INCORPORATION OF RESISTANCE TO BACTERIAL WILT IN INDETERMINATE TOMATOES

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Kerala Agricultural University

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VELLANIKKARA, THRISSUR - 680 656
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2003

DECLARATION

I hereby declare that the thesis entitled **"Incorporation of resistance to bacterial wilt in indeterminate tomatoes"** 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, fellowship or other similar title, of any other University or Society.

Vellanikkara
23.10.2003

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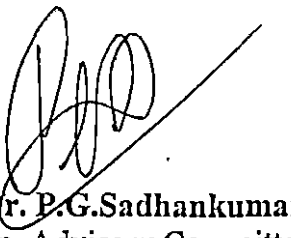
CERTIFICATE

Certified that the thesis, entitled **"Incorporation of resistance to bacterial wilt in indeterminate tomatoes"** is a record of research work done independently by **Miss. Gudi Jacob,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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We, the undersigned members of the Advisory Committee of **Miss. Gudi Jacob,** a candidate for the degree of **Master of Science in Horticulture** with major field in **Olericulture,** agree that the thesis entitled **"Incorporation of resistance to bacterial wilt in indeterminate tomatoes"** may be submitted by Miss. Gudi Jacob, in partial fulfillment of the requirement for the degree.

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EXTERNAL EXAMINER

Acknowledgement

' Unto Him Who is Everything I Owe Everything'

With regardful memories...

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Gudi Jacob

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INTRODUCTION

Tomato, known for it's outstanding nutritive value, is one of the most popular and widely grown vegetable in the world for it's edible fruits. Increased interest in tomato has been created by the fact that its consumption has been correlated to a reduced risk of some types of cancer and ischemic heart diseases. In India, tomato is grown in almost all parts of the country covering about 3.5 lakh hectares with an annual production of 53 lakh tonnes and with an average productivity of 15.8 tonnes ha^{-1} (http://www.indiaagronet.com).

The area under tomato in Kerala is very meagre and is concentrated in the Chittoor taluk of Palakkad district. The main reason for the low spread of the crop in the remaining area is the incidence of bacterial wilt caused by *Ralstonia solanacearum* Yabuuchi *et al.* The warm humid tropical climate and acidic soil condition in the state favour the incidence of this disease. Attempts on disease management have not given satisfactory results. This necessitates the development of resistant lines to this disease.

Resistance breeding programmes taken up in the Kerala Agricultural University has resulted in the development and release of three bacterial wilt resistant varieties viz., Sakthi, Mukthi and Anagha. All these varieties are determinate or semi-determinate and their yield level is comparatively low.

Indeterminate tomatoes give higher yield over a period of time. The indeterminate types available in the country are susceptible to this disease. Further, the indeterminate types are preferred in the homesteads in Kerala. These types will be of use under protected cultivation also. With these points in mind, the present investigation 'Incorporation of resistance to bacterial wilt in indeterminate tomatoes' was taken up with the following objectives:

1. To develop indeterminate tomatoes resistant to bacterial wilt.
2. To generate information on combining ability and heterosis in tomato for different characters.

Review of Literature

2. REVIEW OF LITERATURE

The review of literature on the causal organism of bacterial wilt, it's symptomatology, sources of resistance, growth habits in tomato, combining ability and heterosis of bacterial wilt resistant tomato is briefly dealt in this chapter.

2.1 PATHOGEN

Bacterial wilt caused by *Ralstonia solanacearum* (Smith) Yabuuchi *et al.* is one of the most destructive plant diseases in the warm humid regions of the world. The pathogen is known to attack a wide range of host plants. Walker (1952) reported the first incidence of the disease from Italy in 1882.

Almost one hundred years elapsed since Erwin.F.Smith published the first description of *Pseudomonas solanacearum* E.F.Smith, that causes a wilt disease of solanaceous plants (Smith, 1896). Hedayathullah and Saha (1941) first reported the incidence of bacterial wilt disease in tomato from India.

Pseudomonas solanacearum is a complex pathogen, differing in host range and pathogenicity. Geographical variation occurs in the organism. Buddenhagen *et al.* (1962) classified *Pseudomonas solanacearum* isolates from a wide range of hosts in Central and South America, based on host range, pathogenicity and colony appearance on TZC medium, into 3 races i.e., race 1, race 2 and race 3.

1. Race 1 (Solanaceous strain) - It has 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) - This is restricted to *Musa* spp. 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 subtropics.

Hayward (1964) classified *Pseudomonas solanacearum* into biotypes or biochemical types namely biotype I, biotype II, biotype III and biotype IV, based on their ability to oxidise various carbon sources and on other bacteriological reactions.

1. Biotype I - doesnot 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

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

In a study of thirty tomato isolates of *P. solanacearum* from Assam and Orissa, it was concluded that all isolates belonged to race 1 (Addy *et al.*, 1980).

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.

He *et al.* (1983) obtained a series of isolates from China which oxidised mannitol but not sorbitol or dulcitol, and these were designated as biovar V.

Cook and Sequeira (1988) used RFLP technique to study the relationship between biovars I to IV of Hayward and races 1, 2 and 3 of Buddenhagen *et al.* They divided *P. solanacearum* into two distinct groups. Group I includes strains of race 1, biovars III and IV and Group II includes strains of race 1 biovar I and races 2 and 3. In addition, they were able to distinguish strains of the pathogen both by race and biovar. For example, race 3 strains produced a very distinct gel pattern which suggests that race 3 is a homogenous 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 heterogenous.

Kumar *et al.* (1993) differentiated twelve isolates of *P. solanacearum* from solanaceous hosts into biovars following Haywards classification. All the

isolates from tomato, potato, aubergine and bell pepper (Capsicum) were identified as biovar III or a sub type in biovar III. All the isolates utilised glucose, fructose, sucrose, galactose and glycerol.

Biovar III of *P. solanacearum* can be differentiated from biovar V based on it's ability to utilise the sugar alcohols, sorbitol and dulcitol (Hayward, 1994).

Yabuuchi *et al.* (1992) transferred several species of the r RNA homology group II *Pseudomonas* including, *P. solanacearum* to the genus *Burkholderia.* Later work based on sequencing of 16 sd r RNA genes and polyphasic taxonomy led to the proposal of genus *Ralstonia* and the pathogen has been renamed as *Ralstonia solanacearum* (Yabuuchi *et al.*, 1995).

R. solanacearum pass much of their life cycle living in harmony or in an uneasy truce with their host plants (Allen, 1997).

