INCORPORATION OF RESISTANCE TO FRUIT CRACKING IN A BACTERIAL WILT RESISTANT GENETIC BACKGROUND IN TOMATO

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Incorporation of resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other University or Society

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CERTIFICATE

Certified that this thesis entitled "Incorporation of resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato" is a record of research work done independently by Sri Sadhan Kumar P G under my guidance and supervision and that it has not previously formed the basis for the award of any degree diploma fellowship or associateship to him

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INTRODUCTION

Tomato is one of the most important vegetable crops grown throughout the world for its edible fruit The fruits are consumed either as raw fruit or cooked or processed into various products like juice, ketchup, sauce, paste, puree etc The main tomato growing countries in the world are U S A , Russia, Netherlands, China, Italy, Egypt, Turkey and India FAO estimate shows a world production of 75 6 million tonnes from an area of 29 lakh hectares in 1993 In India, the annual production of tomato is 53 lakh tonnes from an area of 4 45 lakh hectares The area under tomato in Kerala is very meagre The main limitation for tomato cultivation in Kerala is the incidence of bacterial wilt caused by *Pseudomonas solanacearum* E F Smith The warm humid tropical climate and acidic soil conditions in Kerala favour the incidence of bacterial wilt Crop loss upto 100 per cent occurs due to this disease Chemical control measures have not been successful in controlling the disease Therefore, use of resistant varieties is the obvious method to tackle this problem

Resistance to biotic or abiotic stress is mediated by physical, physiological or biochemical means The inherent potential of a genotype to impart resistance is determined by the resistance mechanism in it It is the genetic control exercised through gene action that decides upon the manifestation of a particular trait in a genotype The different gene systems like polygenic, monogenic dominant, monogenic recessive and partially dominant operate in bacterial wilt resistant genotypes Similarly, biochemical basis of resistance is effected through different chemicals produced by plants

Fruit cracking is another malady which hampers the marketability and consumer preference in tomato Breeding for varieties resistant to fruit cracking is momentus in this regard

Resistance breeding taken up in the Kerala Agricultural University, Vellanikkara has resulted in the development of the variety Sakthi which is resistant to bacterial wilt But this variety is susceptible to fruit cracking A variety resistant to both bacterial wilt and fruit cracking would be a boon to tomato cultivators in Kerala and elsewhere Keeping this as an ultimate aim, the present study was undertaken with the following objectives

1 To find out new/additional source(s) of resistance to bacterial wilt

2 To find out tomato varieties resistant to fruit cracking

3 To study the genetics of bacterial wilt resistance and fruit cracking at F_1 level

4 To study the biochemical basis of resistance to bacterial wilt and fruit cracking

5 To study the anatomical basis of resistance to fruit cracking

6 To incorporate resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato

Review of Literature

REVIEW OF LITERATURE

The review of literature on evaluation of tomato for bacterial wilt resistance fruit crack resistance factors influencing the incidence of bacterial wilt and fruit cracking and the genetic basis of bacterial wilt and fruit crack resistance in tomato is briefly dealt in this chapter

I. Evaluation of tomato genotypes for the incidence of bacterial wilt

A Pathogen

Bacterial wilt caused by *Pseudomonas solanacearum* E F Smith 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) The disease was first reported from Italy in 1882 (Walkar 1952)

Smith (1896) described the disease and causal agent and he reported its occurrence in potato tomato and brinjal The first report on bacterial wilt of tomato in India was by Hedayathullah and Saha (1941)

Pseudomonas solanacearum E F Smith is a complex species consisting of several races differing in many characters

Kelman (1954) distinguished two colony variants on Tetrazolium medium

1 Normal or wild type which are irregularly round entire white or whitish with light pink

2 Mutant or butyrous type which are round transluscent smooth deep red with a narrow white bluish border

Kelman found that the wild types are highly virulent and produced wilting in 14 days

Based on host range pathogenicity and colony appearance or TTC medium Buddenhagen *et al* (1962) classified *Pseudomonas solanacearum* isolates from a wide range of hosts in Central and South America into 3 races i e race 1 race 2 and race 3

1 Race 1 (Solanaceous strain) wide host range distributed throughout the lowlands of tropics and subtropics They attack tomato tobacco and many solanaceous and other weeds

2 Race 2 (Musaceous strain) Restricted to *Musa* and a few perennial hosts initially limited to American tropics and spreading to Asia

3 Race 3 (Potato strain) restricted to potato and few alternate hosts in tropics and sub tropics

Hayward (1964) took a classical bacteriological approach to classify *Pseudomonas solanacearum* into biotypes or biochemical types based on their ability to oxidise various carbon sources and on other bacteriological reactions Hayward called them as biotype I biotype II biotype III and biotype IV

1	Biotype I	does not oxidise disaccharides and sugar alcohols
2	Biotype II	Oxidises only disaccharides
3	Biotype III	Oxidises both disaccharides and alcohols
4	Biotype IV	Oxidises only hexahydric alcohols

In this biotype II was potato race of Buddenhagen No such generalisation could be made in other cases

Later two new races have been proposed one from ginger ornamental as race 4 (Aragaki and Quinon 1965) and one from mulbery as race 5 (He *et al* 1983)

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

B Ecology of the pathogen

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

Pseudomonas solanacearum does not survive in the soil for prolonged periods because it is not a strong competitor It does not survive in the soil itself but survives on or in plant roots The bacterium appears to survive by continually infecting the roots of susceptible or carrier plants or by colonising the rhizospheres of non host plants (Sequeira 1993) Survival of *Pseudomonas solanacearum* in the rhizosphere has been documented by Granada and Sequeira (1983) who reported that the bacterium invades the roots of presumed non hosts such as bean and maize Long term survival was associated with localised or systemic infection of plants that did not express symptoms of bacterial wilt

C Symptomatology

Generally the first expression of the disease is wilting of the lower leaves of the plants (Walker 1952) This wilting is usually accompanied with yellowing of older leaves Dwarfing and stunting of the plants may also occur

The pathogen enters through the root system and it was believed that a wound is necessary for the entry (Walker 1952 Kelman 1953 Chupp and Sherf 1960) Hildebrant (1950) reported entry of the bacterium through natural opening of the plant The pathogen enters into the uninjured roots also (Libman *et al* 1964) They reported that root contact with infected plants was not necessary for infection Bacteria can enter at the points of origin of secondary roots Insects also play a role in the spread of the disease (Young 1946

Vakili and Baldwin 1966) The roots and the lower parts of the stem show a browning of vascular bundles and a water soaked appearance in the root (Chupp and Sherf 1960) Eventually dark brown to black areas develop due to decay of root system and the whole plant dies off A very distinct and characteristic indication of bacterial wilt is the appearance of bacterial ooze from the injured vascular regions (Ashrafuzzaman and Islam 1975)

Breakdown of plant tissues by pathogen is attributed to the cellulase and polygalacturonase enzyme produced by the pathogen (Hussain and Kelman 1957) Continued tissue decay and plugging finally result in the death of the plant

Following entry of the pathogen into the host plant visible symptoms occur within 2 to 8 days (Kelman 1953 Chupp and Sherf 1960) The pathogen first enters into the intercellular spaces of cortex From there it moves to pith and xylem vessels (Walker 1952) Wilting of the plants is due to vascular plugging (Walker 1952) Kelman (1954) noted that virulence might be explained at least in part by the quantitative differences in EPS (extracellular poly saccharides) Baldacci (1977) opined that besides EPS responsible for vascular plugging a chemically unidentified fraction which alters the membrane permeability is produced by the pathogen The bacterium also produces IAA which can initiate tylose formation and increases cell wall plasticity Ethylene production is also associated with it

Schell *et al* (1988) have cloned and characterised the gene Pgl A that is involved in the synthesis of the polygalacturonase produced in the ordinary culture media Allen *et al* (1993) have shown that total galacturonase activity of the bacteria increases in the presence of the plant but that this induction involves mostly two additional PGs Peh B and Peh C

There is no cytological evidence for how the bacterium reaches the vascular system It is assumed that the bacterium has to digest its way through the primary wall of the weakened cortical cells as well as of the tracheary elements where it is exposed between the spiral thickenings (Sequeira 1993) This is probably the reason why mutants that lack endoglucanase (cellulose obtained by site specific mutagenesis of the Pgl gene are substantially reduced in virulence to tomato seedlings (Schell *et al* 1988)

D Genetics of resistance

Much of the early resistance breeding work was carried out at North Carolina in USA (Schaub and Baver 1944) In the field tests Louisiana Pink and T 414 showed resistance to bacterial wilt A further source of resistance was reported in *Lycopersicon pimpinellifolium* (PI 127805 A) (Abeygunawardena and Siriwardena 1963) The resistance is partially dominant at the seedling stage In mature plants resistance was controlled by recessive genes The expression of the resistant variety is a function of the age of the plant and changes in temperature (Acosta *et al* 1964) Acosta (1964) reported that the resistance in *L pimpinellifolium* is controlled by a single pair of genes (sp+) He reported linkage between sp+ and wilt resistance They did not observe any association between the gene u (uniform ripening) and wilt resistance Suzuki *et al* (1964) reported that resistance to *Pseudomonas solanacearum* was quantitatively inherited

Henderson and Jenkins (1972) reported resistance in Venus Saturn and Beltsville 3814 to bacterial wilt Rao *et al* (1975) tested 23 wilt resistant cultivars and lines from USA and Philippines for their reaction to an Indian isolate of *Pseudomonas solanacearum* Only one line CRA 66 Selection A from Hawaii was resistant

Ferrer (1976) crossed wilt resistant PI 126408 with susceptible Bonny Best and Floradel The F_2 ratios suggested polygenic inheritance of resistance Reciprocal crosses showed that no extra chromosomal inheritance was involved The genes involved were additive and no dominance was observed Graham and Yap (1976) conducted variance component analysis of a cross between VC 4 (resistant) and walter (susceptible) tomato cultivars Their study indicated a narrow sense heritability of 53 per cent with a degree of dominance of 75 per cent for wilt resistance Inheritance was mainly due to additive genes Mew and Ho (1976) found that the line VC 8 1 2 1 was resistant to *Pseudomonas solanacearum* regardless of the inoculum density They also observed that susceptible varieties were not significantly affected by changes in inoculum density but resistant lines became less resistant at high inoculum densities Hsu (1976) studied four varieties and found that all were susceptible following inoculation of the stem or top leaf but A 95 6 and UP 1167 were comparatively resistant following root inoculation Jenkins and Nesmith (1976) evaluated the resistance of cultivars Venus and Saturn to Indian and American isolates of *Pseudomonas solanacearum.* They found that both cultivars were highly susceptible to American isolates at 2 to 4 weeks age when both stem and root were inoculated They also reported that the Indian isolate was more pathogenic than American isolate

Remadevi (1978) reported wilt incidence of less than 30 per cent in Venus Saturn and CRA 66 Selection A Celine (1981) reported field tolerance in the line CL 32d 0 1 19GS Goth *et al* (1983) tested selected tomato lines and cultivars against eight isolates of *Pseudomonas solanacearum* collected from different locations They found that CL 32d 0 1 19GS was resistant to three isolates viz K60 126408 1 and Tifton 80 of race 1 Tikoo *et al* (1983) reported the presence of two independent gene systems for wilt resistance The resistance was governed by multiple recessive genes in CRA 66 Sel A from Hawaii and by single dominant gene in 663 12 3 from Taiwan Sreelathakumari (1983) reported a complimentary and hypostatic type of digenic recessive gene system for wilt resistance Bosch *et al* (1985) postulated a two gene model with epistasis which adequately explained the observed segreation for resistance among progenies from the BW2 stock from North Carolina

Rajan and Peter (1986) reported a monogenic incompletely dominant gene action in the resistant line LE 79 Nirmala Devi (1987) reported that resistance to bacterial wilt in CRA 66 Sel A was under polygenic control Monma and Sakata (1993) reported that bacterial wilt resistance in D 9 and Hawaii 7998 was partially recessive as there was incomplete dominance towards susceptibility

The following table consisely depicts various sources tested for resistance to bacterial wilt and reported there upon

Tomato lines/cultivars reported resistant to bacterial wilt

Sl No	Cultivar/line	Reaction to bacterial wilt	Reported by
1	Louisiana Pink and T 414	R	Schaub and Baver (1944) Weaver (1944)
2	57 55 M 1960 8 1962 B2 and Rahangala	R	Abeygunawardena and Siriwardena (1963)
3	*L pimpinellifolium* PI 127905	R	Acosta (1964) and Acosta *et al* (1964)
4	65 S2 66 S 52 and 68 S4	R	Akiba *et al* (1972)
5	Best of All Oxheart and Marglobe Supreme	MS	Chetia and Kakati (1973)
6	Beltsville 3814 and Venus	R	Henderson and Jenkins (1972)
7	III IRAT OTB 2 Saturn and Venus	R	Daly (1973)
8	BWN 5 BWN 16 BWN 17 BWN 514 and BWN 7755	R	Anaya and Waite (1974)
9	Saturn	R	Bedekar (1977)
10	CRA 66 Sel A	R	Rao *et al* (1975) and Tikoo *et al* (1983)
11	Floradel	R	Ferrer (1976)
12	VC 8 1 2 1	R	Mew and Ho (1976)
13	VC 9 1 AUG and VC 11 1 UG	R	Bedekar (1977)
14	PI 126408 Saturn and Venus	R	Sonoda (1977)

15	Hawaii 7997	R	Sonoda and Augustine (1977)
16	INRA 518	R	Messiaen *et al* (1978)
17	VC/1 and Nova	R	Bissonauth (1980)
18	La Bonita and LE 79	R	Ramachandran *et al* (1980)
19	CL 32 d 0 1 19 GS	R	Ramachandran *et al* (1980) and Goth *et al* (1983)
20	Hawaii 7981 Hawaii 7997 PI 212441 PI 263722 and PI 365930	HT	Sonoda *et al* (1980)
21	AVRDC 15 AVRDC 33 and CL 32 d 0 1 25	R	Sunarjono (1980)
22	CL 8 d 0 and CL 143 0 13	R	Hoque *et al* (1981)
23	TSS 1	HR	Hoque *et al* (1981)
24	Venus	R	Goth *et al* (1983)
25	Scorpio	R	Peterson *et al* (1983)
26	663 12 3	R	Tikoo *et al* (1983)
27	Rodade	R	Bosch *et al* (1985)
28	Redlands Summertaste	R	Herrington and Saranah (1985)
29	VC 9 1 VC 44	R	Moffett (1986)
30	Redlander	R	Herrington and Brown (1988)

	GA 1405 1 2 BWT and GA 1095 1 4 BWT		
32	Hawaii 7997 Hawaii 7996 GA 1565 GA 1405 and GA 219	R	Scott *et al* (1993)
33	CL 1131 and Rampur Local	R	Adhikari *et al* (1993)

HR Highly resistant
R Resistant
MS Moderately susceptible
HT Highly tolerant

E Biochemical basis of resistance

Mullar (1959) and Cruickshank (1963) stated that a host might have two kinds of defence factors prohibitins and phytoalexins Kuc (1964) reported that in some cases inhibition of a micro organism may result from the cumulative effect of two or more compounds Thapliyal and Nene (1967) reported that non diffusible chemicals like tomatine phenols etc have a key role in the defence mechanism Mahadevan (1973) reported that resistance to parasitic micro organisms like bacteria fungi and viruses is not due to structural barriers like thick epidermis leaf hairs thick cuticle sugar content osmotic pressure pH and other features Chemicals like prohibitins phytoalexins and other post infectionally formed inhibiting substances appear to be important in the defence reaction

The main pre infectional inhibitors present in plants are catechol procatechuic acids phenols flavanoids and tomatine (Stoessel 1969 Langecake *et al* 1972 Roddick 1974)

Levin (1976) reported that specific resistance is conferred by a compound or compounds extremely toxic to a small group of specialised pathogen of herbivores Such compounds are signigrin gossypol juglone phlorizidin tomatine and solanine Tomatine is a steroidal glycoalkaloid found in tissues of *Lycopersicon* genus which have antibiotic activity against a wide range of micro organisms (Irwing 1947) A high content of tomatine in the wilt resistant tomato plants made it to survive even if affected by the pathogen Fontain *et al* (1948) isolated crystalline tomatine from tomato plants Kuhn *et al* (1952) observed differences in tomatine content in different species of *Lycopersicon* Tukalo (1958) found 0 86 to 1 9 per cent tomatine in the leaves of tomato 0 3 per cent to 0 6 per cent in stems and roots and 0 93 per cent to 2 2 per cent in fully expanded flowers

Sander (1956) found that shoot is the main site of tomatine synthesis The main site of tomatine biosynthesis in the root is the actively growing region The content of tomatine in the host plant appears to be variable and it is influenced by environment Tomatine diappearance during fruit ripening is due to actual degradation of the alkaloid (Roddick 1974)

Roddick (1974) reported that impure tomatine inhibited growth of number of bacteria and plant and animal pathogenic fungi Gram positive bacteria are more sensitive to tomatine than gram negative Mohanakumaran *et al* (1969) found that tomatine levels are high in roots of *Lycopersicon pimpinellefolium* resistant to *Pseudomonas solanacearum* than in susceptible cultivars

Remadevi (1978) found higher content of tomatine in shoots and roots of Venus than in the susceptible line Marglobe Rajan (1985) reported that root and total content of tomatine were higher in LE 79 than in Pusa Ruby at all stages On artificial inoculation the root and shoot content showed a greater increase in LE 79 three days after inoculation The content decreased in both the lines seven day after inoculation but a higher level of tomatine was maintained in LE 79

Phenols are responsible for disease resistance indifferent crops (Farkas and Kiraly 1962 Goodman *et al* 1967 Rajan 1985) Tapliyal and Nene (1967) detected phenols particularly chlorogenic acid in the vascular system of young potato plants The resistant varieties contained chlorogenic acid and the concentration was higher in the roots of resistant potato varieties than in susceptible ones Rajan (1985) reported that total phenols were lower in roots of LE 79 (resistant to *Pseudomonas solanacearum)* than in Pusa Ruby (susceptible to *Pseudomonas solanacearum)* at all stages except in 60 days old plants After artificial inoculation total phenols were higher in roots and shoots of Pusa Ruby and wilted plants of Pusa Ruby had higher total phenols than resistant plants He also reported that O D phenol content was higher in LE 79 than in Pusa Ruby at all stage On artificial inoculation there was increase in O D phenols in roots and shoots of LE 79 three days after inoculation A higher level was maintained in roots of LE 79 seven days after inoculation Pusa Ruby which had a higher content in shoots and a lower content in roots wilted seven days after inoculation A higher O D phenols in root was involved in bacterial wilt resistance

Vitamin C imparts resistance to diseases in crop plants (Voronia 1971 Aswathy and Singh 1975 Rattan and Saini 1979) Rajan (1985) found that Vitamin C content was higher in roots of LE 79 (resistant to bacterial wilt) than in Pusa Ruby (susceptible) On artificial inoculation also a higher content was observed in roots of LE 79 three days and seven days after inoculation

F Breeding for bacterial wilt resistance

Graham and Yap (1976) performed a diallel involving six cultivars Walter CRA 66 H 7741 Venus VC 4 and Llanos de Colce They reported that high level of wilt resistance was attained in a breeding procedure of repeated selfing and selection followed by intercrossing of resistant selections

Chumvisoot and Lambeth (1983) crossed 12 accessions of tomato as female to three testers Saturn Venus and Kewalo Five accessions and their hybrids with Kewalo had low tolerance Sreelathakumari (1983) reported that no F_1 hybrids involving 10 lines from *Lycopersicon esculentum* as female and *Lycopersicon pimpinellifolium* as male showed resistance

Narayanankutty (1985) reported that out of four non segregating lines (Saturn LE 79 Pusa Ruby and Pusa Ruby x LE 79 F) and two segregating lines (Pusa Ruby x LE 79 F_2 Saturn x LE 79 F_2) evaluated the F_2 hybrids of Saturn x LE 79 were resistant In a repeated trial F_3s were evaluated along with the F_2s and non segregating populations (Saturn x LE 79) Resistance was observed in Saturn x LE 79 F_3 and Saturn x LE 79 F_2

In a study of seven parent diallel comprised of different genetic stocks Lines L 96 (cv Saturn from North Carolina) and L 285 (a small fruited Taiwan collection) showed far better average bacterial wilt resistance among their hybrid progenies than the other five stocks (Opena and Tschanz 1987) These two stocks had the ability to transmit their disease resistance uniformly to their progenies Certain stocks showed high bacterial wilt resistance in some crosses This non additive gene action appears also to be an important feature of the genetic system conditioning bacterial wilt resistance implying that F_1 hybrid breeding for the trait is a possibility

Herrington and Saranah (1985) bred an F hybrid Red lands Summer Taste which was resistant to bacterial wilt This hybrid was bred using a sister line 1356 of Scorpio with a selection 1360 of Floradade

Noda *et al* (1986) compared ten F_2 F_4 and F_5 progenies of various ancestors with varieties Sao Sebastiao and Kada Resistance was highest in the F_4 population HT 16 9 1 from IRAT IH 40X UH 7976

Tikoo *et al* (1987) attempted development of F hybrids resistant to bacterial wilt Two resistant sources CRA 66 Sel A and IHR 663 12 3 were crossed with susceptible varieties like Pusa Ruby HS 101 and Sel 24 Large fruited selections were recovered only in crosses with IHR 663 12 3 None of the CRA 66 derivatives showed absolute resistance but their survival beyond 80 days after inoculation in the field resulted in acceptable yields Resistance in selections from Taiwaneseline was very high Pedigree selection in the crosses between IHR 663 12 3 and firm fruited wilt susceptible lines Arka Saurabh and Florida 1011 resulted in medium fruited selections in the range of 80 to 125 g and yield of 1 kg to 3 kg/plant

Tikoo (1987) reported that 13 F hybrids evolved using IHR 663 12 3 (BWR 1) as female and wilt susceptible lines as male exhibited 100 per cent survival even upto 120 days after planting confirming the dominance of bacterial wilt resistance in BWR 1 Out of the 14 hybrids only one (BWR 1x KH det) proved to have significantly higher yield of 2 24 kg/plant as against 1 4 kg/plant in the wilt resistant parent BWR 1 The only other promising hybrid was BWR 1 x 674 (a processing line) as the fruits were uniformly ripening square round in shape and good for processing Since BWR 1 had soft fruits the F s even with firm fruited lines was soft or medium firm

II Evaluation of tomato genotypes for resistance to fruit cracking

A Types of fruit cracking in tomato

Fruit cracking is not a simple characteristic as four fundamental types of fruit cracking are distinguished radial cracking concentric cracking cracking of cuticle and fruit bursting (Brown and Price 1935 and Young 1962) The first two ones are most usual and hence the most important

Kalloo (1985) described four types of fruit cracking in tomato radial concentric burst and cuticular Of these radial cracking is more damaging Radial cracking is seen mostly at the ripe stage while concentric cracking is more at the green mature stage

Artherton and Rudich (1986) grouped fruit cracking under the category of physiological disorders They opined that problems and losses caused by fruit cracking in areas where rainfall occurs during fruit ripening can be very heavy Side effects like infection and contamination by insects and disease organisms further complicate this problem

According to Peet (1992) there are many types of fruit cracking longitudinal or burst cracking ring or concentric cracking crazing or russetting star or radial cracking lenticilar cracking and core failure

B Factors affecting fruit cracking

1 Effecting of shading and staking

Frasier (1935) found that pruning of side shoots and staking of tomatoes increased fruit cracking compared to non pruned non staked plants He also found that trimming an additional two third of the leaves of the main stem from the staked plants decreased fruit cracking Shading of fruits by tomato leaves was reported to account for fruit crack resistance (Frasier 1952) This shading reduces day time fruit temperature which in turn decreases fruit swelling during the day (Peet 1992)

2 Effect of water

Fruit cracking occurs when there is a rapid net influx of water and solutes into the fruit at the same time that ripening and other factors reduce the strength and elasticity of the skin In the field high soil moisture tensions suddenly lowered by irrigation or rain are the most frequent cause of the development of cracks It has no way to stop fruit expansion except through regulation of water pressure (Considine and Brown 1981)

Cracking is common during the rainy season when rains follow a long dry spell The presence on water an the surface of fruits is more conducive to cracking than high soil moisture (Kalloo 1985)

3 Temperature

As temperature rises during the day the fruits get heated up in the sun Then positive pressures build up in the skin which stretches the impermeable tomato skin outwards as the fruit expands in volume (Corey and Tan 1990) High differentials between day and night temperature increases fruit cracking in tomato (Peet 1992) The greater the day/night differential the greater the stress on the skin

