic virus. *Capsicum Newsl.* **11**: 132 -137

Barrior, E.P., Mosokar, H.I. and Black, L.L. 1971. Inheritance of resistance of TEV and CMV in *Capsicum frutescens*. *Phytopathology* **61**: 1318

Bell, A.A. 1981. Biochemical mechanism of disease resistance. *A. Rev. Pl. Physiol.* **32**: 21-81

Betti, L., Tanzi, M. and Canova, A. 1986. Genes for resistance to TMV in *Capsicum* sp. Proceedings VIth meeting on genetics and breeding on capsicum and eggplant. Zaragoza, Oct 21-24 pp. 173-176

Bhagyalakshmi, P.V., Ravishankar, C., Subramanyam, D. and Babu, V.G. 1990. Study on heritability, genetic advance and character association in chilli. *South Indian Hort.* **38**: 15-17

Bhatt, J.P. and Shan, N. 1996. Genetic variability in hot pepper. (*Capsicum* spp.) *Recent Hort.* **3**: 79-81

Bidari, V.B. 1982. Distribution and epidemology of chilli viruses in Karnataka. Ph.D. thesis, University of Agricultural Sciences, Bangalore

Bidari, V.B. and Reddy, H.R. 1991. Incidence of chilli mosaic and its distribution in the commercial fields of Karnataka. *J. Plantation Crops.* **19**: 21-25

Bidari, V.B. and Reddy, H.R. 1994. A Survey on mosaic viruses and their distribution in different chilli cultivars in Karnataka. *Mysore J. agric. Sci.* **28**: 52-59

Bosch, S.E., Louw, A.J. and Aucamp, E. 1985. Rodade - Bacterial wilt resistant tomato. *Hort. Sci.* **20**: 458-459

Bral, S.S., Rewal, H.S., Singh, D. and Hundas. 1989. Screening of indigenous germplasm of chilli against virus disease in the south western region of Punjab. *Pl. Disease Res.* **4**: 180

Brown, J.K. and Poulos, B.T. 1990. Serrano golden mosaic virus a newly identified white fly transmitted Gemini virus of pepper and tomato in the United States and Mexico. *Pl. Disease.* **74**: 720

Buddenhagen, I.W. and Kelman, A. 1964. Biological and physiological aspects of bacterial wilt caused by *Pseudomonas solanacearum. A. Rev. Phytopath* **2**: 203-226

Buddenhagen, I.W., Sequeria, L. and Kelman, A. 1962. Designation of races of *Pseudomonas solanacearum. Phytopathology* **52**: 726

Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassld. Cong.* **1**: 277-283

Burton, G.W. and Devane, E.H. 1953. Estimating heritability in tall fescue from replicated clonal material. *Agron. J.* **45**: 478-481

Chattopadhyay, S.B. and Mukherjee, K. 1969. Bacterial wilt of potato in West Bengal. *Bull. bot. Soc. Bengal* **23**: 11-15

Chauhan, S.V.S., Srivastava, J.N. and Kinoshita, T. 1981. Histological and histochemical changes in the anthers of some diseased vegetable crops. *J. Fac. Agric. Hokkaido, Univ.* **60**: 152-157

Chester, K.S. 1950. Nature and Prevention of Plant Disease 2nd ed., McGraw Hill Book Co. Inc., New York, p. 525

Choi, K.S., Pae, D.H., Om, Y.H. and Lee, C.H. 1988. Studies on the breeding of disease resistance in red pepper(*Capsicum annuum* L.). *Res. Rep. Rural Rev. Administration Hort.* **30**:1-8

Chowfla, S.C. and Sharma, P.N. 1990. Management of bell pepper mosaic disease complex in H.P. *Indian Phytopath.* **43**: 349-351

Chupp, C. and Sherf, A.F. 1960. *Vegetable Diseases and their Control.* The Ronald Press Co., New York, p. 695

Conti, M., Caciagli, P. and Casetta, A. 1979. Infection sources and aphid vectors in relation to the spread of cucumber mosaic virus in pepper crops. *Phytopath Mediterranea* **18**: 123-128

Cook, A.A. 1960. Genetics of resistance in Capsicum annuum to two virus diseases. *Phytopathology.* **50**: 364-367

Cook, A.A. 1961. A mutation for resistance to potato virus Y. *Phytopathology.* **51**: 550-552

Cook, A.A. 1962. Isolation of a mutant strain of PVY. *Pl. Disease Rep.* **46**: 569

Cook, A.A. 1963. Genetics of response in pepper to three strains of Potato Virus Y. *Phytopathology* **53**: 720-722.

Cook, A.A. 1977. Breeding for disease resistance in pepper in Florida. *Circ. Fla Agric. Exp. Stn* **251:** 8-10

Cook, A.A. and Anderson, C.W. 1959. Multiple virus resistance in a strain of *Capsicum annuum. Phytopathology* **49**: 198-201

Cook, A.A., Zitter, T.A. and Ozaki, H.Y. 1977 Detray Bell, a virus resistant pepper for Florida. *Circ. Fla Agric. Exp. Stn* **251**: 1-5

Cook, D.R. and Sequeira, L. 1988. The use of Restriction Fragment Length Polymorphism (RFLP) Analysis in taxonomy and Diagnosis. *Bacterial wilt Newsl.* **4**: 4