The genetic variation among strains of *R. solanacearum* belonging to race 2 and related bacteria was investigated by polymerase chain reaction amplification with random primers. A transposon induced mutant *R. solanacearum* strain has lost pathogenicity on it's natural host, banana, but is still retaining the ability to wilt tomato (Thwaites *et al.*, 1997).

Paul (1998) identified bacterial wilt affected tomato and chilli isolates as *R. solanacearum* race 1 biovar III.

Mathew *et al.* (2000) conducted studies on the isolates of *R. solanacearum* from tomato, brinjal and chilli and identified the pathogen as race 1, biovar III and biovar V.

Variability studies conducted on the isolates of *R. solanacearum* of tomato, brinjal and chilli from different locations of Kerala showed the existence of pathogen belonged to race 1, race 3 and biovar III, III A and V (James, 2001 and Mathew, 2001).

2.2 SYMPTOMATOLOGY

Walker (1952) reported that the first expression of the disease is wilting of the lower leaves of the plants and it leads to the entire wilting of the plants. Dwarfing or stunting of the plants may also occur.

The entry of the pathogen is 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 the entry of the bacterium through natural opening of the plant. Chupp and Sherf (1960) reported that the bacteria can enter at the points of origin of secondary roots. The roots and the lower parts of the stem show a browning of vascular bundles and a water soaked appearance in the root. The pathogen enters into the uninjured roots also (Libman *et al.*, 1964).

Eventually, dark brown to black areas develop due to decay of root systems and the whole plant dies off. A very distinct characteristic indication of bacterial wilt is the appearance of bacterial ooze from the injured vascular regions (Ashrafuzzaman and Islam, 1975).

According to Hussain and Kelman (1957), breakdown of plant tissues by the pathogen is due to the cellulase and polygalacturonase enzymes produced by the pathogen. Continued tissue decay and plugging finally result in the death of the plant.

Visible symptoms of the disease occur within 2 to 8 days after the entry of the pathogen into the host plant (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. 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 polysaccharides). The bacterium also produces IAA which can initiate tylose formation and increases cell wall plasticity. Ethylene production is also associated with it.

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.

Sequeira (1993) reported that there is no cytological evidence for how the bacterium reaches the vascular system. It is assumed that the bacterium has to digest it's 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.

Allen (1997) reported that *R. solanacearum* pass much of their life cycle living in harmony or in an uneasy truce with their plant hosts.

2.3 SOURCES OF BACTERIAL WILT RESISTANCE

In field trials carried out at North Carolina in USA, cultivars Louisiana Pink and T-414 from Puerto Rico showed good resistance to bacterial wilt (Schaub and Baver, 1944).

A further source of resistance was reported in *Lycopersicon pimpinellifolium* (PI 127805A) which had partial dominance at seedling stage and the resistance was controlled by recessive genes (Abeygunawardena and Siriwardena, 1963). The expression of the resistance in a variety is a function of the age of the plant and changes in temperature (Acosta *et al.*, 1964).

In an experiment conducted by Henderson and Jenkins (1972) to evaluate resistance in several genotypes, they found the genotypes such as Venus, Saturn and Beltsville-3814 to be resistant to bacterial wilt. Similarly from the work carried out by Ahuja and Waite (1974) they observed more than 90 per cent survival of the seedlings in BWN-514, BWN-16, BWN-17 and BWN-7755 against the attack from pathogen *P. solanacearum.*

Graham and Yap (1976) performed a diallel involving six cultivars Walter, CRA 66, H 7741, Venus, VC-4 and Llanos de Coke. 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.

Mew and Ho (1976) found that the line VC-8-1-2-1 was resistant to *P. solanacearum* regardless of the inoculum density.

Ramachandran *et al.* (1980) evaluated 36 tomato lines for their resistance to bacterial wilt in Kerala. They observed resistance in La-Bonita and CL 32 d-0-19 GS cultivars.

Celine (1981) reported field tolerance in the line CL 32 d-0-1-19 GS.

Chumrisoot 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.

Wilt resistance in cultivar Venus and the line CL 32 d-0-1-19 GS from Taiwan and was broken down when *Meloidogyne incognita* larvae were added at the rate of 100/10 cm pot at the time of inoculation with bacteria (Goth *et al.*, 1983). He also suggested that nematode should be considered as a factor in the development of bacterial wilt resistant lines.

Sreelathakumari (1983) reported that no F_1 hybrids involving 10 lines from *Lycopersicon esculentum* as female and *L. pimpinellifolium* as male showed resistance. She also reported a complementary and hypostatic type of digenic recessive gene system for wilt resistance.

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.

Bosch *et al.* (1985) reported that the back cross progeny of the cultivar Rodade showed the resistance of 72 to 100 per cent. Herrington and Saranah (1985) bred an F_1 hybrid Redlands 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.

Narayanankutty (1985) reported that out of four non-segregating lines (Saturn, LE 79, Pusa Ruby and Pusa Ruby x LE 79 F_1) 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_3.

Moffett (1986) reported resistance in cultivars Scorpio, Redlander and Redlands Summer taste. 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 40 x UH 7976.

Rajan and Peter (1986) reported a monogenic incompletely dominant gene action in the resistant line LE-79.

Cultivars Intan, Ratna, CI 32-6-125-d-0, AV 22 and AV 15 were found to be resistant (Hanudin, 1987). Venus, Bonset and Gerldton were moderately resistant to *P. solanacearum*. Nirmaladevi (1987) reported that resistance to bacterial wilt in CRA 66 Sel A was under polygenic control.

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 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.

Satisfactory source of resistance was reported in cultivars MST 32-1, MST 21-23 and King-Kong F_1 from Taiwan and Caraibo from France (Girard *et al.*, 1988).

Denoyes *et al.* (1989) evaluated 25 varieties for bacterial wilt resistance and among them 15 were found to be resistant including three hybrids. Four varieties were moderately resistant and six varieties were susceptible.

Toyoda *et al.* (1989) selected the leaf explant-derived callus tissues, which were resistant to toxic substances, derived from *P. solanacearum*, in the culture filtrate and they were regenerated into plants. These plants expressed resistance to *P. solanacearum* at the early infection stage by suppressing or delaying the growth of inoculated bacteria. Complete resistance was obtained in self pollinated progeny of regenerants derived from non-selected callus tissues. He also found that these plants showed high resistance when inoculated with the virulent strain used in the experiment, and were also resistant when planted in a field infested with a different strain of the pathogen.