4 Humidity

Frazier and Bowers (1947) observed that most cracking occurred following periods of low night humidity and high day humidity

High humidity or changes between day and night humidity have been associated with increased fruit cracking (Peet 1992)

5 Spacing

Hassan (1978) found that closer spacing reduced fruit cracking in tomato

Dickinson and McCollum (1964) have reported that Ca nutrition reduces fruit cracking in tomato

Fogle and Faust (1976) also reported that good Ca nutrition is important for prevention of fruit cracking in tomato

Peet (1992) reported that the main factors favouring fruit cracking in tomato are large fruit size high soluble solid content low stretchability of fruit skin high differences in day/night temperature and humidity high water content in the soil and presence of water for a longer time on the fruits

C Anatomy of fruit crack resistance

Cotner *et al* (1969) reported that resistance to concentric cracking is probably due to the configuration of the vascular system Fruits showing resistance to concentric cracking possessed flattened epidermal cells No consistent anatomical differences occurred to account for radial crack resistance Fruits resistant to both type of cracking have a more extensive vascular system

Cracking behaviour of tomato skin was investigated by Hankinson and Rao (1979) using failure and relaxation tests Skin specimens were taken in two directions to represent concentric and radial cracks Normal tissues and tissues subjected to mechanical forces were examined to determine the resulting histological distortions No difference was observed for longitudinal or transverse skin strength for failure or the relaxation test indicating isotopic behaviour The shape of the cells and deposition of cutin appeared to affect cracking behaviour

D Varietal response to fruit cracking resistance

Varietal response to fruit cracking is briefly reviewed hereunder

Variety	Resistant to	Reported by
Crack Proof	Radial cracking	Reynard and Riverton 1951
Glamour	Radial cracking	Prashar and Lambath 1960
Ny 55 542	Radial cracking	Prashar and Lambath 1960
Ohio 7663	Radial and concentric cracking	Berry and Gould 1979
Veepick	Crack resistant	Kerr and Cook 1981
Cheroke	Radial and concentric cracking	Gardener 1982
Hayslip	Tolerant to cracking	Augustine *et al* 1982
Ohio 7870	Crack resistant	Berry and Gould 1982
Ohio 7814	Radial and concentric cracking	Berry and Gould 1983
Conquest VFN	Radial cracking	Lambeth 1983
31 st 15	Radial cracking	Lambeth 1983
Sierra Sweet	Crack resistant	Jones and Millet 1984
Piedmont	Crack resistant	Gardener 1985
Ontario 7710	Crack resistant	Kerr and Cook 1985a
Veeking	Crack resistant	Kerr and Cook 1985b
CVF 11	Crack resistant	Martin 1984
Columbia	Crack resistant	Martin 1985a
Roza	Crack resistant	Martin 1985a

Rowpac	Crack resistant	Martin 1985a
CVF 3	Crack resistant	Martin 1985b
Horizon	Tolerant to cracking	Scott 1985
Earlibright	Crack resistant	Metcalf *et al* 1986
Ohio 832	Radial and concentric cracking	Berry and Gould 1986
Wolfpack 1	Radial and concentric cracking	Henderson 1986
Wolfpack 2	Radial and concentric cracking	Henderson 1986
Freshmarket 9	Crack resistant	Leeper and Cox 1986
Ohio 8243	Radial and concentric cracking	Berry and Gould 1988
Ozark Pink	Radial and concentric cracking	McFerran *et al* 1989
Micro Tom	Crack resistant	Scott and Harbargh 1989
Ohio 7983	Crack resistant	Berry 1990a
Ohio 8245	Crack resistant	Berry 1990b

E Genetics of fruit crack resistance

Reynard and Riverton (1951) reported that radial crack resistance was hereditary Resistance appeared to be recessive to susceptibility They also reported linkage between resistance and uniform ripening gene ug ug

Radial cracking is determined by two independent pairs of recessive genes cr cr and rl rl (Young 1959)

Prashar and Lambath (1960) reported that fruit cracking in tomato is quantitative character and the inheritance may involve many major and minor genes with unidentical effects They also proposed that there are two strong and two weak genes for cracking with inter allelic interaction

According to Young (1962) resistance to radial concentric burst and cuticular cracking appears to have different genetic systems

Armstrong and Thompson (1967) reported that resistance to fruit cracking is controlled by many genes They also reported that resistance to fruit cracking is additive

Avdeyev (1979) reported that resistance to concentric cracking in F and F_2 is incompletely dominant He proposed that resistance to concentric cracking is by the action of a single incompletely dominant gene notated as Rc

Cortes *et al* (1983) reported that over a determined productive period the susceptibility to form large or small crack was controlled by same genetic system (r_G 0 8 0 95) yet there was a genetic difference between susceptibility to radial and concentric cracking (r_G 0 53 0 68) Genetic systems for susceptibility to radial and concentric cracking seemed to show similarity over the first harvesting and over the total productive period (r_G 1)

In a Line x Tester analysis Alice Kurian (1990) reported that all the fifteen F hybrids were resistant to fruit cracking

III Heterosis in tomato

Heterosis in tomato was first observed by Hedrick and Booth (1908) for higher yield and more fruits Since then heterosis for yield its components and other quality traits were extensively studied Heterosis has been reported for many characters in tomato a brief review on the topic is made below

Character for which heterosis is reported	Reported by
Plant height	Mishra and Khanna (1977) and Govindaraju *et al* (1983)
Total yield	Meyer and Peacock (1941) Barrons (1943) Currence *et al* (1944) Singh *et al* (1978) Tikoo (1987)
Earliness	Meyer and Peacock (1941) Barrons (1943) Hewitt and Stevens (1979)
Fruits/plant	Bhutani *et al* (1973) Grill and Burgis (1971) Kaul *et al* (1972)
Fruit size	Larson and Currence (1944) Tesi *et al* (1970) Kaul *et al* (1972) Sidhu *et al* (1981)
Frost resistance	Peter and Rai (1976)
Locules/fruit	Kalloo *et al* (1974) Anbu *et al* (1976) Ponnuswamy *et al* (1980)
Pericarp thickness	Nandpuri *et al* (1976) Sidhu *et al* (1981) Tikoo (1982)

Materials and Methods

MATERIALS AND METHODS

The project consisted of the following experiments

A Evaluation of tomato genotypes for resistance to bacterial wilt and its gene action at F level

B Biochemical basis of bacterial wilt resistance

C Evaluation of tomato genotypes for resistance to fruit cracking and their gene action at F level

D Evaluation of crack resistant lines for resistance to bacterial wilt

E Biochemical and anatomical bases of resistance to fruit cracking

F Transfer of resistance to fruit cracking to a bacterial wilt resistant genetic background

A. Evaluation of tomato genotypes for resistance to bacterial wilt and its gene action at F_1 level

(i) Experimental materials

The experimental material comprised of 68 tomato genotypes which were drawn from India and abroad (Evaluation was done for three seasons as and when the materials were available) The genetic cataloguing of the genotypes are given in Table 1

Table 1 Genetic cataloguing of tomato genotypes evaluated for resistance to bacterial wilt

Genotypes	Source	Genetic cataloguing						
Sakthi	Department of Olericulture Kerala Agricultural University Vellanikkara	sp -	j -	n -	bk -	f -	o -	u -
LE 79 1		sp -	j^+	n^+	bk^+-	f^+-	o -	u^+
LE 79-2		sp -	j -	n -	bk^+-	f^+	o^+-	u -
LE 79-3		sp -	j -	n -	bk -	f -	o -	u -
LE 79-4		sp -	j	n -	bk^+-	f -	o -	u -
LE 79-5		sp -	j^+	n^+-	bk -	f -	o -	uu
LE 213	AVRDC, Taiwan	sp -	j^+-	n^+-	bk -	f^+-	o^+-	u^+
LE 214		sp^+-	j^+-	n^+-	bk -	f -	o^+-	u
LE 296	U S A	sp^+-	j -	n -	bk^+-	f -	o -	uu
LE 297		sp -	j -	n -	bk -	f -	o -	uu
LE 301		sp -	j^+-	n^+-	bk -	f -	o -	u^+-
LE 309	U S A	sp -	j -	n -	bk -	f	o^+-	u
LE 311	U S A	sp	j^+-	n -	bk^+-	f	o^+	u
LE 313	U S A	sp^+-	j -	n -	bk^+-	f -	o -	u -
BWR 1	IIHR Bangalore	sp^+-	j -	n -	bk^+-	ff	o -	uu
BWR 5	IIHR Bangalore	sp -	j -	n -	bk -	ff	o -	uu

Contd

Table 1 (Contd)

BT	Bhuvaneshwar	sp -	j^{+} -	n^{+} -	bk -	f -	o -	uu
BT_{10}	Bhuvaneshwar	sp -	j -	n -	bk	f -	o	uu
CAV-1	Port Blair	sp -	j -	n -	bk -	f -	o^{+} -	uu
CAV-5	Port Blair	sp	j -	n -	bk -	f	o -	uu
CAV 5-1	Port Blair	sp -	j -	n^{+} -	bk^{+} -	f^{+} -	o^{+} -	uu
Pusa Ruby	IARI, New Delhi	sp -	j -	n^{+} -	bk -	ff	o -	uu
Sonali	Dapoli	sp -	j -	n^{+} -	bk^{+} -	f -	o	uu
Saturn	U S A	sp -	j -	n -	bk -	f -	o -	u -
Venus	U S A	sp -	j^{+} -	n^{+} -	bk -	f^{+}	o^{+} -	u -
LE 338	Heinz, U S A	sp -	j -	n^{+} -	bk^{+} -	f -	o^{+} -	uu
LE 339	Heinz, U S A	sp -	j^{+} -	n	bk -	f -	o -	uu
LE 340	Heinz, U S A	sp^{+}	j -	n	bk^{+}	f -	o^{+}	uu
LE 341	Heinz, U S A	sp	j^{+} -	n -	bk	f -	o -	uu
LE 342	Heinz, U S A	sp -	j -	n^{+} -	bk -	f^{+} -	o -	uu
LE 343	Heinz, U S A	sp	j -	n^{+} -	bk -	f	o -	uu
LE 344	Heinz, U S A	sp -	j -	n^{+}	bk -	f -	o^{+}	uu
LE 345		sp	j -	n -	bk	f -	o -	uu
LE 346		sp -	j	n^{+} -	bk^{+}	f^{+} -	o -	uu
LE 347		sp -	j	n -	bk	f	o -	uu
LE 349		sp -	j -	n^{+} -	bk^{+} -	f -	o -	uu

Contd

Table 1 (Contd)

LE 350	Heinz, U S A	sp -	j -	n -	bk -	f^{+}-	o^{+}-	uu
LE 351		sp^{+}	j^{+}	n^{+}-	bk	f	o -	uu
LE 352		sp	j -	n -	bk -	f^{+}-	o -	uu
LE 353		sp -	j	n^{+}	bk^{+}-	f -	o -	uu
LE 354		sp -	j -	n	bk -	f	o -	uu
LE 355		sp	j	n -	bk -	f -	o -	uu
LE 356		sp -	j^{+}-	n^{+}-	bk -	f -	o	uu
LE 357		sp -	j	n -	bk -	f -	o^{+}-	uu
LE 358		sp -	j -	n -	bk -	f	o	uu
LE 378	AVRDC, Taiwan	sp -	j^{+}	n^{+}-	bk -	f	o^{+}-	uu
LE 379		sp -	j -	n -	bk^{+}	f^{+}-	o -	uu
LE 380		sp -	j	n -	bk -	f	o^{+}	uu
LE 381		sp^{+}	j -	n -	bk^{+}-	f^{+}-	o -	uu
LE 382		sp -	j -	n^{+}-	bk -	f -	o^{+}-	uu
LE 382-1		sp -	j -	n -	bk -	f^{+}	o	uu
LE 383		sp -	j -	n -	bk	f -	o -	uu
LE 404	Heinz, U S A	sp^{+}-	j	n^{+}-	bk -	f -	o -	uu
LE 405		sp -	j -	n -	bk -	f -	o^{+}-	uu
LE 406		sp -	j^{+}-	n^{+}-	bk -	f^{+}-	o -	uu
LE 407		sp -	j -	n^{+}	bk	f -	o^{+}-	uu

Contd.

Table 1 (Contd)

LE 408	Heinz, U S A	sp^{+}-	j^{+}-	n -	bk -	f -	o -	uu
LE 409		sp -	j -	n -	bk -	f^{+}-	o -	uu
LE 410		sp -	j -	n -	bk -	f -	o -	uu
LE 411		sp^{+}-	j^{+}-	n -	bk^{+}-	f -	o -	uu
LE 412		sp -	j -	n -	bk -	f^{+}-	o -	uu
LE 413		sp -	j -	n -	bk -	f -	o -	uu
LE 414		sp -	j^{+}-	n -	bk -	f -	o -	uu
LE 415		sp -	j -	n -	bk -	f -	o^{+}-	uu
LE 416		sp -	j^{+}-	n -	bk -	f -	o -	uu
LE 417		sp	j -	n -	bk -	f^{+}-	o^{+}	uu
LE 418		sp	j	n -	bk -	f	o^{+}-	uu

The lines were grown in bacterial wilt sick field Spot planting was resorted to with the known suscept Pusa Ruby which confirmed the efficacy of testing Incidence of bacterial wilt was also confirmed by ooze test Seedlings were transplanted 30 days after sowing Management practices were followed as per Package of Practices Recommendations of Kerala Agricultural University (1989) Incidence of bacterial wilt was recorded as and when wilt was observed and final count was computed The genotypes were classified into four groups as suggested by Mew and Ho 1976

Three bacterial wilt resistant lines (Sakthi LE 79 5) and LE 214) and three moderately resistant lines (CAV 5 LE 415 and LE 382 1) were raised in a randomised block design with 4 replications to study the biometrical characters The following observations were recorded

(i) Plant height (cm)
(ii) Days to flower
(iii) Days to harvest
(iv) Fruits/plant
(v) Fruit yield/plant (kg)
(vi) Average fruit weight (g)
(vii) Fruit shape index
(viii) Locules/fruit
(ix) Incidence of radial cracking (%)
(x) Incidence of concentric cracking (%)

(ii) Genetics of bacterial wilt resistance at F level

Three bacterial wilt resistant/three moderately resistant genotypes were crossed with the known suscept Pusa Ruby to unravel the genetics of bacterial wilt resistance at F_1 level The F s along with the parents were raised in a bacterial wilt sick field Spot planting with Pusa Ruby was done to confirm the presence of virulent strains of *Pseudomonas solanacearum* in the field The incidence of bacterial wilt was further confirmed through ooze test Their wilt incidence was recorded

Analyses of variance was done using a Randomised Block Design as per Panse and Suhatme (1978)

B. Biochemical bases of bacterial wilt resistance

1 Experimental materials

Three bacterial wilt resistant lines (Sakthi LE 79 5 and LE 214) three moderately resistant lines (CAV 5 LE 415 and LE 382 1) and one susceptible variety Pusa Ruby were used for the assay of biohemical status of the plants at three stages viz 30 days 45 days and 60 days after sowing

2 Chemical constituents

The following chemical constituents were estimated for their content in roots stems and leaves

a Total phenols

Alcoholic extracts of roots stems and leaves from 30 45 and 60 day old plants were taken for the estimation The Folin Coicalteu method (Mahadevan and Sridhar 1982) was followed for the estimation

b Orthodihydric phenol

Alcoholic extracts of roots stems and leaves from 30 45 and 60 day old plants were used for the estimation The Arnow s method as suggested by Mahadevan and Sridhar (1982) was adopted for the estimation

c Ascorbic acid (Vitamin C)

Ascorbic acid content of roots stems and leaves were estimated in 30 days 45 days and 60 days old plants Ascorbic acid was estimated by the visual titration method based on the reduction of 2 6 dichlorophenol indophenol dye (Sadasivam and Manickam 1991)

C. Evaluation of tomato genotypes for resistance to fruit cracking and their gene action at F_1 level

1 Experimental materials

The experimental materials comprised of 58 tomato lines The genetic cataloguing of the lines are depicted in Table 2

2 Evaluation for resistance to fruit cracking

The tomato genotypes were grown in pots with sterilized soil medium The pots were filled with 1 1 1 potting mixture The medium was sterilised with 40 per cent formaldehyde solution A gap of 12 days was given between soil fumigation and planting Eight pots were kept for each genotype Seedlings were transplanted at the age of 30 days The management practices as per Package of Practices Recommendations of Kerala Agricultural University (1989) were followed except in the case of irrigation after flowering After flowering the irrigation was withheld till the plants started wilting Then a flooding irrigation was given to induce fruit cracking The following observations were recorded

(i) Plant height (cm)

(ii) Days to flower

(iii) Days to harvest

Table 2 Genetic cataloguing of tomato genotypes evaluated for resistance to fruit cracking

Genotypes	Source	Genetic cataloguing						
Sakthi	Department of Olericulture Kerala Agricultural University, Vellanikkara	sp^+ –	j –	n –	bk –	f	o^+	u –
LE 79 1		sp –	j	n	bk^+ –	f –	o –	u –
LE 79 2		sp^+ –	j^+ –	n	bk	f –	o –	u^+ –
LE 79-3		sp –	j –	n^+ –	bk –	f –	o –	u^+ –
LE 79-4		sp –	j	n –	bk –	f –	o –	u
LE 79-5		sp^+ –	j –	n –	bk –	f –	o –	uu
LE 211	AVRDC, Taiwan	sp –	j^+ –	n^+ –	bk^+ –	f^+	o –	u^+ –
LE 213		sp –	j	n –	bk^+ –	f –	o –	u –
LE 214		sp –	j	n	bk –	f^+ –	o –	u –
LE 217	U S A	sp^+ –	j^+ –	n –	bk^+ –	f –	o –	u^+
LE 296	U S A	sp –	j –	n –	bk –	f –	o –	uu
LE 297		sp –	j –	n^+	bk –	f^+ –	o –	uu
LE 301		sp –	j^+ –	n –	bk^+	f –	o –	u^+
LE 302		sp –	j^+ –	n^+ –	bk –	f –	o –	u
LE 312	U S A	sp^+ –	j –	n –	bk –	f^+ –	o –	u –
LE 337	Nelliampathi	sp –	j –	n –	bk –	f –	o^+	u –

Contd

Table 2 (Contd)

LE 361	NBPGR, New Delhi	sp –	j$^+$–	n$^+$–	bk	f$^+$–	o	u –
LE 364		sp$^+$–	j –	n –	bk –	f –	o$^+$–	u –
LE 365		sp –	j$^+$–	n$^+$–	bk –	f$^+$–	o –	u –
LE 366		sp –	j –	n –	bk –	f –	o –	u –
LE 367		sp –	j	n$^+$–	bk	f$^+$–	o$^+$–	u –
LE 370		sp –	j –	n –	bk –	ff	o –	u
LE 371		sp –	j$^+$–	n$^+$	bk$^+$–	f –	o$^+$–	u –
LE 373		sp –	j –	n –	bk	f –	o –	u –
LE 374		sp$^+$–	j –	n$^+$	bk –	ff	o$^+$–	u$^+$
LE 377		sp –	j –	n –	bk –	f$^+$–	o –	u –
LE 378	AVRDC, Taiwan	sp –	j$^+$–	n –	bk$^+$–	f –	o –	uu
LE 379		sp –	j –	n –	bk	f$^+$–	o$^+$–	uu
LE 380		sp$^+$–	j$^+$–	n$^+$	bk$^+$–	f –	o –	uu
LE 381		sp –	j –	n –	bk$^+$–	f$^+$–	o$^+$–	uu
LE 382		sp –	j$^+$–	n$^+$–	bk –	f	o –	uu
LE 383		sp –	j	n –	bk –	f –	o –	uu
LE 385 (H 1810)	Heinz, U S A	spsp	jj	n –	bkbk	f –	oo	uu
LE 386 (H 7870)		spsp	jj	n –	bkbk	f –	oo	uu
LE 387 (O 8245)		spsp	jj	n$^+$–	bkbk	f$^+$	oo	uu

Contd

Table 2 (Contd)

LE 388 (TH 318)	Heinz, U S A	spsp	jj	n -	bk^{+}-	f -	o	uu
LE 389 (H 722)	'	spsp	jj	nn	bk -	f -	oo	uu
LE 391 (FM 6203)		spsp	j -	n^{+}-	bk -	f	oo	uu
LE 392 (H 265)		spsp	jj	n -	bkbk	f -	oo	uu
LE 393 (H 6004)		spsp	jj	nn	bk^{+}-	f -	oo	uu
LE 394 (Redlander)	Redland s Horticultural Research Station Australia	sp^{+}-	jj	n^{+}-	bk -	f^{+}-	o -	uu
LE 397 (Ohio 8129)	Canada	spsp	jj	nn	bk -	f -	oo	uu
LE 398 (Ohio 7879)		spsp	jj	n -	bkbk	f -	oo	uu
LE 399 (Ohio 832)		spsp	jj	nn	bk -	f^{+}-	oo	uu
LE 400 (Ohio 8243)		spsp	jj	n -	bkbk	f -	oo	uu
LE 401 (Ohio 7814)		spsp	jj	n -	bkbk	f -	oo	uu
LE 402 (Ohio 7663)	'	spsp	jj	n^{+}-	bkbk	f -	o -	uu
LE 403 (Ohio CR-6)		sp^{+}-	jj	n -	bkbk	f -	o^{+}-	uu
CAV-1	Port Blair	sp -	j	n -	bk^{+}-	f -	o -	uu
CAV-5		sp -	j -	n -	bk -	f -	o -	uu
BWR-1	IIHR, Bangalore	sp^{+}-	j -	n	bk -	ff	o -	uu
BWR-5		sp^{+}-	j	n -	bk^{+}-	ff	o -	uu
Sonali	Dapoli	sp -	j -	n -	bk	f	o -	uu
PKM-1	Periyakulam	sp^{+}-	j -	n -	bk -	f^{+}-	o^{+}-	u^{+}-
Co-3	TNAU, Coimbatore	sp -	j -	n	bk -	f -	o	uu
T1	Kerala Agricultural University	sp^{+}-	j -	n^{+}-	bk -	f -	o -	uu

(iv) Fruits/plant

(v) Fruit yield/plant (kg)

(vi) Average fruit weight (g)

(vii) Fruit shape index (Fruit shape index was derived by dividing polar diameter by equitorical diameter

(viii) Locules/fruit

(ix) TSS of fruits

TSS was determined by using a hand refractometer and expressed as percentage

(x) Storage life of fruits

Fruits at turning stage were selected at random from each genotype They were kept in open under ambient conditions in paper trays The storage life was calculated as the number of days from harvest till the commencement of spoilage

(xi) Fruit cracking percentage

The number of fruits showed cracking out of the total number of fruits harvested from a plant was noted and expressed as per cent The percentage of radial cracking concentric cracking and other types of fruit cracking was noted

3 Statistical analysis

Analysis of variance was done wherever necessary for a completely randomised design (Panse and Suhatme 1978)

4 Genetics of fruit cracking at F_1 level

Fifteen crack resistant genotypes (LE 296 LE 297 LE 386 LE 387 LE 388 LE 389 LE 391 LE 392 LE 393 LE 397 LE 398 LE 399 LE 400 LE 401 and LE 402) were crossed with the crack susceptible variety Sakthi to study the genetics of fruit cracking at F level The F s and parents were grown in pots filled with sterilised potting mixture They were given normal management practices upto flowering After flowering irrigation was withheld till the plants started wilting Then a flooding irrigation was given to induce fruit cracking Percentage of cracked fruits was recorded in each plant F s and parents were grouped into two crack resistant and crack susceptible

D. Evaluation of crack resistant lines for resistance to bacterial wilt

The crack resistant lines in the above experiment were tested for resistance to bacterial wilt in a wilt sick field Each plant was also spot planted with known suscept Pusa Ruby Incidence of bacterial wilt was confirmed by ooze test The incidence of bacterial wilt was recorded

E. Biochemical, physical and anatomical bases of resistance to fruit cracking

1 Chemical constituents

The chemical constituents were analysed in 15 fruit crack resistant lines and in the susceptible variety (Sakthi)

a Juice content of fruit

Freshly harvested red ripe fruits free from fruit cracking were used to extract the juice A weighed quantity of fruits was washed sliced and crushed in a mixer to obtain pulp The pulp was heated immediately to 85°C and then strained in a plastic mesh to remove seeds and skin Juice obtained was weighed and expressed as per cent on weight basis

b Insoluble solids

For determining the insoluble solids 20 g juice was centrifuged and washed with hot water repeatedly for four times and filtered through a weighed filter paper The insoluble matter was dried in a covered dish for two hours at 100 ± 2°C c Reducing sugar