Cordrey, T.D. and Bergman, E.I. 1979. Influence of CMV on growth and elemental composition of susceptible (*C. annuum*) and resistant (*C. frutescens*) peppers. *J. Am. Soc. hort. Sci.* **104**: 505-510

Coyne, D.P. and Schuster, M.L. 1983. Genetics and breeding for resistance to bacterial pathogen in vegetable crops. *Hort. Sci.* **18**: 30-36

CPRI, 1974. *Scientific Report of Central Potato Research Institute for the triennium 1971-1973.* Central Potato Research Institute, Simla pp. 120-125

Deom, C.M., Murphy. J.F. Paguio, O.R. 1997. Resistance to TEV in *Capsicum annuum* inhibition of virus RNA accumulations. *Molecular Plant microbe Interactions* **10**: 917-921

Devi, R. 1978. Bacterial wilt of tomato in Kerala - Host range and survival of the pathogen and control. Ph.D. thesis, Kerala Agricultural University, Thrissur

Dhawan, P., Dang, J.K., Sangwan, M.S. and Arora, S.K. 1996. Screening of chilli cultivars and accessions for resistance to cucumber mosaic virus and potato virus Y. *Capsicum and Eggplant Newsl.* **15**: 55-57

Doolittle, S.P. and Walker, M.N. 1923. Cross inoculation studies with cucurbit mosaic. *Science N. S.* **57**: 477

Doolittle, S.P. and Walker, M.N. 1925. Further studies on overwintering and dissemination of cucurbit mosaic. *J. agric. Res.* **31**: 1-58

Dubey L.N. and Joshi R.D. 1974. Transmission of mosaic disease by aphid (*Aphis gossypii*). *Phytopathology* **66**: 213-215

Dutta, O.P. and Kishun, R. 1982. Part B. Breeding brinjal for yield, quality and resistance to bacterial wilt (*Pseudomonas solanacearum*). *ICAR A. Rep. IIHR*, Bangalore, pp. 30-36

Eastop. 1985. Aphid vectors in relation to the spread of mosaic disease in pepper. *Phytopath. mediterranea.* **24**: 127-130

Elangovan, M., Suthanthirapandiyan. I.R. and Syed, S. 1981. Genetic variability in certain metric traits of (*Capsicum annuum* L. Var. *grossum*). *Indian J. agric. Sci.* **43**: 918-921

Fegla, G.I. Shawkat, A.L.B. and Mohammed, S.V. 1981. Certain viruses affecting cowpea and their effect on growth and root nodulation of cowpea plants. *Mesopotamia J. Agric.* **16**: 137-152

Ferrer, Z.A. 1976. Resistance to *Pseudomonas solanacearum* in *Lycopersicon esculentum*. *Diss. Abstr. Intl. B.* **36**: 517-518

Gahukar, K.B. and Nariani, T.K. 1982. Studies on an aphid borne mosaic disease of chilli. *Indian Phytopath.* **35**: 73-79

Geetha, P.T. and Peter, K.V. 1993. Bacterial wilt resistance in a few selected lines and hybrids of brinjal (*Solanum melongena*). *J. trop. Agric.* **31**: 274-276

George, T.E. 1989. Breeding for virus resistance in bell pepper. Ph. D. thesis, University of Agricultural Sciences, Bangalore

George , T.E. 1998. *Final Research Report of ICAR Adhoc Scheme on Breeding for Resistance to Mosaic Viruses in Chilli (Capsicum annuum L.).* RARS, Pttambi

George, T.E. and Anand, N. 1991. Breeding for resistance to cucumber mosaic virus (CMV) in bell pepper (*Capsicum annuum* L). Proceedings on Third Kerala Science Congress, Kozhikode pp. 65-67

George, T.E., Anand, N. and Singh, S.J. 1993. Isolation and identification of two major viruses infecting bell pepper in Karnataka. *Indian Phytopath.* **46**: 24-28

George, V.C. 1973. Effect of inter planting cowpea (*Vigna sinensis)* and the application of streptomycin and other chemicals on the wilt disease of Chillies (*Capsicum* spp.) caused by *Pseudomonas solanacearum* and on the rhizosphere micro flora. M.Sc (Ag) thesis, University of Kerala.

Ghildiyal, S.C., Solanki, S.S. and Mishra, Y.K. 1996. Variability studies in different varieties of sweet pepper. (*Capsicum annuum* L). *Recent Hort.* **3**: 76-78

Gillorteg, R., Arteaga, L.M., Ortega, R.G. and Arteaga, M.L. 1988. Response of pepper to two Spanish isolates of CMV. *Capsicum Newsl.* **7**: 7

Gopalakirishnan, T.R. 1996. Ujwala a bacterial wilt resistant chilli variety. *ICAR Sci. Technol. Newsl.* **2**: 23

Gopalakrishnan, T.R. and Peter, K.V. 1991. Screening and selection for bacterial wilt resistance in chilli. *Indian J. Genet. Pl. Breeding* **51**: 332-334

Gopimony, R. 1983. Genetic studies in brinjal with relation to bacterial wilt resistance. Ph.D thesis, Kerala Agricultural University, Thrissur

Gopinath, G..and Madalageri, B.B. 1986. Bacterial wilt (*Pseudomonas solanacearum* E.F. Smith.) resistance in egg plant . *Veg. Sci.* **13**: 189-195

Goth, R.W., Peter, K.V. and Webb, R.E. 1983. Bacterial wilt (*Pseudomonas solanacearum*) resistance in pepper and egg plant lines. *Phytopathology* **73**: 808