Anand *et al.* (1992) reported dominant gene action in the F_1s of BWR-1, BWR-5, 1661, 15 SB and 1836 and incomplete dominance in the F_1s of 1881 and Sonali for resistance to bacterial wilt.

The lines LE-214, LE-217, LE-79, LE-79 LFG, LE 79 DG and LE 79 SPF were found to be resistant (Peter *et al.*, 1992).

Sathyanarayana (1992) conducted studies on bacterial wilt resistant tomato for processing and yield. It was found that the hybrids BWR-15 x 1614, BWR-15 x 1032-1 and BWR-5 x 674 showed high resistance to bacterial wilt.

In an experiment on screening genotypes resistant to *R. solanacearum* biovar I and III, Quezado-Soares and Lopes (1994) found that lines Caraibo, C-38D, CL-1131-0-0-13-0-6 and 72-TR-4-4 were resistant to isolates of both biovars, but the level of resistance depended on the virulence of the isolate.

Thirty tomato genotypes were evaluated for resistance to *R. solanacearum* and observed that the disease incidence ranged from zero in Hawaii 7997, GA 219 and GA 1565 to 83 per cent in Solarset (Chellemi *et al.*, 1995).

A monogenic dominant resistance was reported in Hawaii 7996 (Grimault *et al.*, 1995).

Sadhankumar (1995) screened 68 tomato genotypes for resistance to bacterial wilt and found that Sakthi, LE-79-5, LE-415, LE-214, CAV-5 and

LE-382-1 were resistant and he also found that the genes responsible for resistance in these lines were recessive.

Williams and Williams (1995) compared *R. solanacearum* resistant tomato cultivars as hybrid parents and it was found that hybrids with Hawaii 7998 as one of their resistant parents transmitted greater resistance than the other resistant parents used.

Vudhivanich and Soontarasingh (1995) in an effort to screen for bacterial wilt resistance of tomato, found that among 9 genotypes, CL-5915 and 233 D4-2-1-0 showed resistance while CL-184 and CL-5915-206 D4-2-5-0 had moderate resistance and Seedathip-2, CI-153, Mishou, Seedathip-502 and VF 134-1-2 were moderately susceptible.

Bobisud *et al*, (1996) conducted a field testing of bacterial wilt-resistant tomato somaclones and they found that tomato cv. Healani somaclones showed survival percentages ranging from 40 to 100 per cent, while the original Healani had a survival rate of 0 per cent and resistant cv. Kewalo had 30 per cent survival.

In an experiment to find out variable reaction of tomato lines to bacterial wilt at several locations in South East Asia by Hanson *et al.* (1996), they recorded that mean survival (70%) of CRA-66 derived entries was significantly better than the mean of entries with resistance derived from UPCA 1169 or UPCA 1169 plus Venus or Saturn.

In a work carried out by In-Mooseong *et al.* (1996) to identify resistance among 31 tomato cultivars, they found that the cultivars Naebyongchangsu, Kwangmying and Seojin were mildly resistant to *R. solanacearum* and the remaining cultivars were susceptible.

Chellemi *et al.* (1997) reported for the first time the suppression of bacterial wilt of tomato through the addition of magnesium to soil. He also suggested that for plants not receiving additional applications of calcium or magnesium, total amino acids in the highly susceptible 'Bonny Best' (1.8 mμ) were over twice as concentrations in the xylem fluid of the resistant Hawaii 7997

(0.9 mμ). Concentrations of amino acids in the cultivar with intermediate levels of resistance were also intermediate.

Studies on the genetic nature of bacterial wilt resistance in tomato conducted by Mohamed *et al.* (1997) suggested that resistance identified in *L. esculentum* var. *cerasiforme*. LA 1421 was different from that derived from *L. pimpinellifolium*. Results suggested that selection for resistance from crosses between LA 1421 and Cascade was delayed with a high level of fixation of genes.

A survival of 100 per cent was observed in genotypes such as FMTT-268, FMTT 301, FMTT 115, FMTT 264, Hawaii 7996, Hawaii 7997, Hawaii 7998, F_1-80-465, 10-pink, L 285, BL 31, BL 33, BL 350, CRN 475-BC1-F_7-265-4-19, CRA 66, GA 219 and GA 1565 (Bhattarai *et al.*, 1998). Wilt resistance was reported in tomato cultivars like BT 18, LE 79-5, LE 296, Sakthi and LE 453 (Paul, 1998).

Rajan and Sadhankuar (1998) evaluated 141 tomato lines for identification of bacterial wilt resistant genotypes. Eight lines namely LE 415, Sakthi, CAV-5, LE 474, LE 457, LE 79-5, LE 447 and LE 435 were found to be resistant to bacterial wilt and the lines LE 214 and LE 470 were identified as moderately resistant.

Five bacterial wilt resistant genotypes (Sakthi, LE 79-5, LE 214, LE 415 and LE 421) were crossed with five fruit crack resistant genotypes (LE 296, LE 386, LE 388, LE 393 and LE 399) in a line x tester fashion and the F_1s along with the parents were evaluated for bacterial wilt resistance and fruit crack resistance. All the F_1s were susceptible to bacterial wilt when evaluated in a wilt sick field (Sadhankumar *et al.* 1998).

Sood *et al.* (1998) reported stable source of resistance in the cultivars BWR-5, BT-18, LE-79-5, BL-312, Hawaii 7997, Hawaii 7998 (USA), BF-Okitsu 101 (Japan), CRA 66 (Guadeloupe), Rodade (Australia), R 3034-3-10 N-UG, TML-46-N-12-Nearly NT (Philippines) and Caraibo (Guadeloupe).

Vidyasagar (1998) evaluated 90 tomato genotypes in bacterial wilt sick fields and 30 were proved resistant.

Protein bands PPO-1, PPO-4, PPO-7, PPO-10, PPO-11 and PPO-12 were observed in the root and leaf samples of resistant genotypes namely Sakthi, Kukthi, LE-214 and LE-474 which could be considered as a marker for resistance to bacterial wilt in tomato (Bose, 1999). He also noticed high total phenol and OD phenol content in the resistant lines.

Wang *et al.* (1999) evaluated 82 accessions and hybrids of tomato for disease resistance and they developed two improved disease resistant rootstocks by pedigree selection of five F_1s. These 2 rootstocks were highly resistant to bacterial wilt and different scions grafted with the two rootstocks showed disease resistance.

Rani (2000) reported that the F_1 hybrids LE 415 x Mukthi, LE 415 x Sakthi, LE 415 x BWR-1 and Sakthi x Mukthi are resistant to bacterial wilt.