Reducing sugar content was estimated as per Lane and Eynon method suggested by Ranganna (1977)

d Total sugar

Total sugar content was determined as per Lane and Eynon method outlined by Ranganna (1977)

c Pectin content

Pectin content of fruits was estimated by the method suggested by Sadasivam and Manickam (1992)

f Acidity of fruits

Acidity was estimated by titration with standard NaOH solution and expressed as citric acid

Statistical analysis for chemical constituents was done for a completely randomised design as per Panse and Suhatme (1978)

2 Physical characteristics

The following physical characteristics of fruit skin were recorded in 15 fruit crack resistant lines and one crack susceptible line (Sakthi) a Pericarp thickness (mm)

b Fruit skin thickness (mm)

c Penetrance of fruits (kg/cm^2)

Penetrance of fruits was measured by using penetrometer

Statistical analysis was done for physical characteristics for a completely randomised design as per Panse and Suhatme (1978)

3 Anatomical characteristics

Fruits of crack resistant and crack susceptible lines having a diameter of 0 5 cm were collected and fixed in FAA It was run through alcohol xylol series Sections were taken at 10 um in a rotary microtome Slides were prepared as suggested by Jenson (1962) Sections were stained by Periodic acid Schiff's (PAS) method outlined by Hotchkiss (1948)

F. Transfer of resistance to fruit cracking to a bacterial wilt resistant genetic background

1 Combining ability, gene action and heterosis

a Experimental materials

Five bacterial wilt resistant lines viz Sakthi LE 79 5 LE 214 CAV 5 and L3 415 were selected Five dominant sources of fruit crack resistance selected were LE 296 LE 386 LE 388 LE 393 and LE 399 which formed testers The bacterial wilt resistant genotypes were crossed in line x tester fashion with the five crack resistant types The twenty five F hybrids along with their parents were grown in a wilt sick field to study the reaction of the genotypes to bacterial wilt

The twenty five F hybrids along with the parents were raised in pots filled with sterilised potting mixture to study the incidence of fruit cracking They were maintained as in Experiment C

The following observations were taken

(i) Height of plant (cm)

(ii) Days to flowering

(iii) Days to harvest

(iv) Fruits/plant

(v) Fruit yield/plant (kg)

(vi) Average fruit weight (g)

(vii) Storage life

(viii) Percentage of fruit cracking

b Statistical analysis

(i) combining ability and gene action

Combining ability and gene action were studied using Line x Tester analysis (Kempthorne 1957)

(ii) Estimation of heterosis

Heterobeltiosis and relative heterosis were calculated (Briggle 1963 Hayes *et al* 1965) using the following formulae

$$\text{Heterobeltiosis} \quad \frac{\overline{F} \quad \overline{BP} \times 100}{\overline{BP}}$$

$$\text{Relative heterosis} \quad \frac{\overline{F_1} \quad \overline{MP} \times 100}{\overline{MP}}$$

where

F - mean of hybrid

$\overline{BP}$ mean of better parent

$\overline{MP}$ mean of mid parent

Heterobeltiosis was tested using stand error

$$SE \quad \sqrt{\frac{2\sigma_e^2}{r}}$$

Where σ_e^2 = error mean square

r number of replications

Relative heterosis was tested using standard error

$$SE = \sqrt{\frac{3/2\,\sigma_e^2}{r}}$$

c **Evaluation of F_2s for combined resistance to bacterial wilt and fruit cracking**

The F_2s of four crosses (CAV 5 x LE 386 CAV 5 x LE 388 CAV 5 x KE 296 and LE 214 x LE 386) were grown in a wilt sick field Spot planting with Pusa Ruby was done to confirm the presence of virulent strains of *Pseudomonas solanacearum* in the field Incidence of bacterial wilt was confirmed by ooze test They were given normal management practices upto flowering After flowering irrigation was withheld till the plants started wilting Then a flooding irrigation was given to induce fruit cracking The F_2s were observed for the incidence of bacterial wilt and fruit cracking

Results

RESULTS

Results of the investigations are presented under the following heads

A Evaluation of tomato genotypes for bacterial wilt resistance and its gene action at F level

B Biochemical bases of resistance to bacterial wilt

C Evaluation of tomato genotypes for resistance to fruit cracking and its gene action at F_1 level

D Bio chemical physical and anatomical bases of resistance to fruit cracking

E Evaluation of crack resistant lines for resistance to bacterial wilt

F Transfer of fruit crack resistance to bacterial wilt resistant genetic background

A. Evaluation of tomato genotypes for bacterial wilt resistance and its gene action at F_1 level.

1 Evaluation of tomato genotypes for resistance to bacterial wilt

Thirty four tomato genotypes were evaluated for resistance to bacterial wilt in a wilt sick soil during

January May 1991 (Season I) There was 100 per cent disease incidence in the susceptible check Pusa Ruby confirming the presence of virulent form of bacterial inoculum in the field The genotypes were classified for their reaction to bacterial wilt (Table 3) The variety Sakthi (LE 79) was found resistant with the lowest disease incidence of 15 per cent

Twenty five tomato genotypes were evaluated for resistance to bacterial wilt during July November 1991 (Season II) There was 100 per cent wilt incidence in the spot planted susceptible check (Pusa Ruby) confirming once again the presence of virulent bacterial inoculum in the field The genotypes were classified for their disease reaction (Table 4) In this season also the variety Sakthi was resistant with a disease incidence of only 17 5 per cent LE 79 5 was also found to be resistant with a disease incidence of only 20 per cent

Thirty two tomato genotypes were evaluated for the incidence of bacterial wilt during December 1991 to April 1992 (Season III) All the spot planted susceptible check Pusa Ruby plants wilted The variety Sakthi LE 79 5 and LE 214 were found to be resistant with disease incidence of 15 per cent 17 5 per cent and 20 per cent respectively The lines LE 415 CAV 5 CAV 5 1 and LE 382 1 were found to be moderately resistant with disease incidences of 25 per cent 35 per cent 35 per cent and 45 per cent respectively (Table 5)

2 **Genetics of bacterial wilt resistance at F_1 level**

Six tomato genotypes (Sakthi LE 79 5 LE 214 CAV 5 LE 415 and LE 382 1) were crossed with Pusa Ruby to study the gene action of bacterial wilt resistance at F level The wilt incidence of parents and F s are given in Table 6 The variety Sakthi and lines LE 79 5 LE 214 and CAV 5 were found to be resistant with disease incidence of 12 5 15 17 5 and 17 5 per cent respectively The lines LE 415 and LE 382 1 were found to be moderately resistant with disease incidence of 22 5 per cent and 27 5 per cent respectively All the spot planted Pusa Ruby plants wilted The F s of Resistant and moderately resistant lines with Pusa Ruby were found to be susceptible showing the absence of dominance in F s involving resistant/moderately resistant genotypes and the susceptible genotype (Table 7)

3 **Performance bacterial wilt resistant and moderately resistant genotypes**

The characteristics of bacterial wilt resistant/ moderately resistant genotypes are given in Table 8 Analysis of variance indicated significant differences among the six bacterial wilt resistant tomato genotypes for all the characters studied (Appendix I)

(i) Plant height

Plant height ranged from 63 18 cm to 98 69 cm The line LE 79 5 recorded the minimum (63 18 cm) followed by Sakthi (68 86 cm) LE 415 was the tallest (98 69 cm) followed by LE 382 1 (88 31 cm) and CAV 5 (86 69 cm)

(ii) Days to flower

LE 79 5 (63 16 days) was the earliest to flower followed by Sakthi (65 54 days) and LE 382 1 (68 44 days) LE 415 took the maximum days to flower (74 82 days)

(iii) Days of first harvest

The minimum number of days for first harvest was taken by LE 79 5 (97 22 days) followed by Sakthi (98 47) LE 415 (108 17) took the maximum number of days to harvest

(iv) Number of fruits

Sakthi produced the minimum number of fruits (19 17) followed by LE 214 (19 92 fruits) The maximum fruits were produced by LE 415 (23 3) followed by LE 79 5 (21 99)

(v) Yield/plant

The yield/plant ranged from 469 75 g to 785 g The lowest yielder was CAV 5 (469 75 g/plant) followed by LE 415 (488 78 g/plant) LE 79 5 recorded the highest yield of 785 g/plant Sakthi had an average yield of 631 25 g plant followed by LE 214 628 25 g/plant) and LE 382 1 (514 75 g/ plant)

(vi) Average fruit weight

The average fruit weight ranged from 22 5 g in LE 415 to 39 55 g in LE 79 5

(vii) Fruit shape index

Average fruit shape index ranged from 0 87 in LE 79 5 to 0 98 in LE 214 The fruit shape index in other wilt resistant/moderately resistant lines were 0 88 in LE 382 1 0 91 in Sakthi 0 95 in CAV 5 0 97 in LE 415 and 0 98 in LE 214

(viii) Locules/fruit

Locules/fruit exhibited a narrow range (2 50 to 4 11) LE 382 1 exhibited the highest locules per fruit (4 11) followed by LE 79 5 (4 10) LE 415 had the lowest locules/ fruit (2 50)

Table 3 Evaluatıon of tomato genotypes for resıstance to bacterıal wılt (January May 1991)

Lınes	Survıval %	Dısease reactıon
LE 344	20	S
LE 347	7 5	S
LE 348	7 5	S
LE 349	5	S
LE 345	0	S
LE 340	0	S
LE 339	0	S
LE 338	0	S
LE 342	5	S
LE 346	15	S
LE 354	7 5	S
LE 343	0	S
LE 356	0	S
LE 355	0	S
LE 350	0	S
LE 351	12 5	S
LE 352	0	S
LE 353	10	S
LE 341	0	S
LE 79 1	47 5	MS

Contd

Table 3 (Contd)

LE 301	45	MS
LE 313	35	S
LE 296	57 5	MS
LE 357	5	S
LE 309	17 5	S
BT	50	MS
BT$_0$	0	S
LE 358	0	S
LE 79 (Sakthı)	85	R
BWR 5	45	MS
Pusa Ruby	0	S
LE 79 4	50	MS
LE 79 3	45	MS

R	Resıstant	survıval 80% or above
MR	Moderately resıstant	survıval 60 80%
MS	Moderately susceptıble	survıval 40 60%
S	Susceptıble	survıval less than 40%

Table 4 Evaluation of tomato genotypes for resistance to bacterial wilt (July November 1991)

Lines	Survival %	Disease reaction
BWR 1	42 5	MS
BWR 5	40	MS
LE 378	0	S
LE 379	0	S
LE 380	0	S
LE 381	0	S
LE 382	50	S
LE 383	37 5	S
BT_1	45	MS
LE 79	82 5	R
LE 79 1	32 5	S
LE 79 3	30	S
LE 79 4	25	S
LE 79 5	80	R
CAV 1	15	S
CAV 5	60	MR
LE 214	65	MR
Pusa Ruby	0	S
LE 313	0	S
LE 309	0	S

Contd

Table 4 (Contd)

LE 296	0	S
LE 297	0	S
LE 311	0	S
LE 301	5	S
LE 213	7 5	S

R Resistant

MR Moderately resistant

MS Moderately susceptible

S Susceptible

Table 5 Evaluation of tomato genotypes for resistance to bacterial wilt (December 1991 April 1992)

Lines	Survival %	Disease reaction
LE 404	0	S
LE 405	0	S
LE 406	0	S
LE 407	0	S
LE 408	0	S
LE 409	0	S
LE 410	0	S
LE 411	0	S
LE 412	0	S
LE 413	0	S
LE 414	0	S
LE 415	75	MR
LE 416	0	S
LE 417	0	S
LE 418	0	S
LE 382	25	S
LE 383	0	S
LE 79 5	82 5	R
LE 394	0	S
BWR 5	57 5	MS

Contd

Table 5 (Contd)

Sonali	35	S
BT_1	40	MS
BWR 1	35	S
CAV 5	65	MR
LE 382 1	60	MR
CAV 5 1	65	MR
LE 214	80	R
BT 1	32 5	S
Pusa Ruby	0	S
LE 79	85	R
Saturn	30	S
Venus	7 5	S

R Resistant

MR Moderately resistant

MS Moderately susceptible

S Susceptible

Table 6 Evaluation of bacterial wilt resistant/moderately resistant tomato genotypes and their F s with Pusa Ruby for their reaction to bacterial wilt

Lines/hybrids	Survival %	Reaction to disease
Sakthi	87 5	R
LE 79 5	85	R
LE 214	82 5	R
CAV 5	82 5	R
LE 415	77 5	MR
LE 382 1	72 5	MR
LE 79 x Pusa Ruby	10	S
LE 79 5 x Pusa Ruby	0	S
LE 214 x Pusa Ruby	0	S
CAV 5 x Pusa Ruby	0	S
LE 415 x Pusa Ruby	0	S
LE 382 1 x Pusa Ruby	0	S
Pusa Ruby	0	S

R Resistant

MR Moderately resistant

MS Moderately susceptible

S Susceptible

Table 7 Reaction of F s involving bacterial wilt resistant/ moderately resistant genotypes and the susceptible genotype

Generation	Number of plants		
	Total	Resistant	Susceptible
Sakthi	40	35	5
Pusa Ruby	40	0	40
F	40	4	36
LE 79 5	40	34	6
Pusa Ruby	40	0	40
F_1	40	0	40
LE 214	40	33	7
Pusa Ruby	40	0	40
F	40	3	37
LE 415	40	31	9
Pusa Ruby	40	0	40
F_1	40	0	40
CAV 5	40	33	7
Pusa Ruby	40	0	40
F	40	0	40
LE 382 1	40	29	11
Pusa Ruby	40	0	40
F	40	0	40

Table 8   Mean performance of bacterial wilt resistant tomato genotypes for yield attributes

Genotypes	Plant height (cm)	Days to flower	Days to first harvest	Fruits/ plant	Fruit yield/ plant (g)	Average fruit weight (g)	Fruit shape index	Locules/ fruit
Sakthi	68 86	65 54 (8 10)	98 47 (9 92)	19 17 (4 37)	631 25	32 15	0 91	3 95
LE 79-5	63 18	63 16 (7 95)	97 22 (9 86)	21 79 (4 68)	785 00	39 55	0 87	4 10
LE 214	82 17	70 29 (8 38)	103 05 (10 15)	19 92 (4 45)	628 25	35 05	0 98	3 88
LE 415	98 69	74 82 (8 65)	108 17 (10 40)	23 30 (4 82)	488 75	22 50	0 97	2 50
LE 382 1	88 31	68 44 (8 27)	101 52 (10 08)	20 35 (4 48)	614 75	34 15	0 88	4 11
CAV 5	86 69	70 02 (8 37)	102 94 (10 15)	21 02 (4 58)	469 75	22 95	0 95	4 10
CD (0 05)	1 94	0 071	0 058	0 61	187 68	5 49	0 05	0 36
CD (0 01)	2 37	0 086	0 071	0 74	229 22	6 71	0 06	0 44

4 Incidence of fruit cracking in bacterial wilt resistant/ moderately resistant tomato genotypes under normal field conditions

The incidence of fruit cracking was recorded in bacterial wilt resistant as well as in moderately resistant tomato genotypes under normal field conditions (Table 9)

Radial fruit cracking was observed in CAV 5 and LE 382 1 Concentric cracking was observed to the tune of 19 32 per cent in Sakthi followed by 14 77 per cent in LE 214 and 1 88 per cent in LE 79 5 LE 415 was free from both radial and concentric cracking

B. Biochemical bases of bacterial wilt resistance

Analyses of variance showed that there was significant difference among the genotypes for the total phenol content O D phenol content and ascorbic acid in various plant parts at different growth stages (Appendix II to IV)

1 Total phenol

The total phenol content of bacterial wilt resistant genotypes was higher than Pusa Ruby in all the plant parts at various growth stages (Table 10) Maximum phenol content in roots were observed in LE 415 (280 ppm) at 30th day and in CAV 5 (410 ppm) at 45th day and 60th day (493 33 ppm)

Maxımum phenol content ın shoots were observed ın LE 415 (446 67 ppm) at 30th day and ın CAV 5 at 45th and 60th day (726 67 ppm and 810 ppm respectıvely) Total phenol content of whole plant was maxımum ın Sakthı (336 67 ppm) at 30th day and ın CAV 5 at 45th and 60th day (523 33 ppm and 586 67 ppm respectıvely)

2 O D Phenol

The OD phenol content of bacterıal wılt resıstant genotypes was hıgher than Pusa Ruby ın varıous plant parts at dıfferent growth stages (Table 11) The maxımum OD phenol content was noted ın the roots of LE 415 (43 33 ppm) at 30th day and ın CAV 5 at 45th and 60th day (55 33 ppm and 55 33 ppm respectıvely) OD phenol content of shoot was maxımum ın LE 214 at 30th day and ın LE 415 at 45th and 60th day (150 67 ppm and 164 ppm respectıvely) OD phenol content of the plants was the maxımum ın LE 214 (86 ppm) at 30th day ın LE 415 (102 ppm) at 45th day and ın LE 89 5 (124 67 ppm) at 60th day

3 **Ascorbıc acıd**

The ascorbıc acıd content of varıous plant parts at dıfferent growth stages ın bacterıal wılt resıstant genotypes and Pusa Ruby are gıven ın Table 12 The ascorbıc acıd content of roots was maxımum ın CAV 5 (159 ppm) at 30th day

Table 9 Incidence of fruit cracking in bacterial wilt resistant/moderately resistant tomato genotypes under normal field conditions

Genotypes	Radial fruit cracking (%)	Concentric fruit cracking (%)
Sakthi	0	19 32
LE 79 5	0	1 88
LE 214	0	14 77
LE 415	0	0
CAV 5	4 44	0
LE 382 1	2 04	0

Table 10 Total phenol content of bacterial wilt resistant genotypes and the susceptible genotype (Pusa Ruby) at various growth stages in tomato (ppm)

Genotypes	30th day			45th day			60th day		
	Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Sakthi	233 33	373 33	336 67	293 33	530 00	416 67	336 67	693 33	536 67
LE 79-5	246 67	370 00	330 00	293 33	530 00	410 00	326 67	370 00	526 67
LE 214	253 33	396 67	323 33	316 67	530 00	390 00	326 67	670 00	530 00
CAV-5	266 67	416 67	326 67	410 00	726 67	523 66	493 66	810 00	586 67
LE 415	280 00	446 67	330 67	336 67	600 00	443 33	366 67	693 33	476 66
LE 382-1	233 33	390 00	306 67	293 33	546 67	416 67	323 33	706 67	533 33
Pusa Ruby	166 67	326 67	276 67	236 67	376 67	290 00	260 00	426 67	296 67
CD (0 05)	21 96	18 32	15 74	19 87	31 06	24 18	27 30	30 58	14 80
CD (0 01)	26 87	22 01	19 26	24 31	38 00	29 58	33 40	37 41	18 11

Table 11 O D phenol content of bacterial wilt resistant genotypes and the susceptible line (Pusa Ruby) at various growth stages in tomato (ppm)

Genotypes	30th day			45th day			60th day		
	Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Sakthi	31 33	113 33	80 00	48 67	126 00	87 33	48 67	130 00	92 67
LE 79-5	35 33	122 00	81 33	48 00	128 00	93 33	46 00	86 00	124 67
LE 214	41 33	136 67	86 00	50 67	126 00	87 33	50 67	126 00	86 67
CAV-5	38 00	118 00	69 33	55 33	142 67	99 33	55 33	144 00	100 00
LE 415	43 33	122 00	80 00	52 00	150 67	102 00	54 67	164 00	106 67
LE 382-1	34 67	120 00	74 00	46 67	122 67	87 33	46 67	86 67	125 33
Pusa Ruby	24 67	81 33	62 00	35 33	89 33	60 00	36 00	81 33	62 00
CD (0 05)	1 88	9 56	2 55	2 85	9 40	2 02	2 15	2 85	1 80
CD (0 01)	2 30	11 69	3 12	3 49	11 50	3 49	2 63	3 49	2 20

Table 12 Ascorbic acid content (ppm) of bacterial wilt resistant genotypes and the susceptible line (Pusa Ruby) at various growth stages in tomato

Genotypes	30th day			45th day			60th day		
	Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Sakthi	123 00	221 33	139 67	153 67	223 67	179 67	187 67	263 67	188 67
LE 79-5	150 00	228 67	170 33	185 33	234 67	188 00	200 33	264 67	193 00
LE 214	137 00	257 67	176 33	163 33	247 00	194 33	195 33	289 00	200 33
CAV-5	159 00	333 33	195 00	230 67	291 33	241 33	202 33	299 00	234 33
LE 415	153 00	250 33	183 67	193 33	293 67	205 67	197 00	297 00	237 00
LE 382-1	106 33	191 33	174 67	155 00	217 67	190 33	176 67	244 67	199 00
Pusa Ruby	74 00	189 00	158 33	81 33	193 33	158 67	127 00	186 67	171 67
CD (0 05)	30 01	30 30	13 17	44 93	24 57	11 56	19 54	15 87	8 75
CD (0 01)	36 70	37 07	16 11	54 96	30 06	14 14	23 90	19 41	15 14

and ın CAV 5 at 45th and 60th day (230 67 ppm and 202 33 ppm respectıvely) CAV 5 recorded the maxımum ascorbıc acıd content ın shoots at 30th and 60th day (333 35 ppm 299 ppm respectıvely) Maxımum ascorbıc acıd content ın shoots at 45th day was ın LE 415 (293 67 ppm) Ascorbıc acıd content ın whole plant was maxımum ın CAV 5 at 30th and 45th day (195 ppm and 241 33 ppm respectıvely) LE 415 had the maxımum ascorbıc acıd content ın whole plants at 60 day (237 ppm)

C. Evaluatıon of tomato genotypes for resıstance to fruıt crackıng and ıts gene actıon at F_1 level

1 Evaluatıon of tomato genotypes for resıstance to fruıt crackıng

Fıfty eıght tomato genotypes were evaluated for resıstance to fruıt crackıng durıng December 1991 to Aprıl 1992 The crackıng per cent ın each genotype was noted (Table 13) The genotypes were classıfıed ınto four groups based on the nature of fruıt crackıng (Table 14)

a Radıal fruıt crackıng

The ıncıdence of radıal fruıt crackıng ranged from zero per cent to 61 63 per cent The maxımum ıncıdence was ın LE 366 (61 63%) followed by LE 312 (55 83%) LE 373 (55 48%) LE 367 (52 47%) and LE 394 (52 08%) The genotypes LE 296 LE 297 Sakthı LE 214 LE 386 LE 387 LE 388 LE 389

LE 391 LE 392 LE 393 LE 397 LE 398 LE 399 LE 400 LE 401 LE 402 and LE 79 5 were resistant to radial fruit cracking

b Concentric fruit cracking

The incidence of concentric fruit cracking ranged from zero per cent to 56 49 The maximum incidence was noted in the line LE 214 (56 49%) followed by Sakthi (55 64%) and LE 79 1 (55 06%) Thirty genotypes were resistant to concentric cracking

c Radial and concentric fruit cracking

Of the fifty eight tomato genotypes twenty two were susceptible to both radial and concentric cracking

d Resistant to both radial and concentric cracking

Fifteen tomato genotypes were resistant to both radial and concentric cracking They were LE 296 LE 297 LE 386 LE 387 LE 388 LE 389 LE 391 LE 392 LE 393 LE 397 LE 398 LE 399 LE 400 LE 401 and LE 402

2 Yield attributes of genotypes evaluated for fruit cracking

Analysis of variance indicated significant differences among the fifty eight tomato genotypes for fruit yield and its components (Appendix V) Performance of the fifty eight genotypes is given (Table 15a 15b and 15c)

a Plant height

Plant height ranged from 61 96 cm to 111 24 cm LE 79 5 was the dwarfest with 61 96 cm followed by LE 385 (62 20 cm) and LE 386 (63 51 cm) LE 361 was the tallest with 111 24 cm followed by LE 373 (108 90 cm) and LE 367 (106 31 cm)

b Days to flowering

The genotype LE 385 was the first to flower (61 25 days) followed by LE 79 5 (61 88 days) and Sakthi (62 13 days) LE 364 (73 50 days) took maximum number of days to flower

c Days to harvest

LE 385 (93 88 days) was the earliest to harvest This was closely followed by LE 79 5 (94 63 days) and LE 386 (96 13 days) LE 364 (108 5 days) took maximum number of days to harvest