Granda, G.A. and Sequeria, L. 1983. Survival of *Pseudomonas solanacearum* in soil, rhizosphere and plant roots. *Canadian J. Microbiol.* **29**: 433-440

Grimault, V. and Prior, P. 1994. Invasiveness of *Pseudomonas solanacearum* in tomato, egg plant and pepper a comparative study. *European J. Pl. Path.* **3**: 259-267

Hameed, S., Khan, M.A. and Khalid, S. 1993. Screening of *Capsicum* sp. for TMV resistance. *Pakist. J. Phytopath.* **5**: 78-81

Hayward, A.C. 1964. Characteristics of *Pseudomonas solanacearum. J. appl. Bact.* **27**: 265-277

He, L.Y., Sequeria, L. and Kelman, A. 1983. Characteristics of strains of *Pseudomonas solanacearum* from China. *Pl. Disease Rep.* **67**: 1357-1361

Holmes, F.O. 1937. Inheritance of resistance to tobacco mosaic disease in the pepper. *Phytopathology* **27**: 637-642

Holmes, F.O. 1954. Inheritance of resistance to viral disease in plants. *Adv. Virus Res.* **2**: 1-30

Horvath, J. 1967. Differences in virulence of different strains and isolates of PVY on species and varieties of *Capsicum. Acta Phytopathol.* **2**:17-37

Hundal. J.S., Khurana, N.S. and Kaur, S. 1995. Punjab Surkh a new high yielding variety of chilli. *J. Res. Punjab agric. Univ.* **32**: 240

ICAR. 1969. *Annual Report.* Indian Council of Agricultural Research, New Delhi, pp.23-38

Jawfen, W. and Berke, T. 1997. Sources of resistance to bacterial wilt in *Capsicum annuum. Bacterial wilt Newsl.* (14): 3-4

Jeyarajan, E. and Ramakrishnan, K. 1969. Potato virus on chilli (*Capsicum annuum*) in Tamil Nadu. *Madras agric. J.* **56**: 761-766

Jeyarajan, E. and Ramakrishnan, K.1971. Studies on physiology of chilli (*Capsicum annuum*). Plants affected by potato virus Y II. Effect of water relation mineral metabolism and photosynthetic pigments. *Madras agric. J.* **58**: 213-217

Jha, A. and Raychaudhuri, S.P. 1956. Mosaic diseases of chilli (*Capsicum frutescens* L.) *Indian J. agric. Sci.* **26**: 217-222

Jimenez, T.M., Bustanante, E., Bermudez, W. and Gamboa, A. 1988. Response of four cultivars of sweet pepper to bacterial wilt in Costa Rica. *Manejo Integrado de plagas.* 7: 19-28

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soyabeans. *Agron. J.* **47**: 314-318

Joshi, R.D. and Dubey, L.N. 1976. Effect of cucumber mosaic virus infection on growth, moisture and dry matter content in chilli. *Indian phytopath.* **29**: 238-240

Jyothi, A.R., Abraham, K. and Mathew, J. 1993. Bacterial wilt of chillies in Kerala and reaction of certain chilli accessions to *Pseudomonas solanacearum* E.F. smith. *Bacterial wilt Newsl.* **9**: 6

Kandaswamy, T.K., Janaki, I,P., Ramakrishnan, K., Thangamani, G., Raju, S.K.T. and Sellammai, S. 1963. A preliminary note on virus diseases of chilli in Madras state. *Madras agric. J.* **50**: 110

KAU, 1989. *Final Research Report of ICAR Adhoc scheme on Breeding for resistance to bacterial wilt in chilli and brinjal.* Department of Olericulture, Kerala Agricultural University, Thrissur

KAU, 1996. *Packagae of Practices Recommendations 'Crops'.* Kerala Agricultural University, Thrissur p.176-177

Kaul, B.L. and Sharma, P.P. 1989. Correlation and path coefficient analysis studies in bell pepper (*Capsicum annuum* L.). *South Indian Hort.* **37**: 16-18

Kelman, A. 1953. The relationship of pathogenicity of *Pseudomonas solanacearum.* A literature review and bibliography. *N. Carol. agric. Expt. Stn tech. Bull.* **99**:194

Kelman, A. and Cowling, E.B. 1965. Cellulose of *Pseudomonas solanacearum* in relation to pathogenesis. *Phytopathology* **55**: 148-158

Khan, A.N.A., Shetty, K.S. and Patil, R.B. 1979. Occurrence of bacterial wilt of chilli in Karnataka and its relationship to the wilts of other solanaceous crops. *Indian Phytopath.* **32**: 507-572

Konai, M. and Nariani, T.K. 1980. Reaction of different chilli varieties and *Capsicum* species to mosaic and leaf curl viruses. *Indian phytopath.* **33**: 155

Kostova, D. and Todorov, I. 1986. Some problems of breeding for resistance to Tobacco Mosaic Virus (TMV) in red pepper. *Prva natsionalna konferentsiya po inunogenetika na rasteniyata, Sofiya,* 24-25 Yuri pp.51-55

Kovachevsky, I.C. 1940. Die Reisigkrankheit der paprikapflanzen (*Capsicum annuum*). *Z. pflkarakh* **50**: 289-308