Kurien and Peter (2001) evaluated F_1 hybrids of bacterial wilt resistant/tolerant genotypes Sakthi, LE 214 and LE 206 with HW 208F, St 64, Ohio 8129, TH 318 and Fresh market and they found that these hybrids were completely susceptible to bacterial wilt.

Two heat tolerant tomato lines TML 114 and TML 216 were developed, that are resistant to three biovars of bacterial wilt (Deanon *et al.*, 2002).

Devi *et al.* (2002) conducted a study for the development of bacterial wilt resistant tomatoes for processing. They have crossed wilt resistant genotypes with genotypes suitable for processing and they screened F_1 plants in the nursery and found that they are susceptible to wilt.

Fifty tomato genotypes were screened in the bacterial wilt disease nursery and the variety Sakthi and the genotypes LE 79-5, LE 415, LE 421, LE 582 and LE 583 were resistant and LE 576 and LE 530 were moderately resistant to wilt caused by soil-borne pathogen *R. solanacearum* (Devi *et al.*, 2002).

Kulkarni *et al.* (2002) screened 56 indigenous and exogenous tomato genotypes against *Ralstonia solanacearum* under field conditions by artificial inoculation and he found 18 genotypes to be resistant and 17 susceptible. Seven

genotypes exhibited moderate resistance while 14 showed moderate susceptibility towards *R. solanacearum*.

HT-01 is a derivative from a cross between Solarset and KWR and found to be with bacterial wilt resistance and good fruit quality attributes (Peiris and Kudagamage, 2002). T-245 is another variety with moderate resistance to bacterial wilt disease and good fruit quality characteristics.

Prasanna *et al.* (2002) developed 65 F_1 hybrids by crossing 13 bacterial wilt resistant lines with 5 ripening mutants to develop bacterial wilt resistant tomato F_1 hybrids with extended shelf life. They found that the hybrids IIHR 2199 x IIHR 2052, BWR IF x nor-1, IIHR 2199 x IIHR 1136 were high yielding and resistant to bacterial wilt.

Sadashiva *et al.* (2002) reported that the hybrids TLBR-3 x IIHR 2202, TLBR-3 x IIHR 2200, TLBR-4 x IIHR 2200, TLBR-3 x IIHR-2199 and TLBR-6 x IIHR 2202 are having combined resistance to bacterial wilt and tomato leaf curl virus.

Sadashiva *et al.* (2002) crossed bacterial wilt resistant varieties Arka Abha with IIHR 915 and the parents, hybrids and the segregating populations were screened under artificial conditions for combined resistance to bacterial wilt and root knot nematode. He found 6 lines BN-1, BN-2, BN-3, BN-8, BN-9 and BN-10 to be promising and all the lines except BN-3 were found to have combined resistance to bacterial wilt and nematode. Individual plants were bulked from F_6 onwards resulting in the development of a high yielding line BN-10-2 with combined resistance to bacterial wilt and nematode in F_8.

2.4 GROWTH HABITS IN TOMATO

In a study conducted in mid hills using indeterminate tomato cultivars viz., Solan Gola, Money Maker and Naveen, it was found that Naveen had the heaviest fruits (83.2 g) and produced the highest yield (441 q/ha) (Bhardwaj *et al.*, 1995).

Brovko (1997) reported higher yields of 17-20 kg/m² for indeterminate tomato hybrids namely, Portos, Maidan, Miledi, Figaro, Duet and Murza, while the determinate hybrids yielded 6-8 kg/m².

Danailov *et al.* (1997) tested Bulgarian tomato hybrids having different growth habits suitable for different production trends. The indeterminate tomato hybrid (Viki F_1) exceeded standards Kristi and Carmello for fruit balance, uniformity and hardiness in long term storage.

Anjaneyulu *et al.* (1998) studied the kinetic parameters of phosphorus inflow in determinate, semideterminate and indeterminate genotypes of tomato and they have found that among the 3 groups; the indeterminate genotypes recorded the lowest Imax (number of sites for P absorption) and In (inflow rates).

Cerne *et al.* (1999) reported that the indeterminate tomato cultivar Arletta F_1 and Fontana F_1 yielded more than 100 t/ha.

Dennis (2000) reported that the fruit of indeterminate tomatoes is usually softer and has more gel and thinner walls than determinate type and they have a long fruiting period.

2.5 COMBINING ABILITY

Kalloo *et al.* (1973) reported high variance component due to sca than that due to gca for locule number indicating excess of non-additive type gene action.

Nandapuri and Tyagi (1978) reported additive gene action to be controlling pericarp thickness.

In a study with line x tester analysis involving 15 lines and 3 testers, highly significant sca variance for pericarp thickness was reported (Dixit *et al.*, 1980).

Peter and Rai (1980) conducted studies which revealed the role of both additive and non-additive gene actions in controlling the expression of days to fruit maturity.

Moya *et al.* (1986) have observed additive gene action to be controlling plant height, where as contradicting non-additive gene action for this character has been reported by Sonone *et al.*(1986) and Rajput (1987).

Chandrasekhar and Rao (1989) in a 6 x 6 diallel experiment observed the prominence of additive gene action for fruit firmness.

Yadav *et al.* (1991) observed additive gene effects to control the inheritance of pericarp thickness.

The variance component due to gca was higher than that due to sca showing preponderance of an additive type of gene action for yield (Shrivastava *et al.*, 1993). The predominance of non-additive component for yield was reported by Dod and Kale (1992), Kurien and Peter (1995) and Rai *et al.* (1997).

Sadhankumar (1995) in a combining ability analysis for yield and yield components of tomatoes resistant to bacterial wilt, found that the lines CAV-5, LE-386 and LE-296 were good general combiners for fruits/plant.

Chadha *et al.* (1997) in a combining ability analysis for yield and yield components of tomatoes resistant to bacterial wilt, observed the lines Sonali for days to 50 per cent flowering, BWR-5HR, LE-79-5W and EC 129156 for marketable fruits plant^{-1}, BT-10, BWR-5HR and EC 191540 for average fruit weight and BT-10 and HR for marketable yield plant^{-1} as good general combiners. The crosses EC 129156 x EC 191538 and EC 179906 x EC 191538 were found to be best specific combiners.

Based on processing characters, tomato genotypes were selected and crossed in a 8 x 6 line x tester fashion to study the combining ability and gene action (Kumar *et al.*, 1997). The study showed that, for processing characters, non-additive gene action was more prevalent. The sca effect of the most crosses were related to the sca effect of their parents and the best cross combinations in all the characters involved at least one parent with high gca effect.