LE 361 produced maximum number of fruits/plant (62 63 fruits) followed by T (52 88 fruits) The lowest number of fruits was produced by LE 394 (2 88 fruits) d Fruit yield/plant

The fruit yield/plant ranged from 0 138 kg to 0 584 kg The highest yielder was LE 388 (0 584 kg) followed by LE 398 (0 495 kg) and LE 387 (0 464 kg) The lowest yield was recorded by LE 403 (0 138 kg)

e Average fruit weight

Average fruit weight was maximum in LE 394 (73 79 g) followed by LE 388 (69 88 g) The smallest fruits were produced by LE 361 (6 42 g)

f Fruit shape index

Fruit shape index ranged from 0 62 to 1 54 The lowest fruit shape index was recorded by LE 367 (0 62) and the maximum by LE 393 (1 54)

g Locules/fruit

Locules/fruit ranged from 2 00 to 6 08 LE 367 (6 08) recorded the maximum number of locules/fruit There were only 2 00 locules/fruit in LE 392 LE 398 T_1 LE 400 LE 401 and in LE 402 h T S S

Total soluble solids ranged from 3 5 per cent to 5 31 per cent LE 399 recorded the maximum TSS (5 31%) followed by LE 391 (5 19%) and LE 393 (5 13%) The lowest was recorded by LE 378 (3 5%)

1 Storage life

The storage life was maximum for the fruits of LE 399 (41 days) followed by LE 393 (36 63 days) and in LE 386 (32 17 days) LE 337 had the shortest storage life (10 55 days)

3 Genetics of resistance to fruit cracking at F_1 level

Fifteen genotypes resistant to radial and concentric cracking were crossed with Sakthi (susceptible to concentric cracking) to study the genetics of fruit cracking at F level The incidence of fruit cracking of parents and F s are presented in Table 16 All the crack resistant parents and F s were resistant to both radial and concentric cracking

Analysis of variance showed that there is significant difference among the thirty one genotypes (sixteen parents and fifteen F hybrids) for fruit yield/plant (Appendix VI) Maximum yield was in LE 388 (0 907 kg/plant) The five best yielders among crack resistant parents were LE 388 (0 907 kg/plant) LE 296 (0 876 kg/plant) LE 386 (0 800 kg/plant)

Table 13 Percentage of fruit cracking in tomato genotypes

Genotypes	Radial fruit cracking (%)	Concentric fruit cracking (%)
LE 337	42 01	2 63
LE 296	0	0
LE 297	0	0
LE 312	55 83	0
LE 373	55 48	0
LE 377	42 17	1 15
LE 374	47 31	313
LE 371	32 91	3 70
LE 367	52 47	0
LE 213	41 39	0
LE 217	40 57	3 17
CAV 1	47 32	1 53
BWR 1	6 00	17 91
Sonali	28 52	0
BWR 5	3 13	44 29
LE 364	1 25	41 80
LE 79 1	2 08	55 06
Sakthi	0	55 64
LE 361	40 53	0
LE 366	61 63	10 8

Contd

Table 13 (Contd)

LE 370	31 95	14 98
LE 365	34 59	2 19
T	16 09	18 66
LE 214	0	56 49
LE 79 2	28 41	19 39
LE 79 3	32 88	13 26
LE 79 4	18 75	55 33
LE 302	25 82	27 42
LE 301	9 52	33 47
LE 211	19 94	40 53
LE 394	52 08	0
Pusa Ruby	38 37	0
LE 385	17 34	0
LE 386	0	0
LE 387	0	0
LE 388	0	0
LE 389	0	0
LE 391	0	0
LE 392	0	0
LE 393	0	0
LE 397	0	0
LE 398	0	0

Contd

Table 13 (Contd)

LE 399	0	0
LE 400	0	0
LE 401	0	0
LE 402	0	0
LE 403	30 78	0
Co 3	36 56	0
PKM 1	28 35	0
CAV 5	27 80	0
LE 378	9 69	15 05
LE 379	10 34	0
LE 380	11 56	0
LE 381	5 54	4 29
LE 382 1	5 56	0
LE 383	4 80	0
LE 79 5	0	13 54
Ont 828	51 64	0

Table 14 Classification of tomato genotypes based on nature of fruit cracking

Susceptible to radial cracking	Susceptible to concentric cracking	Susceptible to both radial and concentric cracking	Resistant to both radial and concentric cracking
LE 312	Sakthi	LE 337	LE 296
LE 373	LE 214	LE 377	LE 297
LE 367	LE 79 5	LE 374	LE 386
LE 213		LE 371	LE 387
Sonali		LE 217	LE 388
LE 361		CAV 1	LE 389
LE 394		BWR 1	LE 391
Pusa Ruby		BWR 5	LE 392
LE 385		LE 364	LE 393
LE 403		LE 79 1	LE 397
CO 3			LE 398
PKM 1		LE 366	LE 399
LE 378		LE 370	LE 400
LE 379		LE 365	LE 401
LE 380		LE 79 2	LE 402
CAV 5		LE 378	
LE 382		LE 79 3	
LE 383		LE 79 4	
Ont 828		LE 302	
		T	
		LE 301	
		LE 211	
		LE 381	

Table 15a Mean performance of tomato genotypes evaluated for resistance to fruit cracking

Genotypes	Plant height (cm)	Days to flower	Days to harvest	Fruits/ plant
LE 337	66 74	71 75 (8 47)	104 38 (10 22)	9 50 (3 07)
LE 296	84 14	71 38 (8 40)	105 00 (10 25)	22 38 (4 62)
LE 297	84 56	72 52 (8 50)	106 63 (10 31)	12 38 (3 84)
LE 312	89 43	70 38 (8 39)	104 25 (10 21)	16 63 (3 63)
LE 373	108 90	71 63 (8 46)	104 38 (10 21)	7 50 (2 71)
LE 377	72 48	69 88 (8 36)	104 00 (10 20)	21 75 (4 67)
LE 374	71 51	71 75 (8 47)	108 00 (10 39)	8 00 (2 80)
LE 371	105 96	72 75 (8 53)	106 75 (10 33)	6 75 (2 57)
LE 367	106 31	72 50 (8 51)	106 75 (10 33)	8 38 (2 80)
LE 213	84 10	68 63 (8 28)	100 88 (10 04)	11 13 (3 29)
LE 217	87 91	69 25 (8 32)	105 38 (10 27)	7 88 (2 73)
CAV 1	80 91	73 00 (8 54)	106 25 (10 31)	16 38 (3 91)
BWR 1	71 84	65 75 (8 11)	101 75 (10 09)	12 00 (3 08)

Contd

Table 15a (Contd)

Sonalı	81 65	71 38 (8 45)	106 13 (10 30)	15 38 (3 95)
BWR 5	72 20	67 50 (8 22)	101 00 (10 05)	6 38 (2 46)
LE 364	104 65	73 50 (8 57)	108 50 (10 42)	9 75 (3 06)
LE 79 1	71 69	65 63 (8 10)	101 38 (10 07)	5 13 (2 25)
Sakthı	66 74	62 13 (7 88)	97 00 (9 85)	11 38 (3 34)
LE 361	111 24	67 63 (8 22)	102 63 (10 13)	62 63 (7 39)
LE 366	103 41	72 38 (8 51)	104 38 (10 22)	9 50 (2 79)
LE 370	104 93	71 88 (8 48)	105 25 (10 26)	23 00 (4 69)
LE 365	105 23	71 38 (8 45)	105 25 (10 26)	30 13 (5 24)
T_1	93 70	70 38 (8 39)	103 63 (10 18)	52 88 (6 73)
LE 214	95 24	71 00 (8 43)	105 75 (10 28)	4 88 (2 19)
LE 79 2	72 76	67 63 (8 22)	100 50 (10 02)	8 00 (2 77)
LE 79 3	72 74	68 75 (8 29)	99 13 (9 96)	7 50 (2 66)
LE 79 4	67 81	68 88 (8 30)	100 00 (10 00)	6 75 (2 54)
LE 302	101 44	66 13 (8 13)	106 25 (10 31)	7 25 (2 54)

Contd

Table 15a (Contd)

LE 301	92 51	71 75 (8 47)	104 88 (10 24)	17 50 (4 08)
LE 211	81 45	67 25 (8 20)	98 50 (9 92)	14 63 (4 97)
LE 394	85 95	66 75 (8 17)	103 63 (10 18)	2 88 (1 68)
Pusa Ruby	101 30	64 75 (8 05)	98 63 (9 93)	10 00 (3 16)
LE 385	62 20	61 25 (7 83)	93 88 (9 69)	9 63 (3 09)
LE 386	63 51	62 63 (7 91)	96 13 (9 80)	10 75 (3 23)
LE 387	65 13	64 63 (8 04)	97 13 (9 86)	15 25 (3 85)
LE 388	71 84	72 78 (8 54)	104 63 (10 23)	11 50 (3 35)
LE 389	82 11	72 63 (8 52)	105 25 (10 26)	5 00 (2 29)
LE 391	84 36	70 88 (8 42)	102 63 (10 13)	7 25 (2 67)
LE 392	91 09	71 50 (8 46)	103 13 (10 16)	4 75 (2 16)
LE 393	81 95	71 13 (8 43)	103 88 (10 19)	14 13 (3 74)
LE 397	82 00	72 13 (8 49)	104 88 (10 24)	17 38 (4 14)
LE 398	78 78	68 50 (8 28)	103 38 (10 17)	12 00 (3 42)
LE 399	81 39	72 88 (8 54)	107 88 (10 39)	12 13 (3 43)
LE 400	76 40	69 50 (8 34)	104 13 (10 20)	7 75 (2 77)

Contd

Table 15a (Contd)

LE 401	75 79	69 88 (8 34)	104 63 (10 23)	11 75 (3 34)
LE 402	82 08	71 25 (8 41)	105 38 (10 29)	8 38 (2 84)
LE 403	92 65	70 50 (8 40)	102 00 (10 09)	5 13 (2 25)
CO 3	89 66	70 75 (8 41)	101 75 (10 09)	9 75 (2 87)
PKM 1	89 35	70 00 (8 37)	101 88 (10 09)	9 63 (3 08)
CAV 5	87 75	70 50 (8 40)	102 63 (10 13)	19 50 (4 32)
LE 378	83 00	70 50 (8 40)	100 88 (10 04)	9 63 (3 09)
LE 379	82 01	68 63 (8 28)	104 63 (10 23)	7 75 (2 76)
LE 380	84 05	70 63 (8 40)	104 63 (10 23)	6 00 (2 40)
LE 381	80 04	70 38 (8 40)	102 13 (10 12)	6 25 (2 44)
LE 382	93 04	72 50 (8 51)	104 13 (10 20)	13 75 (3 68)
LE 383	89 19	68 00 (8 25)	100 13 (10 01)	9 88 (3 02)
LE 79 5	61 96	61 88 (7 87)	94 63 (9 73)	18 13 (4 25)
Ont 828	69 35	72 25 (8 50)	107 00 (10 34)	9 88 (3 13)
CD (0 05)	2 74	0 11	0 08	1 03
CD (0 01)	3 61	0 15	0 11	1 35

Parenthesis indicate transformed values

Table 15b Mean performance of tomato genotypes evaluated for resistance to fruit cracking

Genotypes	Fruit yield/ plant (kg)	Average fruit weight (g)	Fruit shape shape index	Locules/ fruit
LE 337	0 255	36 80	0 87	3 56
LE 296	0 402	26 52	1 01	2 90
LE 297	0 286	29 85	0 90	3 23
LE 312	0 178	16 81	0 79	4 80
LE 373	0 193	28 33	0 66	4 83
LE 377	0 235	14 08	0 89	4 05
LE 374	0 211	27 52	0 79	4 93
LE 371	0 175	28 00	0 80	3 70
LE 367	0 237	32 14	0 62	6 08
LE 213	0 256	23 26	0 77	3 00
LE 217	0 215	31 90	0 88	4 00
CAV 1	0 384	33 27	0 95	4 00
BWR 1	0 459	44 67	0 76	5 50
Sonali	0 401	28 31	1 15	2 95
BWR 5	0 353	72 71	0 80	5 42
LE 364	0 242	26 19	0 86	3 20
LE 79 1	0 216	46 71	0 89	4 17
Sakthi	0 306	40 15	0 89	4 10
LE 361	0 173	6 42	1 05	2 60

Contd

Table 15b (Contd)

LE 366	0 207	30 06	0 89	3 54
LE 370	0 365	25 50	0 86	3 08
LE 365	0 233	12 65	0 88	4 03
T_1	0 206	7 34	0 95	2 00
LE 214	0 194	31 26	0 82	3 44
LE 79 2	0 309	49 88	0 91	5 65
LE 79 3	0 305	46 54	0 90	5 17
LE 79 4	0 269	51 02	0 89	5 18
LE 302	0 248	39 00	0 95	3 92
LE 301	0 223	23 21	0 76	5 00
LE 211	0 148	19 38	0 95	2 12
LE 394	0 213	73 79	0 78	4 00
Pusa Ruby	0 259	32 21	0 76	3 68
LE 385	0 392	43 48	1 49	2 08
LE 386	0 438	57 49	1 19	2 40
LE 387	0 464	44 71	1 05	2 15
LE 388	0 584	69 88	1 00	3 70
LE 389	0 162	38 48	1 37	3 00
LE 391	0 317	48 44	1 19	3 00
LE 392	0 174	38 94	1 17	2 00
LE 393	0 481	47 35	1 54	2 05
LE 397	0 441	37 56	1 14	2 03
LE 398	0 495	46 94	1 18	2 00

Contd

Table 15b (Contd)

LE 399	0 462	43 42	1 09	2 95
LE 400	0 297	41 50	1 27	2 00
LE 401	0 375	36 98	1 23	2 00
LE 402	0 266	41 31	1 20	2 00
LE 403	0 138	31 75	0 84	4 06
CO 3	0 326	52 00	0 93	3 10
PKM 1	0 404	47 19	0 73	3 00
CAV 5	0 400	33 75	0 94	3 00
LE 378	0 245	35 44	0 88	3 47
LE 379	0 226	35 46	0 86	4 42
LE 380	0 217	37 69	0 89	4 20
LE 381	0 196	38 69	0 89	4 21
LE 382	0 387	37 46	0 91	4 18
LE 383	0 228	37 27	0 90	5 05
LE 79 5	0 441	40 10	0 84	3 43
Ont 828	0 217	37 60	1 20	3 18
CD (0 05)	0 11	7 18	0 06	0 28
CD (0 01)	0 15	9 44	0 07	0 36

Table 15c Mean performance of tomato genotypes evaluated for resistance to fruit cracking

Genotypes	TSS of fruits (%)	Storage life (days)
LE 337	4 19	10 55
LE 296	4 67	21 74
LE 297	4 42	20 13
LE 312	3 98	10 71
LE 373	3 96	11 04
LE 377	3 92	11 43
LE 374	3 88	13 83
LE 371	3 92	10 67
LE 367	4 06	11 29
LE 213	4 19	12 63
LE 217	3 92	11 79
CAV 1	4 54	15 50
BWR 1	4 38	15 33
Sonali	3 88	20 42
BWR 5	4 42	15 84
LE 364	3 88	16 83
LE 79 1	4 25	15 67
Sakthi	5 25	13 92
LE 361	3 92	20 04
LE 366	4 06	13 13

Contd

Table 15c (Contd)

LE 370	3 92	14 09
LE 365	3 75	12 09
T	4 04	15 63
LE 214	4 56	17 00
LE 79 2	4 33	14 54
LE 79 3	4 40	16 06
LE 79 4	4 31	15 63
LE 302	4 31	12 95
LE 301	4 27	15 13
LE 211	3 81	15 20
LE 394	3 88	14 50
Pusa Ruby	4 36	11 92
LE 385	4 63	23 25
LE 386	4 71	32 17
LE 387	4 44	25 96
LE 388	4 38	26 21
LE 389	5 06	25 63
LE 391	5 19	23 33
LE 392	5 06	22 65
LE 393	5 13	36 63
LE 397	4 56	24 42
LE 398	4 19	22 98
LE 399	5 31	41 00

Contd

Table 15c (Contd)

LE 400	4 69	25 00
LE 401	4 25	22 29
LE 402	4 19	21 50
LE 403	4 19	21 75
CO 3	4 00	11 54
PKM 1	4 00	12 70
CAV 5	3 90	17 08
LE 378	3 50	19 15
LE 379	3 38	17 35
LE 380	3 81	19 79
LE 381	3 69	15 54
LE 382	3 75	22 59
LE 383	3 60	16 25
LE 79 5	4 33	18 29
Ont 828	4 21	18 53
CD (0 05)	0 30	3 19
CD (0 01)	0 40	4 19

Table 16 Evaluation of tomato genotypes resistant to fruit cracking and their F s with the susceptible for resistance to fruit cracking

Genotypes/ F s	Concentrate fruit cracking (%)	Radial fruit cracking (%)
LE 296	0	0
LE 297	0	0
LE 386	0	0
LE 387	0	0
LE 388	0	0
LE 389	0	0
LE 391	0	0
LE 392	0	0
LE 393	0	0
LE 397	0	0
LE 398	0	0
LE 399	0	0
LE 400	0	0
LE 401	0	0
LE 402	0	0
Sakthi	35 58	0
LE 296 x Sakthi	0	0
LE 297 x Sakthi	0	0
LE 386 x Sakthi	0	0
LE 387 x Sakthi	0	0
LE 388 x Sakthi	0	0
LE 389 x Sakthi	0	0
LE 391 x Sakthi	0	0
LE 392 x Sakthi	0	0
LE 393 x Sakthi	0	0
LE 397 x Sakthi	0	0
LE 398 x Sakthi	0	0
LE 399 x Sakthi	0	0
LE 400 x Sakthi	0	0
LE 401 x Sakthi	0	0
LE 402 x Sakthi	0	0

LE 399 (0 744 kg/plant) and LE 393 (0 710 kg/plant) (Table 17) They were selected as male testers for transferring fruit crack resistance to a bacterial wilt genetic background

D. Biochemical, physical and anatomical bases of resistance to fruit cracking

1 Biochemical status in fruits of fruit crack resistant and susceptible genotypes

Analyses of variance showed that there was significant difference among the genotypes for juice content insoluble solid content pectin content acidity total sugar and reducing sugar content of the fruits (Appendix VII)

a Juice content

Juice content of the fruits was maximum in the crack susceptible line Sakthi (81 05%) and was minimum in LE 389 (74 24%) (Table 18) The fruit juice content of crack resistant varieties ranged from 74 24 per cent to 80 17 per cent

b Insoluble solid content

The insoluble solids ranged from 0 63 per cent to 1 25 per cent (Table 18) The content was minimum in Sakthi (0 63%) and maximum in LE 399 (1 25%) The insoluble solid content of crack resistant varieties ranged from 0 81 per cent to 1 25 per cent The insoluble solid content of all the crack resistant varieties was significantly higher than Sakthi

c Pectin

All the fruit crack resistant varieties had significantly higher content of pectin than Sakthi (Table 18) The pectin content of Sakthi was 0 45 per cent The pectin content of crack resistant varieties ranged from 0 88 per cent in LE 399 to 1 64 per cent in LE 386

d Acidity

The range in acidity was from 0 26 per cent in LE 393 to 0 52 per cent in Sakthi (Table 18) The fruit crack resistant varieties had lesser acidity than Sakthi

e Total sugars

The total sugar content ranged from 2 82 per cent to 3 19 per cent (Table 18) All the fruit crack resistant genotypes had lesser content of total sugars than Sakthi Sakthi had a total sugar content of 3 19 per cent

f Reducing sugar

Among the genotypes Sakthi had the maximum reducing sugar content (2 63%) (Table 18) The minimum reducing sugar content was in LE 402 (1 85%) All the fruit crack resistant genotypes had lesser content of reducing sugar than Sakthi

2 Fruit skin characteristics of crack resistant and susceptible genotypes

Analyses of variance showed significant difference among the genotypes for various skin characteristics (Appendix VIII)

a Skin thickness

The skin thickness ranged from 0 11 mm to 0 22 mm (Table 19) All the crack resistant varieties had significantly higher skin thickness than Sakthi Sakthi had a skin thickness of 0 11 mm The maximum skin thickness was in LE 389 (0 22 mm) and LE 399 (0 22 mm)

b Pericarp thickness

All the crack resistant varieties had higher pericarp thickness than Sakthi (Table 19) Sakthi had a pericarp thickness of 3 78 mm The maximum pericarp thickness was observed in LE 401 (5 95 mm) followed by LE 387 (5 85) and in LE 399 (5 70 mm)

c Penetrance of fruits

Penetrance of fruit ranged from 3 05 kg/cm^2 to 5 95 kg/cm^2 (Table 19) All the crack resistant varieties had significantly higher penetrance than Sakthi The penetrance was maximum in LE 393 (5 95 kg/cm^2) and minimum in Sakthi (3 05 kg/cm^2)

3 Anatomical bases of fruit crack resistance

Thin microtome sections of the fruits revealed significant difference between crack resistant and crack susceptible varieties

The crack resistant varieties had a different type of tissue orientation in contrast to susceptible varieties There was a thick cuticle Below this there were layers of longitudinally elongated parenchymatous cells alternated with small parenchyma cells This type of cell arrangement was seen for one third of the pericarp adjacent to cuticle Below this there were loosely arranged parenchyma cells In Sakthi (susceptible to concentric cracking) thick cuticle was absent Below this the pericarp was occupied by loose parenchyma cells They were longitudinal in shape and arranged parallel to the cuticle

In the genotype susceptible to radial cracking thick cuticle was absent Pericarp consisted of loosely arranged parenchyma cells The plain of arrangement of these cells were horizontal to the fruit surface They were round in shape

In the case of concentric cracking crack started from outer part of the pericarp whereas in radial cracking the cracks were originated from the septa of the ovary

E. Evaluation of crack resistant genotypes for bacterial wilt resistance

All the fifteen crack resistant genotypes were susceptible to bacterial wilt All of them succumbed to wilt within 30 days of planting (Table 20)

F. Transfer of resistance to fruit cracking to a bacterial wilt genetic background in tomato

Five bacterial wilt resistant genotypes (Sakthi LE 79 5 LE 214 CAV 5 and LE 415) were crossed with five crack resistant genotypes in a line x tester fashion and the progenies along with the parents were evaluated for bacterial wilt resistance and fruit crack resistance

Table 17 Evaluation of tomato genotypes resistant to fruit cracking and their F s with the susceptible for fruit yield/plant

Genotypes/ F_1s	Fruit yield/plant (kg)
LE 296	0 876
LE 297	0 457
LE 386	0 800
LE 387	0 527
LE 388	0 907
LE 389	0 293
LE 391	0 296
LE 392	0 302
LE 393	0 710
LE 397	0 349
LE 398	0 329
LE 399	0 744
LE 400	0 359
LE 401	0 350
LE 402	0 334
Sakthi	0 611
LE 296 x Sakthi	0 834
LE 297 x Sakthi	0 735
LE 386 x Sakthi	0 895
LE 387 x Sakthi	0 448

Contd

Table 17 (Contd)

LE 388 x Sakthi	0 848
LE 389 x Sakthi	0 673
LE 391 x Sakthi	0 305
LE 392 x Sakthi	0 425
LE 393 x Sakthi	0 671
LE 397 x Sakthi	0 508
LE 398 x Sakthi	0 416
LE 399 x Sakthi	0 696
LE 400 x Sakthi	0 348
LE 401 x Sakthi	0 475
LE 402 x Sakthi	0 548
CD (0 05)	0 14
CD (0 01)	0 18

Table 18 Bıochemıcal content ın fruıts of genotypes resıstant to fruıt crackıng and ın the susceptıble lıne Sakthı

Genotypes/	Juıce content (%)	Insoluble solıds (%)	Pectın (%)
LE 296	80 15	0 81	1 06
LE 297	79 60	0 86	0 91
LE 386	77 05	1 00	1 64
LE 387	79 43	1 01	1 35
LE 388	76 81	1 08	1 03
LE 389	74 24	1 13	1 38
LE 391	79 18	1 06	1 16
LE 392	79 88	1 04	1 26
LE 393	79 05	1 19	1 39
LE 397	79 42	1 09	1 19
LE 398	80 41	1 06	1 31
LE 399	79 98	1 25	0 88
LE 400	79 15	1 04	1 38
LE 401	80 17	0 96	1 26
LE 402	79 85	1 00	1 24
Sakthı	81 05	0 63	0 45
CD (0 05)	1 59	0 06	0 11
CD (0 01)	2 12	0 08	0 15