Kuc, J. 1964. Phenolic compounds and disease resistance in plants. Phenolics in Normal and Diseased Fruits and Vegetables. *Pl. phenolic group of N. Am. Symp. Proc.* (Ed. Runnecklar, V.C.) Imperial Tobacco Co., Montreal. pp. 63-81

Kulkarni, G.S. 1924. Mosaic and other related diseases of crops in Bombay presidency. *Poona agric. Coll. Mag.* **16**: 6-12

Kumar, S. 1995. Incorporation of resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato. Ph.D. thesis, Kerala Agricultural University, Thrissur

Kumar, V. Singh, B.M. and Sugha, S.K. 1993. Variation in isolates of *Pseudomonas solanacearum* from Himachal Pradesh. *Indian J. Mycol. Pl. Path.* **23**: 232-236

Kuriyama, T. 1975. Testing methods for breeding disease resistant vegetables in Japan. *JARQ* **9**: 96-100

Lalman, A. and Tewari, J.P. 1977. Effect of cucumber mosaic virus on the productivity of *Capsicum annuum. Ceobios* **4**: 40

Lane, R.P., Mc Carter, S.M., Kuhn, C.W. and Deom, C.M. 1997. Dempsey a virus and bacterial spot resistant bell pepper. *Hort. Sci.* **32**: 333-334.

Lovisolo, O. and Cont, M. 1976. Viruses and virus diseases of pepper. *India Agricola.* **113**: 90-103

Luo, H.Y., Du, Z.O., Cheng, X.N. and Pu, F.H. 1989. Alate aphid species and their relative importance as field vectors of virus disease of pepper. *Acta Agriculturae Shanghai* **5**: 33-36

Mahalanobis, P.C. 1928. A statistical study at chinese head measurements. *J. Asiatic Soc. Bengal* **25**: 301-377

Manjunath, K.N. and Dutta, O.P. 1987. Genetics of bacterial wilt (*Pseudomonas solanacearum E.F.* Smith) resistance in brinjal (*Solanum melongena* L.) *ICAR A. Rep.* IIHR, Bangalore, p.126

Marchoux, G., Pochard, E. and Selassie, K.G. 1983. New perspectives on control of the viruses affecting peppers (*Capsicum annuum* L) *Mededelingen Van de Facultieit Land bouwwetenschappxen Ri Jk Suniversitiet Gent.* **48**: 847-858

Mathai, P.J., Dubey, C.S., Peter, K.V., Saklani, V.D. and Singh, N.P. 1977. Pant C-1 and Pant C-2 two new promising selections of chilli. *South Indian Hort.* **25**: 123-125

Matos, F.S.A., Lopes, C.A. and Takatsu, A. 1990. Identification of sources of resistance to *Pseudomonas solanacearum* in *Capsicum* sp *Horticultura Brasileria.* **8**: 22-23

Matsunaga, H. and Monma, S. 1995. Varietal differences in resistance to bacterial wilt in related species of *Capsicum annuum Capsicum and Egg plant Newsl.* **14**: 60-61

Matsunaga H., Sakata, V. and Monma, S. 1993. Screening sweet pepper accessions for resistance to bacterial wilt. *Capsicum and Eggplant Newsl.* **12**: 72-75

Mcrae, W. 1924. Economic Botany part III, mycology. *A. Rep. Bd Sci. Advice India.* **23**: 31-35

Mew, T.W. and Ho, W.C. 1976. Varietal resistance to bacterial wilt in tomato. *Pl. Disease Rep.* **60**: 264-268

Miladinovic, Z., Mijatovic, M. and Aleksic, Z. 1985. Reaction of some sublines of interspecies hybrids of *Capsicum* to CMV. *Zastita Bilja.* **36** :33-38

Miladinovic, Z., Stevanovic, D., Mijatovic, M. and marinkovic, N. 1989. Proceedings on Eucarpia VIIth meeting on genetics and breeding on *Capsicum* and eggplant. Kragujevac, Yugosiavia, 27-30 June 1989 pp. 203 205

1993.

Monma, S. and Sakata, Y. Inheritance of resistance to bacterial wilt in tomato. *Proc. ACIAR* **45**: 149-153

Nagai, H. 1968. Breeding sweet pepper varieties resistant to mosaic. *Bragantia* **27**: 311-353

Nagai, H. 1984. Breeding Capsicum for virus resistance. *Informe Agropacuario.* **10**: 55-58

Nandpuri, K.S., Gupta, V.P. and Thakur, P.C. 1970. Correlation studies in chillies. *J. Res. Punjab agric. Univ.* **7**: 501-503

Narayanan, K.K. 1984. Evaluation of intervarietal hybrids of brinjal for yield and resistance to bacterial wilt. MSc.(Ag.) thesis, Kerala Agricultural University, Thrissur

Natarajan, S. Gomathinayagam and David P.M.M 1993. Studies on variability in chilli. *Madras agric. J.* **80**: 388-390

Nicklow, C.W. and Haezebrouck, C.P. 1987. Cucumber mosaic virus resistance in *Capsicum annuum* L. – an update. *Capsicum Newsl.* **7**: 63-64

Nirmaladevi, S. 1987. Studies on genetic resistance to bacterial wilt (*Pseudomonas solanacearum* E.F. Smith) and root knot nematode (*Meloidogyne incognita*) in tomato (*Lycopersicon esculentum* Mill.). Ph.D thesis, University of Agricultural Sciences, Bangalore