In a diallel analysis, additive gene effects were observed in both the generations for fruit weight, total soluble solids, reducing sugar content and seed

weight (Shrivastava, 1998). The best specific combiners identified were Pusa Ruby x Money maker for total soluble sugars and reducing sugars and Pusa Ruby x Pusa Early Dwarf for low seed weight.

Srivastava *et al.* (1998) carried out combining ability analysis through line x tester method using 15 lines and 3 testers. They found that none of the parents was a good general combiner for all the characters. The lines 53106, 6601, 8105 and 8730 were good general combiners for as many as 4 to 5 characters. The ratio of gca/sca, observed less than unity for all the characters, revealed predominance of non-additive variance.

Rani (2000) reported that LE 415 x Mukthi was a good general combiner for fruit plant^{-1} (48.2 fruits plant^{-1}) and fruit yield plant^{-1} (1.5 kg plant^{-1}).

Inbreeding depression study was carried out in 10 x 10 diallel analysis of tomato and the data was analysed for inbreeding depression in F_2 generation for horticultural attributes (Panday and Dixit, 2001). Inbreeding depression was observed in F_2 generation which varied from character to character, and this is due to non-additive gene action.

Roopa *et al.* (2001) crossed 5 lines with extended shelf life and 6 testers with good horticultural qualities and their F_1s were evaluated to study the combining ability. They found that non-additive gene effect was predominant for locule number, TSS, lycopene, vitamin C etc. while additive gene effects were predominant for fruit firmness. Among the lines, IIHR 2052 and IIHR 2053 proved to be the best combiners for shelf-life, fruit firmness and yield. Among the testers, IIHR 858, IIHR 1614 and Flora-Dade proved to be the best combiners for fruit wall thickness, fruit weight, fruit firmness, shelf life and vitamin C. The hybrids IIHR 2053 x IIHR 1614 and IIHR 1136 x PR 3 were found to be good specific combiners for extended shelf life.

2.6 HETEROSIS

The genetic system of tomato offers several advantages for exploiting heterosis. Heterosis in tomato was first observed by Hedrick and Booth (1908) for higher yield and more fruits.

Though tomato is a highly self-pollinated crop, high heterosis observed in this crop has been attributed to the fact that tomato was basically a highly outcrossing genus which was later evolved into a self-pollinating one (Rick, 1956).

High heterosis for yield in tomato is due to inter-cluster crossing than intra-cluster crossing (Khanna and Misra, 1977), It means, higher the taxonomic distance, greater will be the heterosis.

Negative heterosis for locule number is a desirable expression in hybrids (Gowda, 1979). Ashwathappa (1980) reported highly significant heterosis over mid parent (112.06%) for fruit yield, where as it was non-significant over better parent (35.99%). Dixit *et al.* (1980) observed highest heterosis for yield over better parent in the cross Kalyanpur Kuber x Pusa Ruby. Sheela (1986) reported heterosis in the hybrid LE 214 x LE 206 for fruit yield plant^{-1}. Sonone *et al.* (1986) tested 157 hybrids of which 13 gave 80-155 per cent higher yield than the control Pusa Ruby.

Highest heterosis for fruit number was observed in the cross Rutgers x Marmande (Valicek and Obeidat, 1987).

There is no consistent relationship between heterosis and genetic diversity in crosses between ten genotypes of *Lycopersicon esculentum* (Patil and Bojappa, 1988). Pusa Ruby x Sweet 72 showed the highest fruit yield and recorded the highest heterotic effect.

Patil and Patil (1988) analysed tomato fruits from twenty crosses and noted high heterosis in most crosses for total soluble solids, titrable acidity and pericarp thickness. Two superior crosses were identified, namely PC x SW 72 and S 14 x PR.

Dod and Kale (1992) evaluated 66 F_1 hybrids of tomato for quality traits and heterosis were observed in the crosses Punjab Chauhara x Punjab Kesari for number of locules fruit^{-1}. Pusa Early Dwarf x S 12 for pericarp thickness, Pusa Ruby x AC 238 for total soluble solids and Punjab Chuhara x S 12 for ascorbic acid content.

Dod *et al.* (1992) evaluated 66 F_1 hybrids and their parents from 12 x 12 diallel cross for six yield related traits and pronounced heterosis was observed for yield plant^{-1}, days to first harvest, number of fruits plant^{-1} and plant height. The best specific combiner was HS 101 x S2. Bora *et al.* (1993) reported highest heterosis for yield in the hybrids BT 10 x LE-79, BT 1 x BT 10 and BT 10 x K 10.

The hybrids LE 75 x LE 76 and LE 76 x LE 22 gave the highest heterosis for yield and positive heterosis for five other characters (Natarajan, 1993).

Heterosis for yield ranged from 0.7 per cent in Ace VF x F 24 to 71.7 per cent in Ohio 7663 x Rossol (Sidhu and Surjansingh, 1993).

According to Dev *et al.* (1994), heterosis in the F_1 hybrids EC 156 x Marglobe gave 83.18 per cent higher yield than the better parent.

Dod *et al.* (1995) reported that the parents Pusa Ruby, Marglobe, Pusa Early Dwarf, S-12 and Sioux were best general combiners. The crosses HS 101 x S-12, Pusa Early Dwarf x S-12 and Pusa Ruby x S-12 exhibited significant heterosis along with significant sca effects for yield and its contributing characters.

Hegazi *et al.* (1995) observed heterosis in 21 hybrid combinations for total yield, with a maximum value of 58.5 per cent and positive heterosis for number of fruits plant^{-1}.

Sadhankumar (1995) reported heterosis in the hybrid CAV-5 x LE 296 for fruits plant^{-1}. He also reported heterosis in the hybrid CAV-5 x LE 386 for fruit yield plant^{-1} and the hybrid LE 214 x LE 388 recorded heterosis for average fruit weight.

Maximum heterosis was reported in the cross NDT-120 x Kalyanpur Kuber (79.72%) and NDT-5 x NDT-21 (57.86%) (Singh *et al.*, 1995). Some other crosses like NDT-90 x NDT-21, NDT-5 x NDT-21 and NDT-120 x NDT-5 exhibited heterosis for number of fruits, NDT-120 x NDT-121, NDT-5 x NDT-21, NDT-120 x NDT-5 and NDT-120 x Kalyanpur Kuber for average fruit weight. Suresh *et al.* (1995) reported highest heterosis in the crosses namely Hisar Arun x

Sel-30, Hisar Arun x Ace and Hisar Arun x Flora-dade for plant height, branches plants^{-1}, average fruit weight, fruit number and total yield.