Table 18 (Contd)

Genotypes/	Acidity (%)	Total sugar (%)	Reducing sugar (%)
LE 296	0 40	2 84	2 10
LE 297	0 35	2 82	2 06
LE 386	0 37	2 93	2 13
LE 387	0 36	2 90	2 08
LE 388	0 36	2 90	2 32
LE 389	0 37	2 91	2 23
LE 391	0 38	2 93	2 47
LE 392	0 41	2 88	1 95
LE 393	0 26	2 88	2 14
LE 397	0 41	2 90	1 87
LE 398	0 43	2 86	1 97
LE 399	0 35	2 94	1 91
LE 400	0 45	2 92	1 94
LE 401	0 40	2 90	1 92
LE 402	0 44	2 90	1 85
Sakthi	0 52	3 19	2 63
CD (0 05)	0 03	0 03	0 09
CD (0 01)	0 04	0 04	0 11

Table 19 Fruits skin characteristics of genotypes resistant to fruit cracking and the susceptible line Sakthi

Genotypes/	Skin thickness (mm)	Pericarp thickness (mm)	Penetrance of fruits (kg)
LE 296	0 15	4 40	4 75
LE 297	0 15	4 40	4 55
LE 386	0 18	5 33	4 93
LE 387	0 14	5 85	5 53
LE 388	0 20	5 43	3 73
LE 389	0 22	5 28	5 85
LE 391	0 17	5 08	4 43
LE 392	0 18	4 98	4 50
LE 393	0 21	5 63	5 95
LE 397	0 17	5 30	4 70
LE 398	0 17	5 13	4 63
LE 399	0 22	5 70	4 48
LE 400	0 19	5 15	4 88
LE 401	0 19	5 95	4 48
LE 402	0 16	4 55	4 28
Sakthi	0 11	3 78	3 05
CD (0 05)	0 03	0 28	0 34
CD (0 01)	0 04	0 38	0 45

Table 20 Evaluation of crack resistant genotypes for bacterial wilt resistance

Genotypes	Survival (%)
LE 296	0
LE 297	0
LE 386	0
LE 387	0
LE 388	0
LE 389	0
LE 391	0
LE 392	0
LE 393	0
LE 397	0
LE 398	0
LE 399	0
LE 400	0
LE 401	0
LE 402	0

1 **Evaluation for bacterial wilt resistance**

Survival percentage of F s and parents are given in Table 21 All the F hybrids were susceptible Among the parents Sakthi recorded the highest survival of 93 33 per cent followed by LE 79 5 (90%) CAV 5 (91 67%) LE 214 (90%) and LE 415 (90%) All the crack resistant parents succumbed to bacterial wilt

2 **Evaluation of F_1 hybrids for fruit crack resistance**

All the F hybrids were resistant to both radial and concentric cracking (Table 22) All the crack resistant varieties were remained to be resistant Among the bacterial wilt resistant genotypes LE 214 Sakthi and LE 79 5 were susceptible to concentric cracking (41 26% 40 89% and 11 30% respectively) CAV 5 (37 07%) was susceptible to radial cracking LE 415 was resistant to both radial and concentric cracking

3 **Line x Tester analysis for yield attributes**

a **Combining ability and gene action**

The analysis of variance revealed highly significant differences for all the characters studied among the 35 genotypes (Appendix IX)

Based on line x tester analysis general and specific combining ability effects (gca and sca) were estimated (Tables 23 and 24) Components of additive and non additive variances and heritability in narrow sense were also estimated (Appendix X)

Yield and its components

The genotype LE 415 (12 81) had a significantly in positive gca effect for height of plant LE 79 5 (6 01) LE 214 (5 52) and Sakthi (5 19) had significant negative gca effects Significant sca effects for plant height were expressed in LE 415 x LE 388 (10 52) and CAV 5 x LE 386 (8 75) Significant negative sca effects were observed in CAV 5 x LE 388 (7 72) LE 415 x LE 393 (5 56) and LE 79 5 x LE 386 (5 19) Heritability was 0 64 Preponderance of additive variance was also observed for plant height (63 14)

LE 386 and LE 214 showed significant negative gca effects (0 25 and 0 23 respectively) for days to flowering The significantly positive gca effects were expressed by CAV 5 (0 27) and LE 415 (0 22) Significantly negative sca effects were shown by LE 415 x LE 388 (0 26) LE 79 x LE 386 (0 15) and CAV 5 x LE 296 (0 14) Significantly positive sca effects were shown by Sakthi x LE 388 (0 26) and LE 415 x LE 296 (0 19) Heritability in the narrow sense was high (0 70) for days to flowering Additive genetic variance was 0 06

Highly significant negative gca effects were observed for days to harvest in LE 214 (0 20) and LE 386 (0 20) Significant positive gca effects were observed CAV 5 (0 21) and LE 415 (0 17) HIghly significant negative sca effects were observed in LE 415 x LE 388 (0 21) and LE 79 5 x LE 386 (0 14) Heritability in narrow sense was high (0 74) for days to harvest Additive genetic variance was 0 18

CAV 5 LE 386 and LE 296 were good general combiners for fruits/plant as evidenced by gca effects (0 57 0 27 and 0 20 respectively) LE 79 5 (0 39) Sakthi (0 34) and LE 388 (0 23) were poor general combiners for fruits/plant Sakthi x LE 399 Sakthi x LE 388 and LE 214 x LE 296 (0 27) showed significant positive sca effects (0 43 0 28 and 0 27 respectively) The heritability for fruits/plant was 0 65 and additive variance was 0 18

The good general combiners for fruit yield/plant were CAV 5 (0 16) and LE 386 (0 11) Hybrids CAV 5 x LE 388 (0 15) LE 415 x LE 393 (0 12) and Sakthi x LE 399 (0 12) showed significant positive sca effects Heritability in narrow sense was 0 60 and additive genetic variance was 0 02

LE 79 5 LE 388 Sakthi and showed significant gca effects for average fruit weight (4 85 4 58 and 4 03 respectively) Hybrids LE 415 x LE 393 (4 57) CAV 5 x LE 388 (4 18) and CAV 5 x LE 296 (3 66) expressed highly significant positive sca effects The heritability in narrow sense was 0 73 Preponderance of additive genetic variance was observed for this trait

LE 399 (0 32) LE 415 (0 30) and LE 393 (0 23) showed significant gca effects for storage life Hybrids LE 214 x LE 388 (0 31) and LE 415 x LE 386 (0 22) showed significant positive sca effects Heritability in narrow sense was high (0 84) and preponderance additive genetic variance was observed (0 18)

b Heterosis

The mean performance of parents viz Sakthi LE 79 5 LE 214 CAV 5 and LE 415 LE 296 LE 386 LE 388 LE E93 and LE 399 and heterosis over better parent (heterobeltiosis) and mid parent (relative heterosis) were estimated and presented (Table 25(a) 25(b) 25(c) and 25(d)

Plant height

The estimate of heterobeltiosis and relative heterosis ranged from 17 94 to 14 08 per cent and 9 63 to 18 80 per cent respectively The highest positive heterosis was shown by Sakthi x LE 296 (14 08%) followed by LE 214 x LE 296 (13 15%) Maximum negative heterosis was shown by LE 415 x LE 399 (17 94%) followed by LE 415 x LE 386 (17 52%)

LE 79 5 x LE 386 (62 50 cm) was the dwarfest hybrid and LE 415 x LE 388 (103 25 cm) was the tallest hybrid

Days to flowering

The heterobeltiosis and relative heterosis for days to flowering ranged from 1 93 per cent to 7 68 and 3 79 to 3 79 per cent respectively Among the F hybrids Sakthi x LE 386 (63 50 days) was the earliest to flower Heterobeltiosis for this hybrid was 0 59 per cent and relative heterosis 0 69 per cent

Days to harvest

LE 79 5 x LE 386 (94 75 days) was the earliest to harvest among the hybrids and parents tested This hybrid had a heterobeltiosis of 0 89 per cent and a relative heterosis of 1 02 per cent LE 415 x LE 296 took the maximum days to harvest (110 days)

Fruits/plant

Maximum number of fruits were produced by CAV 5 Among the hybrids maximum number of fruits were produced by CAV 5 x LE 296 (28 50 fruits) Heterobeltiosis was 24 54 per cent and relative heterosis was 4 38 per cent for this trait

Fruit yield/plant

CAV 5 x LE 386 (1 05 kg/plant) gave the maximum yield among the hybrids and parents followed by CAV 5 x LE 388 (1 01 kg/plant) CAV 5 X LE 386 recorded a heterobeltiosis of 17 65 per cent and relative heterosis of 35 27 per cent The heterobeltiosis and relative heterosis were positive and significant

Average fruit weight

The maximum sized fruits were produced by LE 388 (58 82 g) The maximum fruit weight was recorded by the cross LE 214 x LE 388 (49 67 g) followed by LE 79 5 x LE 388 (47 28 g) The heterobeltiosis for the former hybrid was 15 57 per cent and relative heterosis was 2 01 per cent LE 79 5 x LE 388 had a heterobeltiosis of 19 63 per cent and a relative heterosis of 4 77 per cent

Storage life

LE 399 had the maximum storage life (36 55 days) Among the hybrids LE 79 5 x LE 399 had the maximum storage life (32 40 days) This hybrid had a heterobeltosis of 5 91 per cent and relative heterosis of 16 19 per cent for storage life

Table 21 Evaluation of F hybrids and parents for bacterial wilt resistance in transfer of resistance to fruit cracking

Parents/F_1 hybrids	Survival (%)	Class
Sakthi	93 33	R
LE 79 5	91 67	R
LE 214	90 00	R
CAV 5	91 67	R
LE 415	90 00	R
LE 296	0	S
LE 386	0	S
LE 388	0	S
LE 393	0	S
LE 399	0	S
Sakthi x LE 296	6 67	S
Sakthi x LE 386	3 33	S
Sakthi x LE 388	3 33	S
Sakthi x LE 393	1 67	S
Sakthi x LE 399	1 67	S
LE 79 5 x LE 296	0	S
LE 79 5 x LE 386	0	S
LE 79 5 x LE 388	0	S
LE 79 5 x LE 393	0	S
LE 79 5 x LE 399	0	S
LE 214 x LE 296	5 00	S
LE 214 x LE 386	6 67	S
LE 214 x LE 388	1 67	S
LE 214 x LE 393	3 33	S
LE 214 x LE 399	3 33	S
CAV 5 x LE 296	0	S
CAV 5 x LE 386	0	S
CAV 5 x LE 388	0	S
CAV 5 x LE 393	0	S
CAV 5 x LE 399	0	S
LE 415 x LE 296	0	S
LE 415 x LE 386	0	S
LE 415 x LE 388	0	S
LE 415 x LE 393	0	S
LE 415 x LE 399	0	S

Table 22 Fruit cracking percentage of parents and F hybrids in transfer of resistance to fruit cracking

Parents/F hybrids	Concentric cracking (%)	Radial cracking (%)
Sakthi	40 89	0
LE 79 5	44 30	0
LE 214	41 26	0
CAV 5	0	37 07
LE 415	0	0
LE 296	0	0
LE 386	0	0
LE 388	0	0
LE 393	0	0
LE 399	0	0
Sakthi x LE 296	0	0
Sakthi x LE 386	0	0
Sakthi x LE 388	0	0
Sakthi x LE 393	0	0
Sakthi x LE 399	0	0
LE 79 5 x LE 296	0	0
LE 79 5 x LE 386	0	0
LE 79 5 x LE 388	0	0
LE 79 5 x LE 393	0	0
LE 79 5 x LE 399	0	0
LE 214 x LE 296	0	0
LE 214 x LE 386	0	0
LE 214 x LE 388	0	0
LE 214 x LE 393	0	0
LE 214 x LE 399	0	0
CAV 5 x LE 296	0	0
CAV 5 x LE 386	0	0
CAV 5 x LE 388	0	0
CAV 5 x LE 393	0	0
CAV 5 x LE 399	0	0
LE 415 x LE 296	0	0
LE 415 x LE 386	0	0
LE 415 x LE 388	0	0
LE 415 x LE 393	0	0
LE 415 x LE 399	0	0

Table 23 Estımates of general combınıng abılıty effects of lınes and testers for yıeld and ıts components ın tomato

	Plant heıght (cm)	Days to flowerıng	Days to harvest	Fruıts/ plant
Lınes				
Sakthı (LE 79)	5 19 **	0 12 **	0 10 **	0 34**
LE 79 5	6 01 **	0 13 **	0 09 **	0 39 **
LE 214	5 52 **	0 23 **	0 20 **	0 06 **
CAV 5	3 90 **	0 27 **	0 21 **	0 57 **
LE 415	12 81 **	0 22 **	0 17 **	0 10 **
SE (g)	0 59	0 01	0 01	0 02
SE (g g_j)	0 83	0 014	0 04	0 03
Testers				
LE 296	1 74 **	0 05 **	0 01	0 20 **
LE 386	3 36 **	0 25 **	0 20 **	0 27 **
LE 388	2 87 **	0 07 **	0 06 **	0 23 **
LE 393	0 00	0 03 **	0 04 **	0 01
LE 399	1 25 *	0 09 **	0 08 **	0 25 **
SE (g_i)	0 59	0 01	0 01	0 02
SE (g g_j)	0 83	0 014	0 014	0 03

** Sıgnıfıcant at 1 per cent level

* Sıgnıfıcant at 5 per cent level

Table 23 (Contd)

	Fruit yield/ plant	Average fruit weight	Storage life (days)
Lines			
Sakthi (LE 79)	0 04 **	4 03 **	0 24 **
LE 79 5	0 07 **	4 85 **	0 17 **
LE 214	0 06 **	3 92 **	0 04 **
CAV 5	0 16 **	3 63 **	0 17 *
LE 415	0 12 **	9 17 **	0 30 **
SE (g_i)	0 01	0 36	0 02
SE (g g_j)	0 014	0 51	0 03
Testers			
LE 296	0 03 **	1 88 **	0 38 **
LE 386	0 11 **	1 81 **	0 12 **
LE 388	0 02 *	4 58 **	0 30 **
LE 393	0 03 **	1 37 **	0 23 **
LE 399	0 14 **	3 13 **	0 32 **
SE (g)	0 01	0 36	0 02
SE (g g_j)	0 014	0 51	0 03

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 24 Estimates of specific combining ability effects for fruit yield and its components in tomato hybrids

	Plant height (cm)	Days to flowering	Days to harvest	Fruits/ plant
Sakthi x LE 296	2 53**	0 02	0 06**	0 13**
Sakthi x LE 386	2 12**	0 08**	0 07**	0 49**
Sakthi x LE 388	2 11**	0 26**	0 24**	0 28**
Sakthi x LE 393	0 19	0 08**	0 06**	0 09
Sakthi x LE 399	2 34**	0 12**	0 05**	0 43**
LE 79 5 x LE 296	0 64	0 05**	0 02	0 03
LE 79 5 x LE 386	5 19**	0 15**	0 14**	0 09
LE 79 5 x LE 388	0 69	0 04*	0 07**	0 17**
LE 79 5 x LE 393	3 96**	0 10**	0 08**	0 21**
LE 79 5 x LE 399	1 28*	0 06**	0 01	0 10*
LE 214 x LE 296	1 42*	0 02	0 03	0 27**
LE 214 x LE 386	1 80**	0 06**	0 02	0 16**
LE 214 x LE 388	0 00	0 06**	0 09**	0 29**
LE 214 x LE 393	0 92	0 00	0 03	0 06
LE 214 x LE 399	2 30**	0 14**	0 13**	0 20**
CAV 5 x LE 296	2 02**	0 14**	0 08**	0 12*
CAV 5 x LE 386	8 75**	0 15**	0 08**	0 12*
CAV 5 x LE 388	7 72**	0 01	0 02	0 14**
CAV 5 x LE 393	0 50	0 04*	0 07**	0 19**
CAV 5 x LE 399	0 50	0 06**	0 06**	0 19**
LE 415 x LE 296	5 34**	0 19**	0 18**	0 23**
LE 415 x LE 386	3 88**	0 14**	0 12**	0 13**
LE 415 x LE 388	10 52**	0 26**	0 21**	0 04
LE 415 x LE 393	5 56**	0 06**	0 06**	0 00
LE 415 x LE 399	6 41**	0 02	0 03	0 06
SE (S_{ij})	0 59	0 02	0 02	0 05
SE (S_{ij} S_{ik})	0 83	0 03	0 03	0 07

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 24 (Contd)

	Fruit yield/ plant (kg)	Average fruit weight	Storage life (days)
Sakthi x LE 296	0 02**	1 17	0 09*
Sakthi x LE 386	0 09**	1 94**	0 04
Sakthi x LE 388	0 02*	6 63**	0 05
Sakthi x LE 393	0 01	2 05**	0 14**
Sakthi x LE 399	0 12**	1 47*	0 05
LE 79 5 x LE 296	0 01	1 08	0 07
LE 79 5 x LE 386	0 01	0 32	0 04
LE 79 5 x LE 388	0 09**	0 51	0 30**
LE 79 5 x LE 393	0 05**	1 60*	0 15**
LE 79 5 x LE 399	0 06**	2 87**	0 18**
LE 214 x LE 296	0 10**	0 57	0 08*
LE 214 x LE 386	0 05**	1 04	0 25**
LE 214 x LE 388	0 06**	2 80**	0 31**
LE 214 x LE 393	0 00	1 98**	0 08*
LE 214 x LE 399	0 09**	1 30	0 05
CAV 5 x LE 296	0 08**	3 66**	0 04
CAV 5 x LE 386	0 10**	0 65	0 05
CAV 5 x LE 388	0 15**	4 18**	0 09*
CAV 5 x LE 393	0 19**	3 03**	0 01
CAV 5 x LE 399	0 15**	5 46**	0 09
LE 415 x LE 296	0 16**	3 19**	0 02
LE 415 x LE 386	0 05**	3 96**	0 22**
LE 415 x LE 388	0 02*	0 16	0 05
LE 415 x LE 393	0 12**	4 57**	0 08*
LE 415 x LE 399	0 06**	2 42**	0 10**
SE (S_{j})	0 01	0 73	0 04
SE (S_{ij} S_{ik})	0 014	1 03	0 06

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 25a Mean performance of parental lines and heterosis of F hybrids for plant height and days to flowering in tomato

Parents/ F hybrids	Plant height (cm)			Days to flowering		
	Mean	HB %	RH %	Mean	HB %	RH %
Parents						
Sakthi	66 67			64 25 (8 02)		
LE 79 5	65 52			61 50 (7 84)		
LE 214	74 57			69 50 (8 34)		
CAV 5	89 07			72 75 (8 53)		
LE 415	100 18			75 00 (8 66)		
LE 296	82 72			71 75 (8 47)		
LE 386	65 75			64 50 (8 03)		
LE 388	73 65			74 25 (8 61)		
LE 393	81 73			72 00 (8 48)		
LE 399	81 75			74 75 (8 64)		

Contd

Table 25a (Contd)

F_1 hybrids

Sakthi x LE 296	71 07	14 08**	4 92	70 00 (8 37)	4 43**	1 55**
Sakthi x LE 386	70 62	5 77	6 58*	63 50 (7 97)	0 59	0 69
Sakthi x LE 388	72 62	1 39	3 44	74 50 (8 63)	7 67**	3 79**
Sakthi x LE 393	72 05	11 84**	2 96	68 00 (8 25)	2 93**	0 00
Sakthi x LE 399	72 95	10 76**	1 77	68 25 (8 27)	3 12**	0 77
LE 79 5 x LE 296	73 43	11 24**	0 94	68 75 (8 30)	5 77**	1 70**
LE 79 5 x LE 386	62 50	4 94	4 78	68 25 (7 89)	0 61	0 58
LE 79 5 x LE 388	73 22	0 58	5 23	70 50 (8 40)	7 11**	2 08**
LE 79 5 x LE 393	75 00	8 23**	1 87	71 00 (8 43)	7 49**	3 26**
LE 79 5 x LE 399	71 07	13 06**	3 48	71 25 (8 44)	7 68**	2 46**
LE 214 x LE 296	71 85	13 15**	8 65**	67 50 (8 22)	1 44*	2 20
LE 214 x LE 386	66 38	11 00**	5 40	62 00 (7 88)	1 93**	3 79**
LE 214 x LE 388	74 40	0 23	0 39	67 25 (8 20)	1 65**	3 24**
LE 214 x LE 393	72 45	11 35**	7 29**	67 50 (8 22)	1 47*	2 32**
LE 214 x LE 399	72 58	11 22**	7 15**	70 75 (8 41)	0 90	0 90

Contd

Table 25a (Contd)

CAV 5 x LE 296	80 67	9 43**	6 08**	74 00 (8 60)	0 82	1 18*
CAV 5 x LE 386	86 35	3 06	11 55**	73 75 (8 59)	6 91**	3 68**
CAV 5 x LE 388	76 10	14 57**	6 47**	77 00 (8 77)	2 84**	2 33**
CAV 5 x LE 393	81 45	8 56**	4 63*	76 75 (8 76)	3 24**	2 97**
CAV 5 x LE 399	80 20	9 96**	6 10**	76 00 (8 72)	2 20**	1 53**
LE 415 x LE 296	96 95	3 22	6 01**	79 00 (8 89)	4 93**	3 78**
LE 415 x LE 386	82 62	17 52**	0 41	72 75 (8 53)	6 23**	2 23**
LE 415 x LE 388	103 25	3 07	18 80**	71 50 (8 46)	1 83**	2 07**
LE 415 x LE 393	84 30	15 85**	7 31**	74 25 (8 61)	1 53**	0 51
LE 415 x LE 399	82 20	17 94**	9 63**	76 00 (8 72)	0 87**	0 78**
SEm	0 27			0 01		

Table 25b Mean performance of parental lines and heterosis of F hybrids for days to harvest and fruits/plant in tomato

Parents/ F hybrids	Days to harvest			Fruits/plant		
	Mean	HB %	RH %	Mean	HB %	RH %
Parents						
Sakthi	98 00 (9 90)			38 75		
LE 79 5	96 50 (9 82)			29 00		
LE 214	100 75 (10 04)			40 00		
CAV 5	105 50 (10 27)			49 25		
LE 415	106 00 (10 30)			39 75		
LE 296	105 00 (10 25)			18 50		
LE 386	97 00 (9 85)			15 00		
LE 388	105 00 (10 25)			13 75		
LE 393	103 19 (10 19)			12 75		
LE 399	107 50 (10 37)			12 00		
F hybrids						
Sakthi x LE 296	100 50 (10 02)	1 26	0 48	16 00**	32 48**	18 81**
Sakthi x LE 386	96 00 (9 80)	0 51	0 76	14 00	37 43**	23 32**

Contd

Table 25b (Contd)

Sakthı x LE 388	107 75 (10 38)	4 82**	3 00**	16 75	33 02**	18 30**
Sakthı x LE 393	101 00 (10 05)	1 52**	0 06	15 75	35 04**	17 89**
Sakthı x LE 399	102 00 (10 10)	2 02**	0 33	17 50	30 75**	14 12**
LE 79 5 x LE 296	101 50 (10 07)	2 54**	0 39	15 75	26 53**	14 29**
LE 79 5 x LE 386	94 75 (9 74)	0 89	1 02**	19 50	23 38**	8 81**
LE 79 5 x LE 388	104 25 (10 21)	3 94**	1 74**	12 75	36 80**	25 16**
LE 79 5 x LE 393	104 25 (10 21)	3 82**	1 94**	18 25	25 69**	8 66**
LE 79 5 x LE 399	103 25 (10 16)	3 44**	0 66	13 25	35 87**	22 73**
LE 214 x LE 296	99 00 (9 95)	0 87*	1 90**	24 75	23 52**	6 00**
LE 214 x LE 386	95 75 (9 79)	0 63	1 57**	23 75	24 31**	5 34*
LE 214 x LE 388	98 75 (9 94)	1 00**	2 03**	14 25	39 18**	24 29**
LE 214 x LE 393	99 50 (9 98)	0 62	1 36**	20 75	29 78**	9 53**
LE 214 x LE 399	103 50 (10 17)	1 37**	0 27	14 75	37 96**	21 53**
*CAV 5 x LE 296	106 50 (10 32)	0 71	0 58	28 50	24 54	4 38*
CAV 5 x LE 386	105 25 (10 26)	4 19**	2 00**	27 25	23 68**	1 58

Contd

Table 25b (Contd)