Pahlen, A.V.N. 1975. Inheritance of resistance to PVY in pepper. *Miselanea Faculdad de Agronomia Y Zootecnia Universidad Nacional de Tucuman.* **54**: 69-74

Panse, V.K. and Sukhatme, P.V. 1978. *Statistical Methods for Agriicultural Workers.* 3rd ed., ICAR, New Delhi, pp. 347

Peter, K.V., Goth, R.W. and Webb, R.E. 1984. Indian hot peppers as new source of resistance to bacterial wilt, Phytophthora root rot and root knot nematode. *Hort. Sci.* **19**: 277-278

Piccirillo, P., Nervo, G. and Porrone, F. 1997. Reaction of genotypes of *Capsicum* sp. to CMV, TMV and TOMV. *Iinformatore Fitopatologico.* **47**: 58-62

Pious, T. 1985. Transfer of clusterness to bell peppers (*Capsicum annuum* L. var. *grossum* Sendt). M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur

Pochard, E. 1977a. Methods for studying partial resistance to CMV in red pepper Capsicum 77. *Third Eucarpia Congress* Avignon – Montfavet, France. 93-104

Pochard, E. 1977 b. Study of resistance of pepper to european strains of PVY Capsicum 77. *Third Eucarpia Congress.* Avignon- montfavet. France. pp. 109-118

Pochard, E. 1982. A major gene with quantitative effect on two different viruses. *Capsicum Newsl.* **1**: 54-56.

Quezado, A.M. and Lopes, C.A. 1995 Stability of the resistance to bacterial wilt of the sweet pepper 'MC –4' challenged with strains of *Pseudomonas solanacearum. Fitopatholegia Brasileria.* **20**: 638-641

Rahim, M.A. 1972. Studies of bacterial wilt of chillies with special reference to varietal resistance, control and changes that are brought about in rhizosphere micro flora. M.Sc(Ag) thesis. University of Kerala

Rajan, S. and Peter, K.V. 1986. Incomplete dominance of bacterial wilt resistance. *Tomato Genet. Coop. Rep.* **36**: 24

Ramakrishnan, K. 1959. Potato virus x on chilli (*Capsicum* spp.). *South Indian Hort.* 7:41-52

Rani, K. Natrajan, S. and Thamburaj, S. 1996a. Genetic variability in chilli (*Capsicum annuum* L) *South Indian Hort.* **44**: 68 –70

Rani, K. Natrajan, S. and Thamburaj, S. 1996b. Correlation and pathanalysis in chilli. (*Capsicum annuum* L.). *South Indian Hort.* **44**: 8-11

Rao, C.R. 1952. *Advanced Statistical Methods in Biometrical Research.* John Wiley and Sons Ltd., London p. 301

Rao, M.V.B. 1972. Bacterial wilt due to *Pseudomonas solanacearum* (Ed. Patel, P.N.) *Bacterial Diseases of Plants in India.* Indian Agricultural Research Institute, New Delhi, p. 68

Rao, P R.D.V.J. 1976. Characterization and identification of some chilli mosaic viruses Ph.D thesis. University of Agricultural Science. Bangalore

Rao, P.R.D.V.J., Yaraguntiah, R.C. and Govindu, H.C. 1980. Reaction of chilli (*Capsicum* spp.) cultures varieties and species to six chilli mosaic viruses. *Mysore J. agric. Sci.* **14**: 11-14

Rathaiah, Y. 1983. Yield and reaction to fruit rot bacterial wilt and cercospora leaf spot of chilli cultivars. *J. Res. Assam agric. Univ.* **4**: 31-33

Saccardo, F. 1974. Sources of resistance to CMV in the genus *Capsicum*. *Genet. Agric.* **28**: 97-104

Sangar, R.B.S., Katware, T.R., Saraf, R.K. and Parihar, M.S. 1988. Field screening of chilli varieties to viral diseases in Madhya Pradesh. *Fm Sci. J.* **3**: 69-71

Schell, M.A., Roberts, D.P. and Denny, T.P. 1988. Analysis of *Pseudomonas solanacearum* Polygalacturonase encoded by Pgl 1 A and its involvement in phytopathogenicity. *J. Bact.* **170**: 4501-4508

Sciumbato, G.L. 1973. Studies on viruses infecting pepper (*Capsicum* sp.) in Louisiana. Ph.D. thesis, Louisiana State University, Baton Rouge

Sequeria, L. 1993. Bacterial wilt: Past, Present and Future. *Proc. ACIAR* **45**: 12-21

Sharma, O.P. and Singh, J. 1985. Reaction of different genotypes of pepper to cucumber mosaic and tobacco mosaic viruses. *Capsicum Newsl.*. **4**: 47

Shekhawat, G.S., Singh, R. and Kishore, V. 1978. Distribution of bacterial wilt and races and biotypes of pathogen in India. *J. Indian Potato. Assoc.* **5**: 155-165

Shifriss, C and Cohen, C. 1986. Resistance to Cucumber Mosaic Virus (CMV) and a linkage with small fruit size. *Capsicum Newsl.* **5**: 48

Shifriss, C. and Cohen, C. 1987. A. Progress in breeding for resistance to CMV in pepper. *Capsicum Newsl.* **6**: 60

Simons, T.N. 1955. Some plant vector-virus relationship of southern celery mosaic virus. *Phytopathology* **45**:217-219

Singh, B. and Rajput, C.B.S. 1992. Component analysis in chillies. *Prog. Hort.* **24**: 32-37