Amaral *et al.* (1996) evaluated tomato cultivars Angela I-5100, Flora-dade, IPA 05, IPA 06, Jumbo and Santa and their diallelic crosses for commercial fruit weight, average thickness of pulp, number of locules per fruit, and content of soluble solids. It was found that the commercial fruit weight was controlled by non-additive effects and number of locules per fruit by equal proportions of additive and non-additive effects.

Cheema *et al.* (1996) evaluated thirteen tomato cultivars and their F_1 hybrids and observed that WIR 4329, Nemadoro and Castle Rock were good general combiners and WIR 4285 x Nemadoro recorded maximum heterosis for yield.

Heterosis over the better parent for yield was reported to be ranging from 31.1 per cent for NDT x Kalyanpur Kuber to 57.9 per cent for NDTS x NDT-21 (Singh *et al.*, 1996).

In a line x tester analysis of tomatoes involving bacterial wilt resistant parents, highest heterosis was observed in the hybrid BWR-HR x EC 179913 and EC 129156 x EC 191538 for marketable yield plant^{-1} and marketable fruits plant^{-1} over the best parent (Vidyasagar *et al.*, 1997).

Bhatt *et al.* (1998) evaluated 66 F_1 hybrids for Vitamin C content and the hybrids Marglobe x Sakthi, Punjab Kesari x Bahar and T_1 x Azad Kranti were identified as the best heterotic combinations.

Nineteen tomato hybrids were evaluated by Biswas *et al.* (1998) and they found that the hybrid DARL-303 recorded highest yield.

Chaurasia and Kalloo (1998) observed highest yield in the hybrids TH 2312 and TO-230 under Varanasi condition.

Highest heterosis was reported in the crosses P-256 x P-253 for average fruit weight, 1181 x P-257, X331 x 1181 and X 331 x U 301 for pericarp thickness, W 321 x U 301 and S 287 x U 301 for total yield (Dhaliwal *et al.*, 1998).

According to Kalloo *et al.* (1998), the tomato hybrids Avinash-2, Hemlata, TH 2312 and Ratna were suitable for Varanasi region, TH 2312, ARTH-13, Avinash-2 and DTH-6 for Bangalore, ARTH-3 for Hisar and Avinash-2 for Coimbatore region.

Kujur *et al.* (1998) evaluated ten F_1 hybrids of tomato and found that the hybrids Rashmi and Karnataka recorded maximum heterosis for TSS, locule number per fruit and acid and sugar percentage under Ranchi condition.

Highest heterosis was reported in the hybrid Pusa Sheetal x Chiku for most of the processing characters (Kumar *et al.*, 1998).

Patil *et al.* (1998) reported maximum heterosis in the cross 32-2 x 85-1 over better parent and the cross 6-1 x Suit for yield over the commercial hybrid Avinash-2.

Shrivastava (1998) reported highest heterosis in the crosses Marglobe x Hisar Arun for acidity, NT-3 x HS-1 for total soluble solids. The best hybrids identified were Marglobe x HS-101, Marglobe x Hisar Arun, Marglobe x NT-3 and NT-3 x HS-101.

Srivastava *et al.* (1998) studied heterosis in relation to combining ability in tomato through a 15 x 3 line x tester analysis and they found that maximum heterosis for yield was exhibited by the cross 6601 x Angoorlata. There was high heterotic response in most of the hybrids which supports the role of non-additive gene action.

Heterosis was observed in F_1 hybrids PKM-1 and Marutham for 100 seed weight and vigour index and found that fruit yield was significantly and positively related to 100 seed weight, seed length, vigour index and dehydrogenase activity (Subburamu *et al.*, 1998).

Wang *et al.* (1998) reported heterosis in the cross combination 9596-25 x Meidong for fruit shape, yield and earliness.

Rani (2000) estimated relative heterosis, standard heterosis and heterobeltiosis for different biometric characters in tomato and she found that

LE 415 x Mukthi was the best F_1 hybrid for fruits per plant (48.2 fruits plant^{-1}), fruit yield plant^{-1} (1.5 kg plant^{-1}) and average fruit weight (43.15 g).

A line x tester analysis was done utilising 4 lines and 2 testers along with their 8 hybrid combinations to study the extent of heterosis in F_1 hybrids over the better parent and also to estimate the magnitude of hybrid vigour in relation to genetic diversity of parents for antioxidant activity (Singh *et al.*, 2002). Highly significant positive heterosis was observed over better parent for ascorbic acid (24.12%), carotenoids (78.11%) and lycopene content (182.43%). The cross Agata x H 36 exhibited highest heterosis for ascorbic acid, whereas cross between Sel-18 and H-24 exhibited maximum heterosis for total carotenoids and lycopene.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was carried out in the Vegetable research plot of the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, which is located at an altitude of 23 M above MSL and between 10° 32" N and 76° 16" E longitude. The area has a warm humid tropical climate. The experimental site has a laterite loam soil. The experiments were conducted during July, 2002 - September, 2003.

The study consisted of the following experiments:

3.1 Development of F_1 hybrids in tomato

3.2 Evaluation of F_1 hybrids for bacterial wilt resistance and indeterminate character

3.3 Line x tester analysis for yield attributes

3.4 Evaluation of F_2 population for resistance to bacterial wilt and indeterminate character

3.1 DEVELOPMENT OF F_1 HYBRIDS IN TOMATO

Three known sources of bacterial wilt resistance viz., Sakthi, Mukthi and Anagha were used as the female parents and four high yielding indeterminate genotypes namely BT-118-4-1-1, Sun 7611, TH 977 and Nidhi were used as the male parents (Table 1).

Table 1. Genotypes/varieties and their source

Genotype/Variety	Source
Sakthi	Kerala Agricultural University, Trichur
Mukthi	Kerala Agricultural University, Trichur
Anagha	Kerala Agricultural University, Trichur
BT 118-4-1-1	Orissa University of Agriculture and Technology, Bhuvaneswar
TH 977	Syngenta India Ltd., Pune
Sun 7611	Namdhari seeds, Bangalore
Nidhi	Namdhari seeds, Bangalore

The seven parents used for crossing were grown in pots during July - October 2002. The pots were filled with potting mixture containing sand, soil and FYM in the ratio of 1:1:1. The medium was sterilised with 40 per cent formaldehyde solution. The management practices as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996) were followed. When the plants flowered, flowers of female parents (lines) were emasculated on the previous day of flower opening. The emasculated flowers were covered with butter paper bags. The pollen grains from the male parents (testers) were collected and pollination was performed on the next day between 7 am to 9 am. Pollinated flowers were labelled and again covered. Thus the following 12 F_1's were generated.