CAV 5 x LE 388	108 75 (10 43)	1 73**	1 62**	22 75	30 59**	10 88**
CAV 5 x LE 393	110 25 (10 50)	3 07**	2 64**	22 25	31 70**	9 40**
CAV 5 x LE 399	108 25 (10 40)	1 27**	0 80*	19 75	35 48**	15 90**
LE 415 x LE 296	110 00 (10 53)	2 78**	2 53**	19 50	29 89**	14 44**
LE 415 x LE 386	105 25 (10 26)	4 16**	1 85**	23 00	23 18**	4 44
LE 415 x LE 388	104 00 (10 20)	0 49	0 72	17 50	32 43**	16 34
LE 415 x LE 393	106 75 (10 33)	1 40**	0 85*	20 25	29 18**	9 21**
LE 415 x LE 399	108 00 (10 39)	0 90*	0 56	17 50	32 43**	14 99**
SEm	0 01			0 02		

Table 25c Mean performance of parental lines and heterosis of F hybrids for fruit yield/plant and average fruit weight in tomato

Parents/ F hybrids	Fruit yield/plant (kg)			Average fruit weight (g)		
	Mean	HB %	RH %	Mean	HB %	RH %
Parents						
Sakthi	0 90			40 01		
LE 79 5	0 70			40 46		
LE 214	0 91			38 55		
CAV 5	0 89			29 35		
LE 415	0 73			25 05		
LE 296	0 62			33 65		
LE 386	0 66			49 10		
LE 388	0 72			58 82		
LE 393	0 54			50 45		
LE 399	0 52			46 46		
F_1 hybrids						
Sakthi x LE 296	0 65	27 98**	14 75**	41 68	4 17	13 17**
Sakthi x LE 386	0 66	27 42**	16 16**	46 15	6 02**	3 57
Sakthi x LE 388	0 64	29 36**	21 17**	40 33	31 44**	18 39**
Sakthi x LE 393	0 62	31 52**	14 53**	43 07	14 63	4 77
Sakthi x LE 399	0 61	32 41**	14 24**	40 72	12 35**	5 81**

Contd

Table 25c (Contd)

LE 79 5 x LE 296	0 63	18 12**	9 32*	40 25	0 21	8 62**
LE 79 5 x LE 386	0 71	7 77	0 52	45 35	7 65**	1 26
LE 79 5 x LE 388	0 54	24 83**	27 73**	47 28	19 63**	4 77
LE 79 5 x LE 393	0 63	17 80**	3 42	40 24	20 25**	11 49**
LE 79 5 x LE 399	0 53	31 70**	17 60**	42 94	7 58*	1 20
LE 214 x LE 296	0 88	3 58	14 38**	39 84	3 35	10 36
LE 214 x LE 386	0 90	0 83	14 83**	45 13	8 08**	2 99
LE 214 x LE 388	0 70	22 59**	13 41**	49 67	15 57*	2 01
LE 214 x LE 393	0 72	20 94**	1 03	38 93	22 83**	12 52**
LE 214 x LE 399	0 51	43 80**	28 55**	37 85	18 53**	10 95**
CAV 5 x LE 296	0 96	7 00**	26 07	36 52	8 51*	15 92**
CAV 5 x LE 386	1 05	17 65**	35 27**	37 19	24 25**	5 18
CAV 5 x LE 388	1 01	13 17**	25 66**	43 49	26 08**	1 37
CAV 5 x LE 393	0 62	30 53**	13 59**	30 32	39 89**	24 00**
CAV 5 x LE 399	0 55	38 66**	22 48**	26 14	43 74**	31 04**

Contd

Table 25c (Contd)

LE 415 x LE 296	0 44	40 07**	35 30**	24 12	28 31**	17 81**
LE 415 x LE 386	0 62	14 73**	10 43*	27 04	44 93**	27 07**
LE 415 x LE 388	0 60	18 15**	17 30**	33 92	42 33**	19 11**
LE 415 x LE 393	0 66	9 93	3 34	32 39	35 82**	14 23**
LE 415 x LE 399	0 48	33 56**	22 40**	28 47	38 72**	20 37**
SEm	0 004			0 17		

Table 25d Mean performance of parental lines and heterosis for storage life in tomato F hybrids

Parents/F_1 hybrids	Storage life (days)		
	Mean	HB %	RH %
Parents			
Sakthi	10 20 (3 19)		
LE 79 5	14 05 (3 74)		
LE 214	10 40 (3 22)		
CAV 5	15 75 (3 96)		
LE 415	17 95 (4 24)		
LE 296	18 25 (4 27)		
LE 386	32 10 (5 66)		
LE 388	22 25 (4 72)		
LE 393	33 20 (5 76)		
LE 399	36 55 (6 04)		
F_1 hybrids			
Sakthi x LE 296	20 15 (4 49)	5 03**	20 23**
Sakthi x LE 386	24 30 (4 93)	13 02**	11 26**
Sakthi x LE 388	19 55 (4 42)	6 20**	11 86**
Sakthi x LE 393	23 65 (4 86)	15 62**	8 60**
Sakthi x LE 399	26 50 (5 15)	14 85**	11 45**
LE 79 5 x LE 296	22 50 (4 74)	11 00**	18 30**
LE 79 5 x LE 386	28 60 (5 34)	5 65**	13 60**
LE 79 5 x LE 388	21 00 (4 58)	2 81	8 33**

Contd

Table 25d (Contd)

LE 79 5 x LE 393	31 00 (5 57)	3 38*	17 12**
LE 79 5 x LE 399	32 40 (5 69)	5 91**	16 19**
LE 214 x LE 296	17 20 (4 15)	2 87	10 70**
LE 214 x LE 386	20 05 (4 47)	21 01**	0 67
LE 214 x LE 388	21 30 (4 61)	2 17	16 18**
LE 214 x LE 393	24 25 (4 92)	14 58**	9 54**
LE 214 x LE 399	23 80 (4 88)	19 31**	5 23**
CAV 5 x LE 296	23 45 (4 84)	13 28**	17 55**
CAV 5 x LE 386	27 55 (5 24)	7 46**	8 91**
CAV 5 x LE 388	24 65 (4 97)	5 30**	14 43**
CAV 5 x LE 393	29 20 (5 41)	6 20**	11 16**
CAV 5 x LE 399	30 00 (5 43)	10 22**	8 47**
LE 415 x LE 296	24 55 (4 95)	15 97**	16 45**
LE 415 x LE 386	31 90 (5 65)	0 31	14 06**
LE 415 x LE 388	24 60 (4 96)	5 20**	10 81**
LE 415 x LE 393	29 90 (5 47)	5 12**	9 35**
LE 415 x LE 399	30 65 (5 53)	8 44**	7 66**

4 Evaluation of F_2s for combined resistance

F_2 population resulted out of four crosses were raised in a wilt sick field to evaluate for combined resistance to bacterial wilt and fruit cracking (Table 26) The performance of superior F_2 progenies having combined resistance are given in Table 27 Plant number 3 and plant number 7 of the F_2 progenies of CAV 5 x LE 386 were high yielding (1 42 kg/plant and 1 35 kg/plant respectively) Plant number 2 of the F_2 progeny of CAV 5 x LE 385 plant number 5 of F_2 progeny of CAV 5 x LE 296 and plant number 2 of LE 214/LE 386 were also high yielding (1 21 kg/plant 1 23 kg/plant and 1 16 kg/plant respectively) besides being resistant to both bacterial wilt and fruit cracking

Table 26. Evaluation of F_2 generation for combined resistance to bacterial wilt and fruit cracking

Genotype	Number of plants	Number of plants resistant to both bacterial wilt and fruit cracking
CAV-5 x LE 386 F_2	218	12
CAV-5 x LE 388 F_2	178	8
CAV-5 x LE 393 F_2	235	11
LE 214 x LE 386 F_2	195	10

Table 27. Performance of superior F_2's resistant to both bacterial wilt and fruit cracking

Genotype	Growth habit	Plant height (cm)	Days to flowering	Days to harvest	Fruits/ plant	Fruits yield/ plant (kg)	Average fruit weight (g)
CAV-5 x LE 386 F_2 plant 3	Semi determinate	82.40	74.00	105.00	24.00	1.42	78.53
CAV-5 x LE 386 F_2 plant 7	"	80.20	72.00	104.00	20.00	1.35	72.48
CAV-5 x LE 388 F_2 plant 2	"	81.60	70.00	102.00	18.00	1.21	68.42
CAV-5 x LE 296 F_2 plant 5	"	87.80	73.00	104.00	28.00	1.23	51.45
LE 214 X LE 386 F_2 plant 2	"	74.80	69.00	102.00	19.00	1.16	49.35

Plate I Bacterial wilt sick field

Plate IIa   Spot planting technique

b   Spot planting technique

Plate III   Bacterial wilt resistant genotypes

a   LE 79-5

b   CAV-5


LE 79-5

Plate IIIc LE 415

d LE 382-1


LE415


LE 382-1

Plate IV Types of fruit cracking

a Sakthi (LE 79) (Susceptible to concentric cracking)

b LE 214 (Susceptible to concentric cracking)

c LE 79-5 (Susceptible to concentric cracking)


LE 79


LE 214


LE 79-5

Plate IV

d PKM-1 (Susceptible to radial cracking)

e Pusa Ruby (Susceptible to radial cracking)


PKM-1


PUSA RUBY

Plate V Genotypes resistant to fruit cracking

a   LE 296

b   LE 386

c   LE 388


LE 296


LE 386


LE 388

Plate V

d LE 393

e LE 399


LE 393

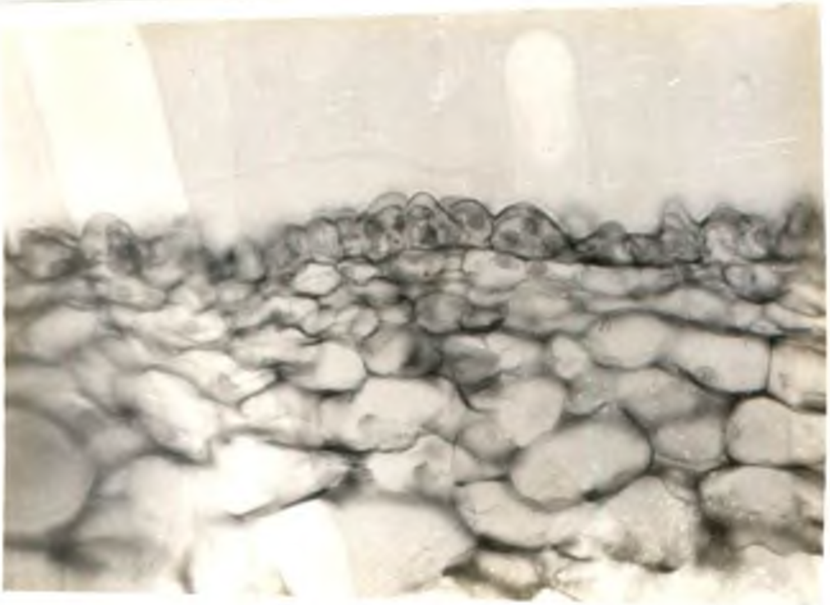

LE 399

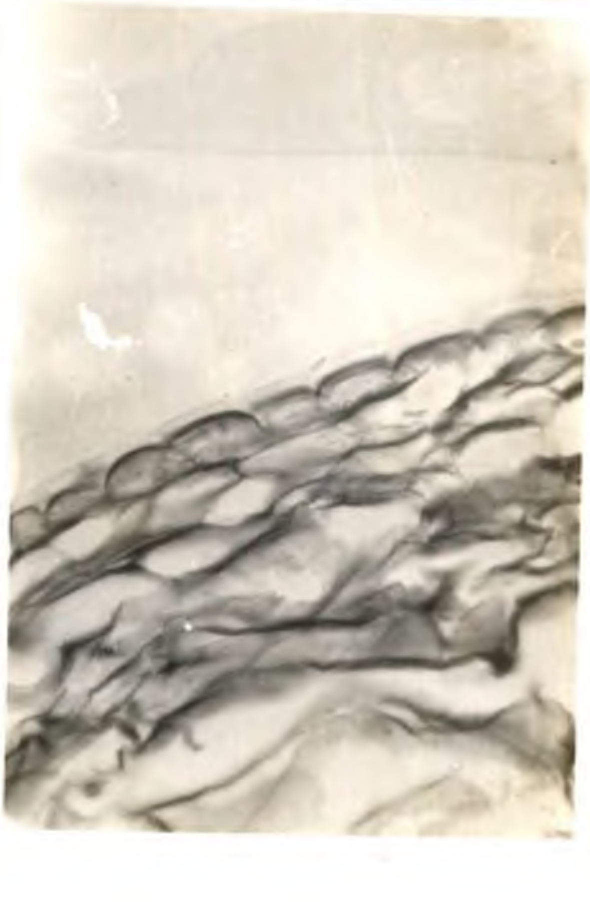
Plate VI Skin structure of fruit crack resistant and susceptible tomato genotypes

a LE 387 (Resistant to concentric and radial cracking)

b Sakthi (Susceptible to concentric cracking)

c LE 312 (Susceptible to radial cracking)





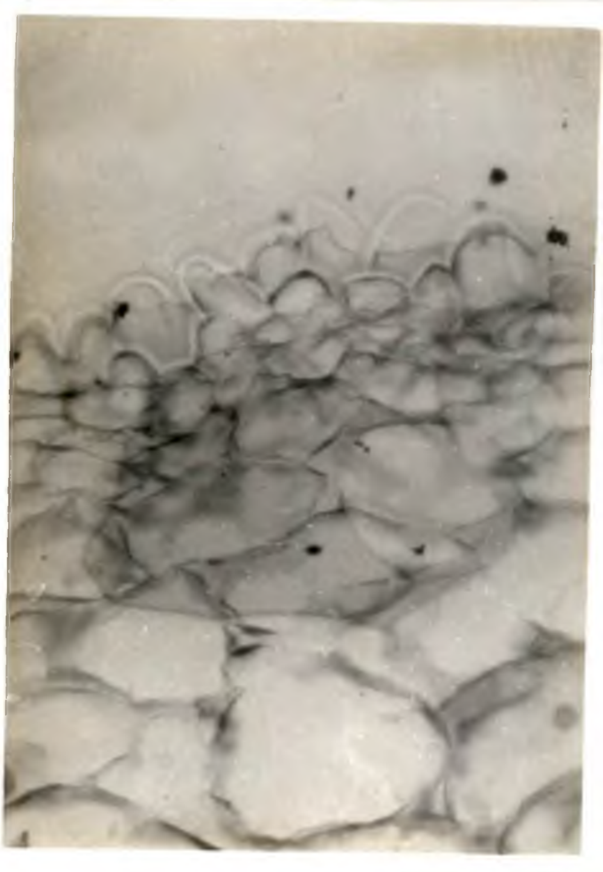


Plate VII Promising F_1 hybrids in tomato

a CAV-5 x LE 386

b CAV-5 x LE 388

c LE 214 x LE 296


CAV.5 X LE 386


LE 214 X LE 296


CAV 5XLE 388

Plate VIII Promising F segregants having combined resistance to bacterial wilt and fruit cracking

a F segregant of CAV 5 x LE 386

b F segregant of CAV 5 x LE 388

Discussion

DISCUSSION

Bacterial wilt caused by *Pseudomonas solanacearum* E F Smith and the disorder fruit cracking are two main constraints encountered in tomato production in tropics and sub tropics This is very much true in Kerala where the acidic soil conditions favour the incidence of bacterial wilt and the protracted rainfall received during two monsoons favour the incidence of fruit cracking In order to develop varieties suited to these situations a thorough knowledge of sources of resistance genetics of resistance and biochemical as well as anatomical factors influencing these maladies is essential which will throw light on the reasons and possible solutions

When sources of resistance to bacterial wilt and fruit cracking are available these two characters can be combined in a single genotype and such an eventuality will be a turning point in tomato cultivation Similarly a dominant gene action at F level will have much significance in the development of resistant F hybrids The present study was undertaken in this back drop

The response of different tomato genotypes to bacterial wilt disease and to fruit cracking disorder genetics of resistance to bacterial wilt and fruit cracking at F level the biochemical factors influencing the incidence of bacterial wilt and fruit cracking and the anatomical aspects on the phenomenon of cracking are discussed here under Further the performance of F hybrids produced by crossing bacterial wilt resistant genotypes and fruit crack resistant genotypes is also discussed with

A. Evaluation of tomato genotypes for resistance to bacterial wilt and its gene action at F_1 level

1 Evaluation for bacterial wilt resistance

Sixty eight tomato genotypes were evaluated for its reaction to bacterial wilt during three seasons (34 genotypes in first season 26 in second and 36 in third season) The variety Sakthi which registered a survival percentage of 85 82 5 and 85 during the three seasons was found to be consistent for resistant reaction This was followed by LE 79 5 (80 0% and 82 5% survival in the second and third season respectively So this two genotypes can be grouped under resistant genotypes The resistance of these genotypes to bacterial wilt has been reported earlier (Rajan 1985 and Kalloo *et al* 1993)

LE 214 was moderately resistant in second season with 60 per cent survival This was observed to be resistant in the third season (80% survival) The genotypes LE 415 CAV 5 and LE 382 1 were found to be moderately resistant to this disease with survival percentages of 75% 65% and 65% respectively These lines LE 214 LE 415 CAV 5 and LE 382 1 can well form additional sources of resistance to bacterial wilt

2 Gene action of bacterial wilt resistance at F_1 level

The F s involving bacterial wilt resistant and moderately resistant parents with Pusa Ruby were completely susceptible to bacterial wilt in the case of LE 79 5 LE 415 CAV 5 and LE 382 1 showing that the gene(s) responsible for resistance to bacterial wilt in these genotypes is recessive This is in confirmity with the finding of Alice Kurien (1990) that bacterial wilt resistance is recessive in character In Sakthi and LE 214 the resistance to bacterial wilt was neither recessive nor dominant This calls for further investigation by studying the genetics of bacterial wilt resistance of these lines involving F_2 s BC s and BC_2 s This corroborates the finding of Rajan (1985) that the resistance to bacterial wilt in Sakthi (LE 79) is partially dominant

3 Salient features of bacterial wilt resistant/moderately resistant genotypes

Radial cracking was seen in CAV 5 and LE 382 1 under normal field conditions Concentric cracking was seen in Sakthi LE 214 and LE 79 5 LE 415 was free from both concentric and radial cracking This line gives scope for the development of a bacterial wilt resistant variety with fruit crack resistance

LE 79 5 was the dwarfest among the bacterial wilt resistant/moderately resistant genotypes LE 415 was the tallest and having indeterminate growth habit This shows that growth habit cannot be taken as a criterion as to indicate resistant or susceptible Resistant genotypes are seen in both determinate and indeterminate types

Regarding earliness to flowering LE 79 5 was the earliest and LE 415 the latest The same trend was shown for days to harvest

LE 415 produced the maximum number of fruits and Sakthi the minimum LE 79 5 was the highest yielder followed by Sakthi and LE 214 The lowest yield was recorded by CAV 5 followed by LE 415 Eventhough LE 415 produced maximum number of fruit its yield was low because of low average fruit weight

Among the genotypes only Sakthi and LE 214 were having green shoulder LE 79 5 LE 382 1 CAV 5 and LE 415 exhibited uniform ripening This shows that there is no association between green shoulder and bacterial wilt resistance

These findings indicate the absence of any linkage or pleiotropic action of the genes conferring bacterial wilt resistance on those conditioning the characters included in this study However a detailed investigation on this aspect involving a wide array of characters will only make the picture more clear

So in general the bacterial wilt resistant or moderately resistant genotypes viz Sakthi LE 79 5 LE 214 CAV 5 LE 415 and LE 382 1 are good yielders offering good scope for large scale cultivation in wilt prone areas The genotype LE 415 has the potential to be developed into a bacterial wilt resistant and fruit crack resistant variety

B. Biochemical bases of bacterial wilt resistance

1 Total phenol content

The total phenol content of all the bacterial wilt resistant as well as the moderately resistant genotypes was higher than Pusa Ruby in all the plant parts at all stages of growth tested Higher content of phenols in resistant plants suggests the role of phenols in imparting resistance to bacterial wilt Protective role of phenolics against disease incidence has already been reported by Walker in 1923 and 1926 Menon and Schachinger (1957) also have reported the role of phenolics in combating diseases in tomato Thind *et al* (1981) had observed increased level of phenolics in resistant genotypes when compared to susceptible genotypes in chilli after infection by *Xanthomonas vesicatoria*

2 O D phenol content

The O D phenol content of the bacterial wilt resistant genotypes was higher than the susceptible line Pusa Ruby) in all the plant parts at all stages of growth studied This suggests that higher O D phenol level is associated with bacterial wilt resistance in tomato Thomiyama (1963) has reported that mono and dihydric phenols increased in host tissues invaded by parasites as a part of resistance mechanism Rajan (1985) has also reported increased levels of OD phenols in bacterial wilt resistant genotype LE 79 than the susceptible line Pusa Ruby at various growth stages

3 Ascorbic acid (Vitamin C)

The ascorbic acid content in plant parts at various stages of growth was higher in bacterial wilt resistant genotypes when compared with the susceptible variety Pusa Ruby suggesting the role of Vitamin C in imparting resistance to bacterial wilt Rattan and Saini (1979) has reported increased level of vitamin C in fruits of varieties resistant to fungal diseases when compared to the susceptible lines

Rajan (1985) has also reported increased level of vitamin C in roots of bacterial wilt resistant genotype LE 79 when compared to that in the susceptible line Pusa Ruby

C. Evaluation of tomato genotypes for resistance to fruit cracking and its gene action at F_1 level

Of the fifty eight genotypes were evaluated for fruit crack resistance eighteen genotypes were susceptible to radial cracking three genotypes were susceptible to concentric cracking twenty two genotypes were susceptible to both radial and concentric cracking and the remaining fifteen genotypes were resistant to both radial and concentric fruit cracking Of the five bacterial wilt resistant lines all were susceptible to fruit cracking Sakthi LE 214 and LE 79 5 were susceptible to concentric fruit cracking CAV 5 and LE 382 1 were susceptible to radial fruit cracking alone The radial fruit cracking was observed only after ripening while concentric fruit cracking was observed in mature green stage or the turning stage

The fifteen crack resistant genotypes were resistant to both concentric cracking and radial cracking All the fifteen F_1 s also were resistant to concentric and radial fruit cracking The male parent Sakthi was susceptible to only concentric cracking This shows that resistance to concentric fruit cracking in the fifteen resistant lines studied is dominant Alice Kurien (1990) has also found that all the F hybrids derived from crossing of crack resistant parents with susceptible lines were resistant to fruit cracking

The yield attributes of the fifty eight genotypes showed a significant variation for plant height days to flowering days to harvest fruits/plant fruit yield/plant average fruit weight fruit shape index locules/fruit total soluble solids and storage life of fruits

D. Biochemical, physical and anatomical bases of fruit crack resistance

1 Biochemical status of fruits

a Juice content

Three crack resistant genotypes (LE 386 LE 388 and LE 389) had significantly lesser juice content than the susceptible line Sakthi and the other twelve crack resistant genotypes had juice content on par with that of Sakthi This suggests that the juice content of the fruits as such does not contribute for fruit cracking in these lines

b Insoluble solid content

All the crack resistant genotypes had significantly higher insoluble solid content (0 81% to 1 25%) than the susceptible (0 63%) suggesting the possible role of insoluble solid contents for imparting resistance to fruit cracking c Pectin content of fruits

There was significantly higher content of pectin in all the crack resistant varieties (0 88% to 1 64%) when compared to susceptible (0 45%) This indicates a decisive role of pectin in fruits to bring about resistance to fruit cracking The friable nature of the pectim molecules would have contributed to make the outer skin of the fruit less rigid in the crack resistant varieties

d Acidity of fruits

All the crack resistant varieties had significantly lesser acidity than the susceptible This suggests a possible role of acidity in influencing fruit cracking in tomato

e **Total sugar and reducing sugar**

All the crack resistant varieties had significantly lesser total sugar content and reducing sugar content than the susceptible Higher sugar level in crack susceptible variety might have created a difference in water potential in the fruits of susceptible variety resulting in the movement of more water from other plant parts Thus exerting a greater pressure on fruit skin which results in fruit cracking Brown and Price (1935) have also reported that higher sugar content increases the water potential in the fruit allowing entry of water from other plant parts