Singh, B.R., Gupta, S.P., Panday, R. and Tripathy, D.F. 1990. Response of some chilli lines to mosaic. *Indian. J. Virol.* **6**: 113-115

Singh, J. and Kaur, S. 1986. Present status of hot pepper breeding for multiple disease resistance in Punjab. Proceedings on VI Eucarpia meeting on Genetics and Breeding in Capsicum and Egg Plant, Spain, 21-24 Oct., pp. 174-180

Singh, J. and Thakur, M.R. 1977. Genetics of resistance to TMV, CMV and Leaf Curl Virus in hot pepper Capsicum 77. *Third Eucarpia Congress.* Avignon – Montfavet, France, pp.119-126

Singh, S. and Chenulu, V.V. 1985. Studies on resistance to virus diseases in *Capsicum* species III. Inheritance of resistance to PVY. *Indian Pythopath.* **38**: 479-483

Singh, S.J. 1973. Reaction of chilli varieties (*Capsicum* spp.) to mosaic and leaf curl viruses under field conditions. *Indian J. Hort.* **30:** 444-447

Singh, S.S., Singh, H.B. and Patel, K.K. 1996. Effect of chilli mosaic virus infection on total yield of chilli variety Jwala in Faizabad. *J. Living World* **3**: 5-8

Smith, E.F. 1896. A bacterial disease of the tomato eggplant and Irish Potato. (*Bacillus solanacearum*) U.S. *Dept. Agric. Div. Veg Phvs. Path. Bull.* 12: 1-28

Smith, P.G., Villalon, B. and Villa, P.L. 1987. Horticultural clasification of pepper grown in United States. *Hort. Sci.* **22**: 11-13

Sohi, H.S., Rao, M.V.B., Rawat, R.O. and Keshun, R. 1981 Effect of crop rotation on bacterial wilt of tomato and eggplant. *Indian J. agric. Sci.* **51**: 572-573

Sreelathakumari, I. 1983. Incorporation of two main sources of resistance to bacterial wilt in F_1 generation of tomato (*Lycopersicon lycopersicum* [L.] Karst.). M.Sc.(Ag.) thesis, Kerala Agricultuural University, Thrissur

Swaminathan, M. and Sreenivasan, K. 1971. Studies on brinjal hybridization. II. Transferencne of bacterial wilt resistance from a wild brinjal variety to cultivated brinjal varieties. *Agric. Res. J. Kerala* **9**: 11-13

Tanzi, M., Betti, L. and Canoova, A., 1986 comparison of flowering and early yield in susceptible and resistant pepper cvs. infected by a TMV pepper strain. *Capsicum Newsl.*. **5:** 46-47

Tewari, V.P. 1991. A multipurpose perennial chilli-Pusa Sadabahar. *Indian Hort.* **35**: 29

Tewari, V.P. and Anand, O.P.S. 1977. Incorporation of virus resistance in improved chillies. *Madras agric. J.* **64**: 822-823

Thakur, P.C. 1993. Correlation studies in sweet pepper. (*Capsicum annuum* L). *Capsicum Newsl.*. **12:** 55-56

Tikoo, S.K. Anand, N. and Kishun, R. 1983. Presence of two independent genetic systems for resistance to bacterial wilt (*Pseudomonas solanacearum*). *Intl. Cong. Genet.*, New Delhi, December, 12-21. Abstr. 1338

Tobias, I., Molner, B., Salamon, P. and Beczner, L. 1978. Effect of viruses pathogenic to red pepper on some varieties of vegetable pepper. *Kertgazdasag* **10**:51-59

Varghese, G. 1991. Evaluation of F_1 hybrids resistant to bacterial wilt and inheritance of resistance in brinjal. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur.

Vasudeva, R.S. 1954. Report of the division of mycology and plant pathology . *Scient. Rep. agric. Res. Inst. New Delhi*, **53**: 79-89

Vijayagopal, P.D. and Sethumadhavan, P. 1974. Studies on the intervarietal hybrids of (*Solanum melongena* L.). *Indian Hort.* **35**: 229-241

Vijayalakshmi, Y., Rao, R.M., Reddy, E.N. and Murthy, N.S.R.C. 1988. Phenotypic and genotypic correlations between different economic traits in chilli (*Capsicum annuum* L). *South Indian Hort.* **36**: 245-247

Villalon, B. 1981. Breeding peppers to resist virus diseases. *Pl. Disease* **65**: 557-562

Villalon, B. 1986. New multiple virus resistant cultivars. *Phytoopathology* **76**: 1120

Walker, J.C. 1952. *Diseases of Vegetable Crops.* Mc Graw Hill Book Co., New York. pp. 529

Yanshuzhan, A., Julirova, S.and Xuxiagrui, T. 1996. Genetic analysis of resistance to CMV in Sweet (hot) pepper. *Acta Horticulturae Sinica.* **23**: 45-48

Zitter, T.A. and Cook, A.A. 1973. Inheritance of tolerance to a pepper virus in Florida *Phytopathology.* **63**: 1211-1212.