1. Sakthi x BT 118-4-1-1
2. Sakthi x Sun 7611
3. Sakthi x TH 977
4. Sakthi x Nidhi
5. Mukthi x BT 118-4-1-1
6. Mukthi x Sun 7611
7. Mukthi x TH 977
8. Mukthi x Nidhi
9. Anagha x BT 118-4-1-1
10. Anagha x Sun 7611
11. Anagha x TH 977
12. Anagha x Nidhi

3.2 EVALUATION OF F_1 HYBRIDS FOR BACTERIAL WILT RESISTANCE AND INDETERMINATE CHARACTER

The twelve F_1 hybrids along with their parents were grown in a bacterial wilt sick field at a spacing of 60 x 60 cm, accommodating 20 plants/genotype/ replication during January 2003 to April 2003. Both the hybrids and parents were spot planted with known susceptible variety Pusa Ruby. The infection of bacterial wilt was confirmed through ooze test. Management practices were followed as per the Package of Practices Recommendations of Kerala Agricultural University (1996), and the per cent bacterial wilt incidence was

recorded. The genotypes were classified into resistant, moderately resistant, moderately susceptible and susceptible according to Mew and Ho (1976).

R	-	Resistant	-	Survival 80 per cent or above
MR	-	Moderately resistant	-	Survival 60 to 80 per cent
MS	-	Moderately susceptible	-	Survival 40 to 60 per cent
S	-	Susceptible	-	Survival less than 40 per cent

The F_1s were classified into determinate/indeterminate/semideterminate based on growth habit.

Simultaneously their evaluation was also done in pots filled with sterilized potting mixture under green house conditions during January - April 2003. The following observations were recorded.

i) Plant height (cm)

Plant height from the ground level to the top of the plant was measured in cm at 45 days after transplanting.

ii) Days to flowering

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

iii) Days to fruit set

The number of days from sowing to first fruit set was recorded.

iv) Days to first harvest

The days taken from sowing to the first harvest of ripe tomatoes was recorded.

v) Fruits per plant

Fruits harvested periodically from each plant were added to obtain the total number of fruits plant^{-1}.

vi) Fruit yield per plant (g)

Weight of the fruits harvested periodically from each plant were added to obtain the fruit yield plant^{-1}.

vii) Crop duration

The days from sowing to the final harvest was recorded as crop duration.

Five fruits from each plant were considered for recording the following fruit characters.

viii) Average fruit weight (g)

Total weight of five fruits from each plant was taken and their average was calculated.

ix) Locules per fruit

Locules per fruit were counted from the cross sections of five fruits.

x) Fruit flesh thickness (mm)

Flesh thickness of five fruits from each plant were measured and average was taken.

xi) TSS (°Brix)

Total soluble solids in the fruit was recorded using Erma refractometer.

3.3 STATISTICAL ANALYSIS

3.3.1 Combining ability

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

3.3.2 Estimation of heterosis

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

The formula used were

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

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

Where $\overline{F_1}$, $\overline{BP}$ and $\overline{MP}$ were the mean performance of F_1 hybrid, better parent and mid parent respectively. Significance of heterosis was tested using student 't' test.

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

To test the significance over the mid parent

CD = t value x SE

$$CD(0.05) = te_{(0.05)} \times \sqrt{\frac{3\,MSE}{2r}}$$

To test the significance over better parent

$$CD(0.05) = te_{(0.05)} \times \sqrt{\frac{2\,MSE}{r}}$$

3.4 EVALUATION OF F_2 POPULATION FOR RESISTANCE TO BACTERIAL WILT AND INDETERMINATE CHARACTERISTICS

The F1's were selfed and F_2's were developed. The field evaluation of the F_2's along with their parents was done during June 2003 to September 2003. The F_2 population was raised in a bacterial wilt sick field. Ooze test was carried out to confirm the infection of bacterial wilt in affected plants. The F_2 progenies were observed for the incidence of bacterial wilt and indeterminate characteristics.

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

Results

4. RESULTS

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

4.1 Development of F_1 hybrids in tomato

4.2 Evaluation of F_1 hybrids and parents for bacterial wilt resistance and indeterminate character

4.3 Line x tester analysis for yield attributes

4.4 Evaluation of F_2 progenies for bacterial wilt resistance and indeterminate characters

4.1 DEVELOPMENT OF F_1 HYBRIDS IN TOMATO

Three bacterial wilt resistant varieties viz., Sakthi, Mukthi and Anagha (Plate 1) were crossed with four indeterminate genotypes viz., BT 118-4-1-1, TH 977, Sun 7611 and Nidhi (Plate 2) in a line x tester fashion to develop twelve F_1 hybrids.

4.2 EVALUATION OF F_1 HYBRIDS AND PARENTS FOR BACTERIAL WILT RESISTANCE AND INDETERMINATE CHARACTER

4.2.1 Evaluation for bacterial wilt resistance

Twelve F_1 hybrids and their seven parents were grown in a bacterial wilt sick field. The per cent of wilt incidence is presented in Table 2.

All the F_1 hybrids were susceptible to bacterial wilt. Among the parents, the lowest wilt incidence was observed in Anagha (12.5 per cent) followed by Sakthi (15 per cent) and Mukthi (20 per cent).

4.2.2 Evaluation for indeterminate character

All the hybrids except Sakthi x BT 118-4-1-1 were indeterminate in growth habit. Sakthi x BT 118-4-1-1 was semideterminate in growth habit. Among the parents, Sakthi, Mukthi and Anagha were semi determinate whereas BT 118-4-1-1, Sun 7611, TH 977 and Nidhi were indeterminate.

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

Genotype	Per cent bacterial wilt incidence	Score
Sakthi	15	R
Mukthi	20	R
Anagha	12.5	R
BT 118-4-1-1	100	S
Sun 7611	100	S
TH 977	100	S
Nidhi	100	S
Sakthi x BT 118-4-1-1	100	S
Sakthi x Sun 7611	100	S
Sakthi x TH 977	100	S
Sakthi x Nidhi	100	S
Mukthi x BT 118-4-1-1	100	S
Mukthi x Sun 7611	100	S
Mukthi x TH 977	100	S
Mukthi x Nidhi	100	S
Anagha x BT 118-4-1-1	100	S
Anagha x Sun 7611	100	S
Anagha x TH 977	100	S
Anagha x Nidhi	100	S

R - Resistant
S - Susceptible

Plate 1. Bacterial wilt resistant varieties used for hybridisation

BT 118-4-1-1

Sun 7611

TH 977

Nidhi

Plate 2. Indeterminate varieties used for hybridisation

The growth habit of different tomato genotypes are presented in Table 3.