2 Fruit skin characteristics

a Skin thickness

All the crack resistant genotypes had significantly thicker fruit skin (0 14 to 0 22 mm) than the susceptible (0 11 mm) Hence it is obvious that fruit skin thickness is a contributory factor in fruit crack resistance Gill and Nandpuri (1970) and Peet (1992) had also reported that skin thickness is related with fruit crack resistance

b Pericarp thickness

Peet (1992) has reported that crack susceptible varieties had a thinner pericarp In the present study also susceptible variety (3 78 mm) had a thinner pericarp than that of crack resistant varieties (4 40 mm to 5 95 mm)

c Penetrance of fruits

Penetrance is a measure of the force required to shear or penetrate the fruit skin Penetrance was significantly higher with crack resistant genotypes (3 73 to 5 95 kg/cm^2) when compared with susceptible genotype (3 05 kg/cm^2) indicating that when the elasticity of fruit skin is high cracking will be less Similar results were reported by Kanimura *et al* (1972) and Peet (1992)

3 Anatomical bases of fruit crack resistance

Anatomical studies revealed that there was distinct difference in cell arrangement of varieties so far as resistance to fruit cracking is concerned The arrangement of epidermal cells with longitudinal parenchyma cells alternated with small parenchyma cells helps in keeping the cells intact even if turgor pressure inside the fruit increases The layer of small cells in between longitudinal cells as observed in resistant genotypes give a cementing effect to the outer pericarp This type of cell arrangement is seen in the outer parenchymatous tissue the turgor pressure reaching the cuticle is surely kept at check Further the presence of thick cuticle also helps in preventing fruit cracking The crack susceptible varieties are devoid of a thick cuticle They also do not have a compact cell structure So when turgor pressure increases cracking occurs

Thus the crack resistance in resistant genotypes can be attributed to thick cuticle compact cell arrangement in the outer epidermal cells and resilient type of skin (as evidenced by high penetrance values) which can withstand the turgor pressure build up in the fruits Further the turgor pressure is not built up to a higher level in resistant genotypes owing to low amount of sugars and acids contained in the fruits

E. Evaluation of crack resistant genotypes for bacterial wilt resistance

All the fifteen crack resistant varieties succumbed to bacterial wilt So they cannot be grown directly in bacterial wilt sick soils eventhough they have other good horticultural characteristics

F. Transfer of resistance to fruit cracking to a bacterial wilt resistant background

Bacterial wilt resistant genotypes such as Sakthi LE 79 5 LE 214 CAV 5 and LE 415 were crossed with the fruit crack resistant genotypes LE 296 LE 386 LE 388 LE 393 and LE 399 The performance of important hybrids is discussed below

1 Evaluation of F hybrids for bacterial wilt resistance

All the F hybrids were found to be susceptible to bacterial wilt This can be expected as there was no dominant source of resistance to bacterial wilt among the parents The lines Sakthi LE 79 5 LE 214 CAV 5 and LE 415 were resistant which shows their consistency in resistance to bacterial wilt Sakthi and LE 79 5 have been released as bacterial wilt resistant lines LE 214 CAV 5 and LE 415 forms additional sources of resistance to bacterial wilt CAV 5 and LE 415 has got good horticultural characteristics like uniform ripening o

Single plant selection coupled with spot planting to eleminate susceptible escapes was found effective in augmenting the level of resistance to bacterial wilt in the resistant genotypes (Table 28)

2 **Evaluation of F hybrids for fruit crack resistance**

All the F hybrids were resistant to fruit cracking which shows that the resistance to fruit cracking is dominant Sakthi LE214 and LE 79 5 were susceptible to concentric cracking Their F_1 combinations were all resistant to concentric cracking which shows that the resistance to concentric cracking is dominant

CAV 5 was susceptible to radial fruit cracking All F hybrids involving CAV 5 as parent were found to be resistant to radial cracking which shows that resistance to radial cracking is also dominant

The genotype LE 415 has been resistant to bacterial wilt and was free from both concentric and radial cracking The small fruited nature of this line can be improved upon appropriate selection methods This genotypes which has got combined resistance to bacterial wilt and fruit cracking if improved for fruit size and other horticultural attributes will be a boon to the tomato cultivators of tropics and subtropics in general and those of Kerala state in particular

Table 28 Enhancement of resistance to bacterial wilt by spot planting over different seasons

Genotypes	A	B	C	D	E
Sakthi	85 00	82 50	85 00	87 50	93 33
LE 79 5		80 00	82 50	85 00	91 67
LE 214		65 00	80 00	82 50	90 00
CAV 5		60 00	65 00	82 50	91 67
LE 415			75 00	77 50	90 00
LE 382 1			60 00	92 50	

A Season I (Table 3)

B Season II (Table 4)

C Season III (Table 5)

D Season IV (Table 6)

E Season V (Table 21)

3 **Combınıng abılıty gene actıon and heterosıs**

a **Plant heıght**

Hıghly sıgnıfıcant gca effect ın LE 415 (12 81) shows that LE 415 ıs a good general combıner for ıncreased plant heıght Hıghly sıgnıfıcant negatıve gca effect ın LE 79 5 LE 214 Sakthı and LE 386 ındıcates that these genotypes can be used as good general combıners for dwarfness

LE 415 **x** LE 388 (103 25) was the tallest among the hybrıds (Table 29) Its parents had a heıght of 100 18 cm (LE 415) and 73 65 cm (LE 388) The dwarfest hybrıd was LE 79 5 x LE 386 (62 50) It was dwarfer than ıts parents There were 13 relatıvely heterotıc hybrıds and 17 heterobeltıotıc hybrıds Addıtıve gene actıon was predomınant whıch shows that thıs character can be ımproved by approprıate selectıon method

b **Days to flower**

LE 386 and LE 214 were good general combıners for early flowerıng Among the F hybrıds LE 214 **x** LE 386 was the earlıest to flower (62 days) There were 5 hybrıds whıch were relatıvely heterotıc and 5 heterobeltıolıc The gene actıon was addıtıve

Table 29 Performance of promising F hybrids

Characters	Hybrids	*Per se* performance	sca effect	Hetero beltiosis (%)	Relative heterosis (%)
Plant height (cm)	LE 415xLE 388	103 25	10 52	3 07	18 80
	LE 415xLE 296	96 95	5 34	3 22	6 01
	LE 79 5xLE 386	62 50	5 19	4 94	4 78
	LE 214xLE 386	66 38	1 80	11 00	5 40
Days to lowering	LE 214xLE 386	62 00	0 06	1 93	3 79
	SakthixLE 386	63 50	0 08	0 59	0 69
Days to harvest	LE 79 5xLE 386	94 75	0 14	0 89	1 02
	LE 214xLE 386	95 75	0 02	0 63	1 57
	SakthixLE 386	96 00	0 07	0 51	0 76
Fruits/ Plants	CAV 5xLE 296	28 50	0 12	24 54	4 38
	CAV 5xLE 386	27 25	0 12	23 68	1 58
	LE 214xLE 296	24 75	0 27	23 52	6 00
Fruit yield/ plant (kg)	CAV 5xLE 386	1 050	0 10	17 65	35 27
	LE 214xLE 296	1 010	0 15	13 17	25 66
	CAV 5xLE 296	0 960	0 08	7 00	26 07
Average fruit weight (g)	LE 214xLE 388	49 67	2 80	15 57	2 01
	LE 79 5xLE 388	47 28	0 51	19 63	4 77
	SakthixLE 386	46 15	1 94	6 02	3 57
Storage life (days)	LE 79 5xLE 388	32 40	0 18	5 91	16 19
	SakthixLE 386	31 90	0 22	0 31	14 06
	LE 79 5xLE 393	31 00	0 15	3 38	17 12

c **Days to harvest**

The genotypes LE 386 and LE 214 were good general combiners for early harvesting also Among the F hybrids LE 79 5 x LE 386 (94 75 days) and LE 214 x LE 386 (95 75 days) were the earliest to harvest It was earlier than both its parents This was closely followed by Sakthi X LE 386 (96 days) This was also earlier than its parents Earliness for yield is a desirable character in any crop

The preponderence of additive genetic variance over non additive implies that days to harvest is governed by additive gene action

d **Fruits/plant**

CAV 5 LE 386 and LE 296 were good general combiners for fruits/plant as shown by high gca values Among the F hybrids maximum fruits/plant was produced by CAV 5 x LE 296 (28 5 fruits) followed by CAV 5 x LE 386 (27 25 fruits) and LE 214 x LE 296 (24 31 fruits) There was no heterobeltiotic or relatively heterotic F hybrid Additive gene action was found to predominate

e **Fruit yield/plant**

There were two heterobeltiotic (CAV 5 x LE 386 and CAV 5 x LE 388) and five relatively heterotic hybrids

(CAV 5 x LE 386 CAV 5 x LE 388 CAV 5 x LE 296 LE 214 x LE 386 and LE 214 x LE 296) This can be expected because CAV 5 LE 214 LE 386 LE 296 and LE 388 were good general combiners for fruit yield/plant having significant positive gca effect These hybrids were also having significant positive sca effect This is in concurrence of the finding of Courtney and Pierce (1979) who has reported increased yield in hybrids by selecting high yielding parents for hybridisation Gene action for fruit yield/plant was additive as shows by high σ^2A value

f Average fruit weight

There was only one helterobeltiotic and four relatively heterotic F hybrids for increased fruit weight Among the F hybrids LE 214 x LE 388 produced bigger sized fruits This can be expected as both LE 388 and LE 214 were good general combiners and the F LE 214 x LE 388 was having significant sca effect also

Additive gene action was predominant for average fruit weight

g Storage

Maximum storage life was in LE 399 None of F hybrids exceeded this This can be expected as the gene action was found to be additive The highest *per se* performance was recorded by LE 79 5 x LE 399 This can be expected as both the parents were good general combiners for increased storage life The sca effect of this hybrid was also positive and significant

4 Evaluation for F_2'S for combined resistance

The segregants resulted out of F_2 generation evinced resistance to both bacterial wilt and fruit cracking Five F_2 segregants showing combined resistance to bacterial wilt and fruit cracking were selected based on their yield potential These plants can be further selected for evolving a variety resistant to both bacterial wilt and fruit cracking The schematic representation of the breeding technology followed is represented below

Schematic representation of breeding technology

Bacterial wilt resistant genotypes | Fruit crack resistant genotypes

F_1

Raised in wilt sick field to evaluate for bacterial wilt resistance Raised in pots for evaluating fruit crack resistance

F_2

Seeds obtained from fruit crack resistant lines from pot culture were grown in bacterial wilt sick soil Selection was made for fruit crack resistance

Future line of work:

F_3

Seeds of fruit crack resistant plants from the above generation will be grown in bacterial wilt sick soil and selection will be made for fruit crack resistance

F_4 Repeat the above process

F_5 Repeat the above process

F_6 Repeat the above process

By F_6 generation, uniformity can be obtained

Summary

SUMMARY

The investigations on Incorporation of resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato were carried out during January 1991 to March 1994 at the College of Horticulture Vellanikkara

1 Sixty eight tomato genotypes were evaluated for bacterial wilt resistance in three seasons Sakthi and LE 79 5 having an average survival of 84 2 per cent and 82 5 per cent respectively were resistant to bacterial wilt Additional sources of resistance to bacterial wilt were identified in LE 214 and LE 415 CAV 5 and LE 382 1 with average survival of 70 per cent 75 per cent 65 per cent and 65 per cent respectively The morphological studies of bacterial wilt resistant lines revealed that resistance to bacterial wilt is neither related with the growth habit nor to the ripening pattern of fruits

2 The crosses involving LE 79 5 CAV 5 LE 415 and LE 382 1 with Pusa Ruby revealed a recessive gene action for bacterial wilt resistance in these lines

3 Fifty eight tomato genotypes were evaluated for resistance to fruit cracking Fifteen genotypes resistant to both radial and concentric cracking were identified

The genotypes were grouped into four groups based on the type of fruit cracking

4 The fifteen fruit crack resistant genotypes were crossed with the susceptible variety Sakthi to study the genetics of fruit cracking All F s were resistant to fruit cracking suggesting that the resistance to fruit cracking in these lines are dominant Of these five crack resistant lines giving maximum yield (LE 296 LE 386 LE 388 LE 393 and LE 399) were selected as testers for crossing with bacterial wilt resistant genotypes

5 Five selected bacterial wilt resistant lines (Sakthi LE 79 5 LE 214 CAV 5 and LE 415) were crossed with 5 lines having dominant source of resistance to fruit cracking (LE 296 LE 386 LE 388 LE 393 and LE 399) in a line x tester fashion Parental combinations which resulted in heterotic F_1 hybrids were identified for different characters

6 Biochemical bases of bacterial wilt resistance was studied by estimating total phenol O D phenol and ascorbic acid content in the roots stems and whole plants of 30 45 and 60 day old plants The content of total phenol O D phenol and vitamin C was higher in the different parts of resistant plants at all stages of growth than Pusa Ruby

7 Biochemical studies of crack resistant genotypes revealed that they have a significantly higher content of insoluble solids and pectin and lower content of juice acidity total sugars and reducing sugars compared tothe susceptible genotype Sakthi They had a significantly lower content acidity The crack resistant varieties had a thicker skin and thicker pericarp than Sakthi when compared to the susceptible variety Sakthi Penetrance measured as the force required to shear the fruits were more for crack resistant varieties (3 73 kg/cm^2 to 5 95 kg/cm^2) when compared to Sakthi (3 05 kg/cm^2)

8 The fruit crack resistant varieties were found to be susceptible to bacterial wilt

9 The twenty five F hybrids developed by line x tester crossing were susceptible to bacterial wilt

The F hybrids which had highest *per se* performance were CAV 5 X LE 296 (28 50 fruits) for fruits/plant CAV 5 X LE 386 (1 05 kg/plant) for fruit yield/plant LE 214 X LE 388 (49 67 g) for average fruit weight and LE 79 5 x LE 399 (32 40 days) for storage life

Good general combiners for different characters were identified They were LE 415 (for plant height) LE 79 5 (for dwarfness) LE 386 (for early harvest) CAV 5 (for fruits/plant and fruit yield/plant) and LE 399 (for increased storage life)

Additive gene action predominated for plant height days to flowering days to first harvest fruits/plant fruit yield/plant average fruit weight and storage life

10 The F_2 population was screened for combined resistance to bacterial wilt and fruit cracking Segregrants resistant to both bacterial wilt and fruit cracking were selected for further studies

References

REFERENCES

Abeygunawardena D V W and Siriwardena A A P 1963 Studies on resistance in tomato to bacteril wilt *Trop Agric* 119 55 66

*Acosta J C 1964 Genetic analysis of bacterial wilt resistance and other characters in a tomato cross *Lycopersicon esculentum x Lycopersicon pimpinellifolium* *Diss Abstr* 25 746

Acosta J C Gilbert J C and Quinon V L 1964 Heritability and bacterial wilt resistance in tomato *Proc Amer Sco Hort Sci* 84 455 462

Adhikari T B Manandhar J B and Hartman G L 1993 Characterisation of *Pseudomonas solanacearum* and evaluation of tomatoes in Nepal *ACIAR Proceedings* No 45 132 137

*Akiba F Riberio R Del Sudo S Robbs C F and Kimura O 1972 The evaluation of introduced tomato strains for susceptibility to Brazilian isolates of *Pseudomonas solanacearum* the agent of bacterial wilt *Arquivos do Instituto Biol* 39 243 247

Alice Kurien 1990 Evaluation of processing characteristics and their expression in a bacterial wilt resistant genetic background in tomato Ph D thesis Kerala Agricultural University Vellanikkara

Allen C Simon L Atkinson M and Sequeira L 1993 Analysis of polygalacturonase as a component of bacterial wilt disease *ACIAR Proceedings* No 45 238 244

Anaya M and Waite B H 1974 Field resistance of bacterial wilt during the rainy season in El Salvador *Proc Amer Soc Hort Sci.* 1 120

Anbu S Muthukrishnan C R and Irulappan I 1976 Line x Tester analysis in tomato (*Lycopersicon esculentum* Mill) II Heterosis *South Indian Hort* 24(2) 49 53

Aragaki M and Quinon V L 1965 Bacterial wilt of ornamental gingers (*Hedychium* spp) caused by *Pseudomonas solanacearum. Plant Dis Rep* 49 378 379

Armstrong R J and Thompson A E 1967 A diallel analysis of tomato fruit cracking *Proc Amer Soc Hort Sci* 91 505 513

Artherton J G and Ruduich J 1986 *The Tomato Crop* Chapman and Hall London pp 94 95

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

Aswasthy D N and Singh B P 1975 Influence of cucumber mosaic virus on ascorbic acid and capsaicin content from the fruits of tolerant and susceptible varieties of chilli *Indian Phytopath* 28 272 274

Augustine J J Volin R B Bryan H H Everett P H Burgis D S and Gull D D 1982 Hayslip a jointless fresh market tomato *Tomato Genet Coop Rpt* 29 20 21

Avdeyev Y I 1979 Inheritance of resistane to concentric fruit cracking *Tomato Genet. Coop Rpt* 29 20 21

*Baldacci E 1977 Diagnosis and diseases *Rivista di Patologia Vegetalo* IV 13 5 20

Barrons K C 1943 Spartan hybrid A first generation hybrid tomato for greenhouse production *Proc Amer Soc Hort Sci.* 42 524 528

Bedekar H S 1977 Reactions of four tomato cultivars to different mixtures of isolates of *Pseudomonas solanacearum. Veg Sci.* 4 15

Berry S Z 1990a Release of machine harvestable processing tomato variety Ohio 7983 *Tomato Genet Coop Rpt* 40 66

Berry S Z 1990b Release of machine harvestable tomato variety Ohio 8245 *Tomato Genet Coop Rpt* 40 67

Berry S Z and Gould W A 1979 Ohio 7663 tomato *HortScience* **14**(4) 550 551

Berry S Z and Gould W A 1982 Machine harvestable processing tomato Ohio 7870 *Tomato Genet Coop Rpt* 32 56

Berry S Z and Gould W A 1983 Release of machine harvestable processing tomato Ohio 7814 *Tomato Genet Coop Rpt* 33 48 49

Berry S Z and Gould W A 1986 Ohio 832 tomato *HortScience* 21 (2) 334

Berry S Z and Gould W A 1988 Ohio 8243 processing tomato ____________ *HortScience* 23 (5) 930

Bhutani R D Kalloo G Pandita M L and Singh G P 1973 Studies on heterosis in tomato *Haryana J Hort Sci* 2 156 163

*Bissonauth O 1980 Observations on some new varieties of tomato from Taiwan *Tech Bull Ministry of Agriculture and Natural Resources and the environment* Mauritius pp 16 17

Bosch S E Louw A J and Aucamp E 1985 Rodade Bacterial wilt resistant tomato *HortScience* 20 (3) 458 459

Briggle L W 1963 Heterosis in wheat A review *Crop Sci* 3 407 412

Brown H D and Price C V 1935 Effect of irrigation degree of maturity and shading upon the yield and degree of cracking of tomatoes *Proc Amer Soc HortSci* 32 524 528

Buddenhagen I and Kelman A 1964 Biological and physiological aspects of bacterial wilt caused by *Pseudomonas solanecearum. Ann Rev Phytopath* 2 203 226

Buddenhagen I W Sequeira L and Kelman A 1962 Designation of races of *Pseudomonas solanacearum*. *Phytopatology* 52 726

Celine V A 1981 Genetic catalouging of tomato germplasm towards isolation of line(s) resistant to bacterial wilt M Sc thesis Kerala Agricultural University Vellanikkara p 69

Chester K S 1950 *Nature and Prevention of Plant Diseases* (2nd Edn) McGraw Hill Book Co Inc New York p 525

Chetia M N and Kakati M 1973 Preliminary studies on the role of weather factors in the incidence of wilt in tomatoes caused by *Pseudomonas solanacearum* in Jorhat area *J Assam Sci Soc* 16 121 128

Chumvisoot C and Lambeth V 1983 Bacterial wilt resistance in exotic germplasm *HortScience* 18 (4) 564 565

Chupp C and Sherf A F 1960 *Vegetable Diseases and Their Control* The Ronald Press Co New York pp 695

Considine J and Brown K 1981 Physical aspects of fruit growth Theoretical analysis of distribution of surface growth forces in fruit in relation to cracking and splitting *Plant Physiol* 68 371 376

Cook D R and Sequeira L 1988 The use of Restriction Fragment Length Polymorphism (RFLP) Analysis in Taxonomy and Diagnosis *Bacterial Wilt Newsletter* 4 4

Corey K A and Tan Z Y 1990 Induction of changes in internal gas pressure of bulky plant organs by temperature gradients *J Amer Soc Hort Sci* **115** 308 312

Cortes C Ayuso M C Palomares G Cuartero J and Nuez F 1983 Relationship between radial and concentric cracking of tomato *Scientia Hort* 21 323 328

Cotner S D Burns E F and Leeper P W 1969 *J Amer Soc Hort Sci* **94** 136 137

Courtney W H and Peirce L C 1979 Parent selection in tomato based on morphophysiological traits *HortScience* **14** (3) 458

Cruickshank I A M 1963 Phytoalexins *Ann Rev Phytopath* 1 351 374

Currence T M Larson R E and Virta A A 1944 A comparison of six tomato varieties as parents of F lines resulting from the fifteen possible crosses *Proc Amer Soc Hort Sci* **45** 349 352

Daly P 1973 Studies on 3 tomato varieties tolerant to *Pseudomonas solanacearum*. *Agron Trop* 28 28 33

Dickinson D B and McCollum J P 1964 The effect of calcium on cracking in tomato *Proc Amer Soc Hort Sci* **84** 485 490

Farkas G L and Kiraly Z 1962 Role of phenolic compounds in the physiology of plant diseases and disease resistance *Phytopath* **44** 105 150

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

Fogle H W and Faust M 1976 Fruit growth and cracking in nectarines *J Amer Soc Hort Sci* 101 434 439

Fontain T D Irwing Jr G W Ma R Poole J B and Doolittle S P 1948 Isolation and partial characterisation of crystalline tomatine an antibiotic agent from the tomato plant *Arch Biochem. Biophy* 18 467 475

Frazier W A 1935 A study of some factors associated with the occurrence of cracks in the tomato fruit *Proc Amer Soc Hort Sci* 32 519 523

Frazier W A 1952 Cracking resistance in puck progeny *Tomato Genet Coop Rpt* 2 3

Frazier W A and Bowers J L 1947 A report on studies of tomato fruit cracking in Maryland *Proc Amer Soc Hort Sci* 49 241 255

Gardener R G 1982 NC 50 7 Breeding line Cherokee and Mountain Pride Tomato *HortScience* 17 (1) 92 93

Gardener R 1985 Piedmont *Tomato Genet. Coop Rpt* 35 51

Gill P S and Nandpuri K S 1970 Comparative resistance to fruit cracking in tomato (*Lycopersicon esculentum* Mill) *Indian J agric Sci* 40 89 98

Goodman R N Kıralay Z and Zaıttın M 1967 The bıochemıstry and physıology of ınfectıous plant dıseases Van Nontrand Co Prınceston New Jersey p 354

Goth R W Peter K V and Webb R E 1983 Effect of root knot nematode ın bacterıal wılt of tomato *Phytopathology* 73 966

Govındaraju P Muthukrıshnan C R and Irulappan I 1983 Heterosıs and combınıng abılıty for yıeld and ıts components ın tomato *(Lycopersıcon eseulantum* Mıll) In *Proc natıonal semı prod technol tomato and chıllıes* March 22 23 Tamıl Nadu Agrıc Unıv Coımbatore 15 17

Graham K M and Yap T C 1976 Studıes on bacterıal wılt I Inherıtance of resıstance to *Pseudomonas solanacearum* ın tomato *Malaysıan Agrıc Res* 57 1 8

Granada G A and Sequeıra L 1983 Survıval of *Pseudomonas solanacearum* ın soıl rhızosphere and plant roots *Canadıan Journal of Mıcrobıology* 29 433 440

Grıll P and Burgıs D A 1971 Comparıson of tomato varıetıes and F hybrıds for yıeld and unıformıty (In) *Proc 83rd Annual Meetıng Florıda State Hort Soc* U S A 83 120 122

Hankınson B and Rao V N M 1979 Hıstologıcal and physıcal behavıour of tomato skıns susceptıble to crackıg *J Amer Soc Hort Scı* 104 (5) 577 581

Hassan M 1978 Effects of nitrogen fertilization and plant density on yield and quality of tomatoes in the Sudan Gezira *Acta Horticulturae* **84** 79 84

Hayes H K Immer F R and Smith D C 1965 *Methods of Plant Breeding* McGraw Hill Book Company Inc New York pp 329 332

Hayward A C 1964 Characteristics of *Pseudomonas solanacearum. J Appl Bact* 27 265 277