Appendices

Appendix I. Analysis of variance for thirteen characters in 53 genotypes of chilli

Source of variation	Degrees of freedom	Plant height (cm)	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (g)	Driage (%)	Number of branches	Total duration (days)
Replication	1	0.75	0.2031	7	3.75	0.0029	0.00036	0.00097	12.68	0.0061	22	0.1992	0.3007	7
Treatment	52	271.82	39.391	50.66	51.74	8.59	0.8892	0.4561	326.58	1.915	2875.69	3.02	2.146	148.41
Error	52	0.1663	0.1095	1.39	2.58	0.0012	0.0008	0.00881	3.43	0.00917	8.27	0.033	0.3677	4.6
CD		0.8196	0.6651	2.369	3.23	0.0696	0.0568	0.1886	3.731	0.1924	5.78	1.15	1.218	4.31
CV		0.7224	1.012	1.7375	1.5408	0.5524	0.8956	3.7848	3.0349	1.537	2.2242	0.88	6.2736	1.1246

Appendix II. Quantitative characters of 53 chilli accessions

Accession Number	Plant height (cm)	Plant spread (cm)	Days to first flower	Days to first harvest	Fruit length (cm)	Fruit girth (cm)	Pedicel length (cm)	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (g)	Driage (%)	Number of harvests	Total duration (days)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
CA 33	41.00	30.70	69.00	103.50	4.52	2.91	2.92	55.50	2.22	89.00	19.78	9.50	186.50
CA 53	42.15	29.95	66.00	103.00	5.48	3.23	2.14	76.50	2.28	142.35	22.76	10.50	192.00
CA 67	56.70	28.90	67.50	105.00	7.28	3.24	2.84	72.50	2.45	130.90	21.35	10.00	209.00
CA 87	67.10	32.60	77.00	113.50	7.81	2.80	2.61	51.00	2.10	94.80	21.56	10.50	209.00
CA 94	66.25	32.80	76.00	111.00	7.28	3.01	2.64	65.50	2.97	129.50	19.73	11.50	210.00
CA 153	59.55	31.10	66.00	103.50	7.89	3.68	2.81	66.00	2.74	132.70	20.51	9.00	193.00
CA 186	60.90	26.20	64.50	102.00	4.58	3.48	2.12	64.00	3.36	163.05	22.31	9.50	201.00
CA 219	48.70	31.35	70.00	104.50	5.50	2.91	2.88	64.00	2.26	105.00	19.49	10.50	187.00
CA 337	41.10	29.50	61.00	98.50	4.22	2.31	1.79	76.50	2.28	135.50	19.49	10.00	185.50
CA 451	53.10	38.20	69.50	103.50	7.81	3.92	2.52	40.50	3.84	127.00	20.45	9.50	186.00
CA 452	56.20	32.45	705.00	105.00	8.07	4.03	2.61	44.00	4.02	122.00	21.65	9.00	191.00
CA 517	44.70	40.05	71.50	107.00	4.32	3.09	2.12	79.00	2.38	138.00	22.65	7.50	180.00
CA 591	80.90	38.80	65.00	102.00	9.16	2.24	3.12	59.00	2.46	114.00	19.49	11.50	209.00
CA 644	66.75	31.00	705.00	106.00	7.79	3.01	2.53	71.50	1.98	126.05	19.43	10.50	186.00
CA 695	40.60	29.45	65.50	101.00	7.39	2.88	2.76	60.50	2.97	118.30	18.68	9.00	191.00
CA 696	58.40	33.55	65.50	101.50	4.31	3.92	1.93	31.00	3.98	104.85	19.45	9.00	185.50
CA 698	64.35	30.70	83.00	120.50	7.59	2.56	2.69	62.50	2.99	107.00	20.43	8.50	192.00
CA 699	65.20	29.15	75.50	11.50	5.92	2.93	2.47	53.00	1.85	100.15	21.20	10.50	197.00
CA 701	41.80	33.10	79.00	118.00	7.99	3.28	2.72	61.50	2.82	122.10	19.78	10.00	193.00
CA 702	82.20	45.85	64.00	101.50	5.57	3.32	2.09	64.00	2.26	110.85	22.80	10.50	196.00
CA 703	58.10	29.90	62.00	98.50	4.12	2.67	2.76	66.50	2.13	112.50	20.99	11.50	197.00
CA 710	57.70	30.20	66.00	101.50	4.47	3.05	2.71	66.00	2.23	111.60	21.87	12.00	198.00
CA 714	61.90	35.80	70.00	108.00	8.98	3.22	2.55	41.50	4.13	159.45	21.83	9.00	190.50
CA 715	60.10	29.50	59.00	95.00	10.11	2.58	3.24	36.00	3.95	125.55	21.76	8.50	189.50

(Contd.....)