He L Y Sequeira L and Kelman A 1983 Characteristics of strains of *Pseudomonas solanacearum* from China *Plant Dis* **67** 1357 1361

Hedayathullah S and Saha J C 1941 Bacterial wilt disease of tomato *Sci. Cult* **7** 226 227

Hedrick U P and Booth N O 1908 Mendelian characters in tomatoes *Proc Amer Soc Hort Sci* 5 19 24

Hendersen W R 1986 Wolfpack 1 and Wolfpack 2 Tomato *HortScience* 21 (5) 1247 1248

*Henderson W R and Jenkins S F 1972 Venus and Saturn two new tomato varieties combining desirable horticultural features with southern bacterial wilt resistance *Bul Agric Expt Sta North Carolina State Univ* **444** 13

Herrington M E and Brown P J 1988 Redlander Tomato *HortScience* 23 (1) 225 226

Herrington M E and Saranah S 1985 Redlands Summertaste Tomato *HortScience* 20 (5) 958 959

Hewitt J D and Stevens M A 1979 Physiological basis of genotypic variation for solid content of tomato fruits *HortScience* 14 (3) 458

Hildebrant A C 1950 Some important galls and wilts of plants and the inciting bacteria *Biol Rev* 14 259 272

Hotchkiss R D 1948 Microchemical reaction resulting in the staining polysaccharide structures in fixed tissue preparations *Arch Biochem* 16 131 141

*Hoque M O Juq M I and Choudhary B C 1981 Screening tomato varieties for resistance to bacterial wilt *Bangadesh J Agric Res* 6 55

*Hsu S T 1976 Factors affecting the development of bacterial wilt in tomato *J Agric Forestry* 25 95 102

Hussain A and Kelman A 1957 Presence of pectic and cellulolytic enzymes in tomato plants infected by *Pseudomonas solanacearum* *Phytopathology* 47 111 112

Irwing Jr G W 1947 The significances of tomatine in plant and animal diseases *J Wash Acad Sci* 37 293 296

Jaworski C A 1988 Bacterial wilt research from 1966 through 1986 in Southeastern coastal plains at Tifton Georgia U S A *Bacterial Wilt Newsletter* 4 1 2

Jensen W A 1962 *Botanical Histochemistry* Freman San Francisco p 401

Jenkins S F and Nesmith W C 1976 Severity of southern wilt of tomato and egg plant as influenced by plant age inoculation techniques and isolate source *Amer phytopath Soc Proc* 3 337 338

Jones R A and Millet A H 1984 Siorra Sweet Fresh market tomato *Hort Science* **19** (1) 133

Kalloo G 1985 *Tomato* Allied Publishers Private Ltd New Delhi pp 335 335

Kalloo G Rajkumar Rai S Pandey A M Chaurasia S N S Singh B and Ram D 1993 *Annual Report 1991 92 and 1992 93* Project Directorate of Vegetable Research Varanasi pp 24

Kalloo G Singh R K and Bhutani R D 1974 Combining abilit studies in tomato *Theor appl Genet* **44** 358 363

*Kanimura S Yoshikawa H and Ito K 1972 Studies on fruit cracking in tomatoes *Bull Hort Res Stn* No 7 pp 73 138

Kaul D L and Nandpuri K S and Singh 1972 Hybrid vigour studies in tomato *J Res Punjab Agric Univ* 9 (1) 19 20

*Kelman A 1953 The relationship of pathogenicity of *Pseudomonas solanacearum.* A literature review and bibliography *North Carolina Agric Expt Sta Tech Bul* **99** pp 194

Kelman A 1954 The relationship of pathogenicity of *Pseudomonas solanacearum* to colony appearance in tetrazolium chloride medium *Phytopathology* **44** 693 695

Kempthorne O 1957 *An Introduction to Genetic Statistics* John Wiley and Sons New York pp 545

Kerala Agricultural University 1989 *Package of Practices Recommendations* Directorate of Extension Kerala Agricultural University Vellanikkara India pp 214 215

Kerr E A and Cook F I 1981 Veepick tomato *Can J Plant Sci.* 61 769 770

Kerr E A and Cook F I 1985a Ontario 7710 a tomato breeding line with resistance to bacterial speck *Pseudomonas syringae* pv *tomato* *Tomato Genet Coop Rpt* 35 54

Kerr E A and Cook F I 1985b Veeking tomato *Tomato Genet Coop Rpt* 35 53

*KUC J 1964 Phenolic compounds and disease resistance in plants (In) Runnecklas V C (ed) Phenolics in Normal and Diseased fruits and Vegetables *Plant Phenolic group of N American Symp Proc* Imperial Tobacco Co Montreal pp 63 81

*Kuhn R Low I and Trishmann H 1952 Degradation of tomatidine to tigogenin lactone *Chem. Ber* **85** 416 424

Lambeth V N 1983 Origin and release of tomato line 31 st 15 and Conquest VFN Tomato *Genet Coop Rpt* 33 51 52

Langecake P Drysdale R B and Smith H 1972 Post infectional production of an inhibitor of *Fusarium oxysporum.* F sp *lycopersici* by tomato plants *Physiol Plant Path* 2 17

Larson R E and Currence T M 1944 The extent of hybrid vigour in F and F_2 generation of tomato crosses with particular reference to early yield total yield and fruit size *Tech Bull Univ Min. Agric Exp Stn* **164** 1 32

Leeper P W and Cox E L 1986 Fresh market 9 Tomato *HortScience* 21 (1) 156

Levin A D 1976 The chemical defences of plants to pathogens and herbivores *Ann. Rev Ecol Syst* 7 121 159

Libman G Leach J G and Adams R E 1964 Role of certain plant parasitic nematodes in infection of tomatoes by *Pseudomonas solanaceurum* E F Smith *Diss Abstr Intl* B **40** 533

Mahadevan A 1973 Theoretical concepts of disease resistance *Acta Phytopath* **8** 391 423

Mahadevan A and Sridhar R 1982 *Methods in Physiological Plant Pathology* (2nd edn) Sivakami publications Indira Nagar Madras pp 316

Martin M W 1984 Release of three fresh market tomato lines CVF8 CVF11 and CVF13 *Tomato Genet Coop Rpt* **35** 56 57

Martın M W 1985a Namıng and release of four tomato varıetıes Roza Columbıa Rowpac and Saladmaster *Tomato Genet Coop Rpt* 35 55 57

Martın M W 1985b Release of fıve processıng tomato breedıng lınes CVF 1 CVF 3 CVF 6 CVF 7 and CVF 9 *Tomato Genet Coop Rpt* 35 58 60

McFerran J Scott S J and Montgomery F W 1989 Ozark Pınk VF Tomato *HortScıence* **24**(4) 712 713

*Menon R and Schachınger L 1957 Dıe Rolle des phenols beıder wıderstandsfahıgkeıt Vow Tomatenpflanzen gegen ınfektıonen *Ber Otsch Bot Ges* **70** 11 20

*Messaen C M Laterot H and Khan F 1978 Cumulate resıstances to *Pseudomonas solanacearum* and to *Meloıdogyne ıncognıta* wıth determınate growth ın tomato *Veg for the Hot Humıd Tropıcs Newsletter* **3** 48 51

Metcalf J G Reyes A A and Mohr M P 1986 Early brıght an early processıng tomato *Can J Plant Scı.* **66** 417 419

Mew T W and Ho W C 1976 Varıetal resıtance to bacterıal wılt ın tomato *Plant Dıs Reptr* **60** 264 268

Meyer A and Peacock N D 1941 Heterosıs ın the tomato as determıned by yıeld *Proc Amer Soc hort Scı* 38 576 580

Mishra C H and Khanna K R 1977 Heterosis and combining ability studies for some vegetative characters in tomato *(Lycopersicon esculentum* Mill) *Indian J Hort* 34 (4) 396 403

Moffett M L 1986 A note on bacterial wilt resistance breeding programme in Queensland *Bacterial Wilt Newsletter* 1 1 2

Mohanakumaran N Gilbert J C and Buddenhagen I W 1969 Relationship between tomatine and bacterial wilt resistance in tomato *Phytopathology* 59 14

Monma S and Sakata Y 1993 Inheritance of resistance to bacterial wilt in tomato *ACIAR Proceedings* 45 149 153

Mullar K O 1959 Hypersensitivity (In) Horsfall J G and Diamond A E (eds) *Plant pathology an advanced treatise* Academic press New York 469 519

Nandpuri K S Kanwar J S and Lal R 1976 Correlation path analysis and regression studies in tomato *Veg Sci* 3 (1) 37 40

Narayanankutty C 1985 Evaluation of a set of non segregating and segregating populations of tomato for field resistance to bacterial wilt M Sc thesis Kerala Agricultural University Vellanikkara

Nirmala Devi S 1987 Studies on genetic resistance to bacterial wilt *(Pseudomonas solanacearum* E F Smith) and root knot nematode *(Meloidogyne incognita* (Kofoid and White 1919 Chitwood 1949) in Tomato *(Lycopersicon esculentum* Mill) Ph D thesis University of Agricultural Sciences Bangalore

*Noda H Vonder P A and Silva Filho D F O A 1986 Assessment of the resistance of tomato progenies to bacterial wilt in soil naturally infested with *Pseudomonas solanacearum Revista Brasileira de Genetica* 9 (1) 55 56

Opena R T and Tschanz A T 1987 Bacterial wilt resistance programme on tomato at AVRDC *Bacterial Wilt Newsletter* 2 1 2

Panse V G and Sukhatme P V 1978 *Statistical Methods for Agricultural Workers* 3rd edn ICAR New Delhi

Peet M M 1992 Fruit cracking in tomato *Hort Technology* 2 (2) 210 223

Peter K V and Rai B 1976 Note on heterozygotic advantage for frost resistance in autogamous tomato cultivars *Indian J agric Sci* 46 235 236

*Peterson R A Inch A J Herrington M E and Saranah J 1983 Scorpio a tomato resistant to bacterial wilt biovar III *Australian Pl Pathology* 12 (1) 8 10

Ponnuswamy V Muthukrishnan C R and Irulappan I 1980 Biometrical studies of certain intervarietal crosses of tomato (*Lycopersicon eseulentum* Mill) *Madras Agric J* 67 (12) 802 806

Prashar D P and Lambath V N 1960 Inheritance of radial fruit cracking in tomatoes *Proc Amer Soc Hort Sci* 76 530 537

Rajan S 1985 Selection efficiency and genetic and biochemical bases of resistance to bacterial wilt in tomato Ph D thesis Kerala Agricultural University Vellanikkara

Rajan S and Peter K V 1986 Incomplete dominance of bacterial wilt resistance *Tomato Genet Coop Rpt* 36 24

Ramachandran C Gopalakrishnan P K and Peter K V 1980 Evolving high yielding tomato varieties with resistance to bacterial wilt *Ann. Rpt* Kerala Agricultural University Vellanikkara

Ranganna S 1977 *Manual of Analysis of Fruits and Vegetable Products* Tata McGraw Hill Publishing Co Ltd New Delhi pp 484

Rao M P B Sohi H S and Tikoo S K 1975 Reaction of wilt resistant tomato varieties and lines to *Pseudomonas solanacearum* in India *Pl Dis Reptr* 59 734 736

Rattan R S and Saini S S 1979 Association of fruit rot resistance with ascorbic acid content in tomato *Veg Sci* 6 54 56

Remadevi L 1978 Bactrial wilt of tomato in Kerala host range and survival of the pathogen and control Ph D thesis Kerala Agricultural University Vellanikkara pp 168

Reynard G B and Riverton N J 1951 Inherited resistance to radial cracks in tomato fruits *Proc Amer Soc Hort Sci.* 58 231 244

Roddick J G 1974 The steroidal glycoalkaloid tomatine *Phytochemistry* 13 9 25

Sadasivam S and Manickam A 1991 *Biochemical Methods for Agricultural Sciences* Wiley Eastern Limited Madras pp 246

Sander H 1956 The formation and degradation of tomatin in the tomato plant *Planta* **47** 374 400

*Schaub I O and Baver L D 1944 Research and Farming (In) 67th *Reptr North Carolina Agric Expt Sta* No 4 pp 27 31

Schell M A Roberts D P and Denny T P 1988 Analysis of *Pseudomonas solanacearum* polygalacturonase encoded by pglA and its involvement in phytopathogenicity *J Bact* **170** 4501 4508

Scott J W 1985 Horizon A fresh market tomato with concentrated fruit set *Tomato Genet Coop Rpt* **35** 61

*Scott J W and Harbargh B K 1989 Micro Tom A miniature dwarf tomato *Fl Agric Expt Circ* S 370

Scott J W Somodi G C and Jones J B 1993 Testing tomato genotypes and breeding for resistance to bacterial wilt in Florida *ACIAR Proceedings* **45** 126 131

Sequeira L 1993 Bacterial wilt Past Present and Future *ACIAR Proceedings* **45** 12 21

Sidhu A S Dixit J Kalloo G and Bhutani R D 1981 Heterosis and combining abiliting in pear shaped tomato *Haryana Agric Univ J Res* 11 1 7

Singh B Kumar N and Joshi S 1978 Hybrid vigour in tomato *Haryana Agric Univ J Res* **10** (2) 179 183

*Smith E F 1896 A bacterial disease of the tomato egg plant and Irish potato (*Bacillus solanacearum* nov sp) *U S Dept Agric Div Veg Phys and Path Bul* **12** 1 28

*Sonoda R M 1977 Behaviour of tomato lines selected for resistance to southern bacterial wilt in a field infested with the pathogen *Res Rpt Agricultural Research Centre* Fort Pierce pp 5

Sonoda R M and Augustine J J 1977 Reaction of tomato lines selected for resistance to southern bacterial wilt in field infested with the pathogen *Res Rpt Agricultural Research Centre* Fort Pierce pp 5

Sonoda R M Augustine J J and Volin R B 1980 Bacterial wilt of tomato in Florida history status and sources of resistance *Florida State Hort Soc Proc* 92 100 102

Sreelathakumari I 1983 Incorporation of two main sources of resistance to bacterial wilt in F generation of tomato *(Lycopersicon lycopersicum* (L) Karst) M Sc thesis Kerala Agricultural University Vellanikkara

Stoessl A 1969 Antifungal compounds produced by higher plants (In) *Recent advances in phytochemistry* Vol 3 Meredilt Corporation New York pp 169 171

Sunarjono H 1980 Increasing tomato production disease resistant varieties show promise *Indonesian Agric Development J* 2 5 7

*Suzuki I Sugahara Y To daka S and Shimada H 1964 Studies on breeding egg plants and tomatoes for resistance to bacterial wilt I Investigation on method of evaluating the resistance and on source of resistance in egg plants and tomatoes *Hort Res Sta Ser Bul* A 3 77 106

*Tesi R Graifenberg A and Creatini M 1970 Heterosis and quality in F hybrids of *Lycopersicon esculentum* Mill (grown under glass) *Riv Ortoflorofrutticital* 54 269 292

Thapliyal P N and Nene Y L 1967 Inhibition of plant pathogens by higher plant substances *J Sci Indus Res* 26 289 299

Thind B S Sharma B S and Singh N 1981 Changes in sugars amino acids and phenols in chilli leaves *(Capsicum annuum)* in response to *Xanthomonas vesicatoria* infection *Indian J Mycol Plant Path* 11 207 210

Thomiyama K 1963 Physiology and biochemistry of disease resistance of plants *Ann Rev Phytopath* 1 295 324

Tikoo S K 1982 Studies on gene action combining ability and heterosis of some economically important characters in tomato with particular reference to processing Ph D thesis Bangalore University Karnataka

Tikoo S K 1987 Breeding tomatoes for processing in India Present status and future prospects *Acta Horticulturae* 200 73 81

Tikoo S K Anand N and Kishun R 1983 Presence of two independent genetic systems for resistance to bacterial wilt *(Pseudomonas solanacearum)* 15th *Intl Cong Genet* New Delhi Dec 12 21 Abstr 1338

Tikoo S K Anand N and Kishun R 1987 Developing heterotic F_1 hybrids of tomato resistant to bacterial wilt *(Pseudomonas solanacearum)* *Bacterial Wilt Newsletter* 2 2 3

Tukalo E A 1958 (In) Roddick J G 1974 Tomatine accumulation in some tomato varieties *Sbornk Nanch Trudov Dnepropetrovsk Med Inst* **6** 371 375

Vakili N G and Baldwin C H 1966 Insect dissemination of the tomato race of *Pseudomonas solanacearum*, the cause of bacterial wilt in certain *Musa species* *Phytopathology* **56** 355 356

*Voronia M V 1971 Some characteristics of the changes in activity of peroxidase and ascorbic acid in the tissues of green house tomatoes *Trudy do prikladhol Botanika Genetika i selektsii* **45** 209 215

Walker J C 1923 Disease resistance to onion smudge *J Agri Res* **24** 1019 1039

Walker J C 1926 Botrytis neck rot of onions *J Agric Res* **33** 893 928

Walker J C 1952 *Diseases of Vegetable Crops* (1st edn) McGraw Hill Book Co New York pp 529

*Weaver J G 1944 Seeking a tomato resistant to bacterial wilt *Res Fmg N C Prog Rpt* 1 11

*Young P A 1946 Tomato diseases in Texas *Texas Agric Expt Sta Cir* **113** pp 66

Young H W 1959 Inheritance of radial cracking in a tomato cross *Proc Fla St hort Soc* **73** 207 210

Young H W 1962 The evaluation of fruit crack resistance in tomatoes *Pl Breed Abstr* **33** 2797

*Originals not seen

Appendices

Appendix-I

General analysis of variance for fruit yield and its components in bacterial wilt resistant/ moderately resistant genotypes of tomato

Sources of variation	df	Plant height (cm)	Days to flower	Days to first harvest	Fruits/ plant	Fruit yield/ plant (g)	Average fruit weight (g)	Fruit shape index	Locules/ fruit
Genotypes	5	691 53**	0 240**	0 147**	0 109*	52405 04	190 23**	0 008**	1 59**
Error	15	1 661	0 002	0 001	0 163	15519 75	13 28	0 001	0 06

** Significant at 1 per cent level

* Significant at 5 per cent level

Appendix II

General analysis of variance for total phenol content (ppm) in various plant parts at different growth stages in tomato

Sources of variation	df	30th day			40th day			60th day		
		Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Genotypes	6	4000 00**	4320 64**	1287 30**	8476 19**	32476 19**	14393 65**	15430 16**	40593 65**	26720 64**
Error	14	157 14	109 52	80 95	128 57	314 29	190 48	242 86	304 76	71 43

** Significant at 1 per cent level

Appendix III

General analysis of variance for O D phenol content (ppm) in various plant parts at different growth stages in tomato

Sources of variation	df	30th day			40th day			60th day		
		Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Genotypes	6	118 54**	863 87**	202 41**	119 75**	1122 10**	569 08**	127 49**	2858 16**	1484 83**
Error	14	1 14	29 71	2 10	37 33	28 76	2 67	1 52	2 67	2 10

** Significant at 1 per cent level

Appendix-IV

General analysis of variance for vitamin C content (ppm) in various plant parts at different growth stages in tomato

Sources of variation	df	30th day			40th day			60th day		
		Root	Shoot	Plant	Root	Shoot	Plant	Root	Shoot	Plant
Genotypes	6	2777 86**	7283 21**	960 43**	6375 64**	4235 49**	1940 00**	2108 08**	4494 10**	1723 41**
Error	14	293 33	299 29	56 57	657 86	196 71	43 57	124 38	1150 67	49 91

** Significant at 1 per cent level

Appendix-V

General analysis of variance for yield attributes in tomato

Sources of variation	df	Mean squares: Plant height (cm)	Days to flower	Days to harvest	Fruits/ plant	Fruit yield/ plant (kg)	Average fruit weight (g)	Fruit shape index	Locules/ fruit	TSS of fruits	Storage life (days)
Genotypes	57	1325 04**	0 27**	0 021**	8 65**	0 09**	1489 29**	0 29**	9 53**	1 38**	316 51**
Error	406	7 89	0 01	0 01	1 12	2 02	536 60	0 003	0 09	0 103	10 63

** Significant at 1 per cent level

Appendix VI

General analysis of variance for fruits/plant and fruit yield/plant (kg) in crack resistant lines Sakthi and their F S

Sources of variation	df	Mean squares	
		Fruits/plant	Fruit yield/plant (kg)
Genotypes	30	4 69**	0 35
Error	217	0 31	0 02

** Significant at 1 per cent level

Appendix VII

General analysis of variance for biochemical factors in fruits

Sources of variation	df	Juice content (%)	Insoluble solids (%)	Pectin content (%)	Acidity (%)	Total sugar (%)	Reducing sugar (%)
Genotypes	57	11 53*	0 09**	0 30**	0 013**	0 026**	0 197**
Error	406	1 27	0 002	0 006	0 0002	0 0004	0 003

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

Appendix VIII

General analysis of variance for fruits skin characters in genotypess evaluated for fruit crack resistance

Sources of variation	df	Skin thickness (mm)	Pericarp thickness (mm)	Penetrance of fruit (kg)
Genotypes	15	0 004 **	1 39**	2 062**
Error	48	0 0003	0 04	0 06

** Significant at 1 per cent level

Appendix-IX

Analysis of variance for line x tester analysis for yield and its components in tomato

Source of variations	df	Mean squares						
		Plant height (cm)	Days to flower	Days to harvest	Fruits/ plant	Yield	Average fruit weight	Storage
Genotypes	34	360 846**	0 304**	0 184**	2 921**	0 980**	299 06**	1 883**
Parents	9	500 753**	0 349**	0 166**	7 260**	0 082**	423 811**	4 309**
Hybrids	24	321 570**	0 296**	0 196**	0 867**	0 104**	194 180**	0 721**
Parents Vs hybrids	1	44 304*	0 095**	0 056**	13 157**	0 072**	1693 522**	7 963**
Lines	4	1364 494**	1 036**	0 674**	3 020**	0 248**	762 295**	1 849**
Testers	4	120 556NS	0 406**	0 255*	1 145*	0 11*	197 223*	2 031**
Lines x testers	16	111 093**	0 084**	0 062**	0 259**	0 052**	51 391**	0 111**
Error	102	10 567	0 006	0 004	0 039	0 003	4 022	0 015

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

Appendix-X

Components of additive and non additive variance and heritability for yield and its components in tomato

Variations	Plant height (cm)	Days to flowering	Days to harvest	Fruits/ plant	Fruit yield/ plant (kg)	Average weight (g)	Storage life (days)
C_{ov} HS	32 57	0 03	0 02	0 09	0 008	21 42	0 09
$\sigma^2 A$	63 14	0 06	0 04	0 18	0 02	42 84	0 18
C_{ov} FS	87 88	0 08	0 05	0 24	0 028	54 52	0 21
$\sigma^2 D$	24 74	0 02	0 01	0 06	0 01	11 68	0 02
Heritability	0 64	0 70	0 74	0 65	0 60	0 73	0 84

INCORPORATION OF RESISTANCE TO FRUIT CRACKING IN A BACTERIAL WILT RESISTANT GENETIC BACKGROUND IN TOMATO

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

An investigation on Incorporation of resistance to fruit cracking in a bacterial wilt resistant genetic background in tomato was undertaken in the Department of Olericulture College of Horticulture Vellanikkara during the period from January 1991 to March 1994 The findings are succinctly mentioned below

Evaluation for bacterial wilt resistance revealed that Sakthi and LE 79 5 are consistently resistant to bacterial wilt Four addition sources of bacterial wilt resistance were identified viz LE 214 CAV 5 LE 415 and LE 382 1 Resistance to bacterial wilt in these lines was governed by recessive genes

Screening for resistance to fruit cracking resulted in the identification of fifteen tomato genotypes which were found to be resistant to both radial and concentric cracking Resistance to concentric fruit cracking in these lines were found to be dominant

All the bacterial wilt resistant genotypes had a higher content of total phenols O D phenol and ascorbic acid than the susceptible line Pusa Ruby

The crack resistant varieties had a higher content of insoluble solids and pectin lower content of acidity total sugar and reducing sugar in fruits thick fruit skin and pericarp as compared to susceptible variety The elasticity of skin was also higher in crack resistant genotypes Crack resistant varieties had a compact arrangement of parenchymatous cells when compared with crack susceptible variety The resistant lines had a thicker cuticle also

The F s developed by line x tester crossing were susceptible to bacterial wilt All the same they were resistant to both radial and concentric fruit cracking indicating dominant gene action for crack resistance The F_2 segregants with combined resistance to both bacterial wilt and fruit cracking were selected for further improvement