Appendix II (Contd.....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
CA 716	61.65	29.95	60.00	98.50	9.38	4.65	3.57	41.00	6.27	198.20	19.08	8.50	186.50
CA 725	63.10	32.50	72.00	110.00	4.51	2.45	1.85	64.50	2.07	110.15	21.70	9.50	181.50
CA 727	62.70	30.50	61.50	99.50	5.39	3.55	2.01	59.00	2.91	112.50	19.38	8.50	189.00
CA 728	90.65	38.00	70.50	107.00	12.36	5.49	2.78	53.50	6.78	352.75	20.53	9.00	193.00
CA 729	49.80	25.65	61.50	97.50	3.88	2.76	1.81	64.00	2.06	103.50	20.17	9.50	186.00
CA 730	52.00	40.60	59.50	94.00	4.65	2.95	2.20	48.50	2.04	95.35	19.99	9.00	186.00
CA 731	48.95	30.45	71.00	104.50	2.70	2.35	2.00	108.50	0.94	101.85	22.93	12.00	195.00
CA 733	61.00	30.15	60.00	96.50	7.22	2.52	1.90	53.50	2.34	98.50	19.77	8.50	191.00
CA 734	59.65	29.70	63.50	96.50	5.51	2.72	2.20	63.50	2.48	116.00	21.74	10.50	180.00
CA 737	43.40	42.00	71.50	105.00	3.55	3.40	1.19	64.50	1.26	84.40	21.24	9.50	188.00
CA 738	58.70	31.30	71.00	104.00	6.64	3.70	2.35	66.50	2.72	131.70	19.40	9.50	187.50
CA 739	47.90	36.20	69.50	105.50	7.15	3.30	2.50	64.00	3.32	159.70	19.06	10.00	193.00
CA 740	41.70	30.15	69.00	104.00	7.45	2.80	2.95	60.50	3.32	151.00	21.31	9.50	183.00
CA 744	57.70	42.70	68.00	102.00	8.36	3.02	2.49	59.00	3.14	151.50	21.81	9.50	189.00
CA 745	40.55	42.05	69.00	104.50	8.51	3.29	1.53	55.50	3.01	138.70	22.68	9.00	183.50
CA 746	62.75	29.60	68.50	104.00	6.51	3.19	2.22	61.50	2.47	121.35	20.05	9.50	182.00
CA 747	53.35	30.45	72.00	109.00	4.34	4.90	2.29	72.50	3.51	145.65	19.74	9.50	188.00
CA 748	49.75	30.10	68.00	104.00	4.93	2.57	2.44	55.00	2.62	105.00	19.84	8.50	189.00
CA 750	60.60	31.80	70.00	107.00	7.84	4.95	2.34	71.50	2.84	138.60	22.34	9.00	192.00
CA 751	50.20	37.70	72.00	107.50	6.07	2.45	2.77	58.50	2.97	121.80	21.73	9.00	185.00
CA 752	57.40	29.45	74.00	112.50	7.40	3.01	3.55	61.50	2.41	106.00	22.45	8.00	195.00
CA 753	50.40	29.80	70.00	107.00	3.47	2.80	3.24	68.00	1.52	100.75	21.46	8.50	187.00
CA 754	48.80	34.90	61.00	101.00	7.22	3.20	2.62	60.50	3.26	132.50	22.57	8.50	196.00
CA 755	82.80	40.45	72.50	109.50	12.82	2.34	2.88	55.50	2.76	145.00	21.77	11.50	208.50
CA 756	78.30	36.70	61.50	100.00	6.44	3.22	2.41	60.50	3.59	213.35	19.77	11.50	202.00
CA 757	40.20	33.50	70.00	107.00	7.88	3.75	3.16	63.00	2.82	108.15	20.20	9.50	177.50
CA 758	42.75	26.35	68.00	106.00	7.89	2.61	2.79	71.50	2.22	137.05	21.18	8.50	166.50
CA 759	56.85	28.40	67.00	105.00	5.91	3.75	2.62	59.00	3.07	130.30	21.48	10.50	196.00
CA 760	66.05	29.70	67.00	105.50	4.88	2.85	2.57	55.50	2.91	104.85	21.74	9.00	185.00

SCREENING OF CHILLI (*Capsicum annuum* L.) GENOTYPES FOR RESISTANCE TO BACTERIAL WILT AND MOSAIC

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

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ABSTRACT

The investigation on "Screening of chilli (*Capsicum annuum* L.) genotypes for resistance to bacterial wilt and mosaic" was conducted at the vegetable research farm of Department of Olericulture, College of Horticulture, Vellanikkara during 1997-'98.

Fifty three chilli accessions collected from various parts of the country and abroad were evaluated in the wilt sick soil. The level of resistance to bacterial wilt varied with the accessions. Out of the 53 accessions tested, 15 were resistant, 16 were moderately resistant, 13 were moderately susceptible, and the remaining nine were highly susceptible. Among the 15 resistant accessions nine were short fruited, five were long fruited and remaining one was medium long fruited. The chilli lines were catalogued as per the IBPGR descriptor. The extent of genetic variability for 13 characters viz. plant height, plant spread, days to first flower, days to first harvest, fruit length, fruit girth, pedicel length, number of fruits per plant, average fruit weight, fruit yield per plant, driage, number of harvests and total duration were studied. The genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic gain were estimated.

Significant differences were observed among the 53 genotypes for almost all the characters studied. Among the 53 genotypes the earliest flowering (59 days) genotype was CA 715 and the highest yielding (352.75 g) genotype was CA 728. CA 731 recorded the maximum number of fruits (108.50) per plant. High heritability coupled with high genetic gain was observed for the characters - fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant. The highest positive correlation with yield was expressed by the total duration. Average fruit weight exhibited the highest positive direct effect on yield. Based on the genetic divergence the 53 genotypes were grouped into seven clusters.

Out of 53 accessions evaluated for mosaic resistance, nine were resistant, twelve moderately resistant and the remaining 32 were susceptible. The resistance showed by the nine accessions was confirmed by standard methods. The accessions CA 337, CA 731, CA 738, CA 739 and CA 744 were found to possess the resistance to both bacterial wilt and mosaic and can be recommended for disease prone areas. The F_1s developed using the resistant parents were found susceptible to both bacterial wilt and mosaic.