4.3 LINE x TESTER ANALYSIS FOR YIELD ATTRIBUTES

4.3.1 Combining ability

The analysis of variance revealed highly significant differences for plant height, days to flowering, days to fruit set, days to first harvest, fruit yield per plant, average fruit weight, crop duration, locules per fruit, fruit flesh thickness and TSS studied among the 19 genotypes (Appendix-I).

Based on line x tester analysis, general and specific combining ability effects (gca and sca) were estimated (Table 4 and 5). Components of additive and non-additive variances and heritability in narrow sense were also estimated (Appendix-II).

Plant height

The genotypes Nidhi (7.40) had a significantly high positive gca effect for plant height. Sun 7611 (-7.31) and Mukthi (-4.51) had significant negative gca effects. Highly significant positive sca effects for plant height was expressed in Sakthi x Nidhi (15.98) and Mukthi x BT 118-4-1-1 (13.73). Highly significant negative sca effects were observed in Sakthi x BT 118-4-1-1 (-21.23) and Mukthi x Nidhi (-9.20).

Days to flowering

Sun 7611 (4.82) and Mukthi (3.30) showed significant positive gca effects for days to flowering. The significantly negative gca effects were expressed by BT 118-4-1-1 (-4.92) and Anagha (-3.51). Significantly negative sca effects were shown by Anagha x Nidhi (-3.12).

Days to fruit set

Highly significant positive gca effects were observed in Mukthi (2.03). Anagha showed significantly negative gca effects (-2.94) for days to fruit set. Highly significant positive sca effects were expressed by Mukthi x TH 977 (7.33). Anagha x Nidhi (4.82) and Sakthi x Sun 7611 (3.44). Highly significant negative

Table 3. Growth habit of tomato F_1 hybrids and their parents

Genotype	Growth habit
Sakthi	Semideterminate
Mukthi	Determinate
Anagha	Semideterminate
BT 118-4-1-1	Indeterminate
Sun 7611	,,
TH 977	,,
Nidhi	,,
Sakthi x BT 118-4-1-1	Semideterminate
Sakthi x Sun 7611	Indeterminate
Sakthi x TH 977	,,
Sakthi x Nidhi	,,
Mukthi x BT 118-4-1-1	,,
Mukthi x Sun 7611	,,
Mukthi x TH 977	,,
Mukthi x Nidhi	,,
Anagha x BT 118-4-1-1	,,
Anagha x Sun 7611	,,
Anagha x TH 977	,,
Anagha x Nidhi	,,

Table 4. Estimates of general combining ability effects of lines and testers for yield and it's components in tomato

Lines/ Testers	Plant height	Days to flowering	Days to fruit set	Days to 1st harvest	Fruit yield per plant	Fruits per plant	Average fruit weight	Crop duration	Locules per fruit	Fruit flesh thickness	TSS
Lines											
Sakthi	2.95	0.21	0.91	-0.09	19.86**	-0.22	6.83**	3.12*	0.10	0.15*	0.09*
Mukthi	-4.51**	3.30**	2.03*	1.41**	-12.01*	-0.01	-2.44**	-8.75**	-0.05	-0.77**	-0.08*
Anagha	1.56	-3.51**	-2.94*	-1.32*	-7.85	0.24	-4.39**	5.62**	-0.05	0.62**	-0.01
SE(gi)	2.23	0.75	0.49	0.38	5.23	0.34	0.67	1.18	0.05	0.06	0.03
SE(gi-gj)	3.15	1.06	0.69	0.54	7.39	0.48	0.95	1.67	0.07	0.08	0.04
Testers											
BT 118-4-1-1	-2.28	-4.92**	-1.18	-0.07	59.10**	0.65	5.50**	1.33	-0.11	0.16	-0.09
Sun 7611	-7.31**	4.82**	1.19	-1.09	-38.41**	-0.75	-5.13**	0.17	0.04	-0.53**	-0.04
TH 977	2.19	-0.88	-0.51	0.35	0.49	0.04	-2.05	5.33**	0.09	0.03	-0.02
Nidhi	7.40**	0.98	-0.30	-0.81	-21.18**	0.05	1.68	-6.83**	-0.01	0.34**	-0.15*
SE(gi)	2.73	0.92	0.60	0.47	6.41	0.42	0.81	1.45	0.06	0.08	0.04
SE(gi-gj)	3.86	1.30	0.85	0.66	9.06	0.59	1.15	2.05	0.08	0.11	0.06

* Significant at 5% level

** Significant at 1% level

Table 5. Estimates of specific combining ability effects for yield and it's components in tomato hybrids

Lines/F_1 hybrids	Plant height	Days to flowering	Days to 1st fruit set	Days to 1st harvest	Fruit yield per plant	Fruits per plant	Average fruit weight	Crop duration	Locules per fruit	Fruit flesh thickness	TSS
Sakthi x BT 118-4-1-1	-21.23**	-2.70	0.05	1.51*	62.77**	0.41	0.65	-3.96	0.10	0.10	0.27**
Sakthi x Sun 7611	-0.55	0.72	3.44**	1.12	-14.71	-0.34	2.78*	-0.29	-0.15	-0.46**	-0.02
Sakthi x TH 977	5.80	-0.58	-3.21**	-0.51	32.24**	-0.98	-1.55	3.54	-0.35**	0.19	-0.14*
Sakthi x Nidhi	15.98**	2.55	-1.18	-2.12**	-80.30**	0.91	-1.88	0.71	0.40**	0.17	-0.11
Mukthi x BT 118-4-1-1	13.73**	0.02	-1.51	-2.34**	-5.75	0.30	0.57	0.42	-0.10	-0.43**	-0.45**
Mukthi x Sun 7611	0.86	-2.77	-2.17*	-1.73*	-24.54*	0.75	-5.54**	6.58**	0.00	0.60**	0.30**
Mukthi x TH 977	-5.39	2.18	7.33**	3.19**	-61.74**	0.06	4.62	-4.58	0.05	0.10	0.08
Mukthi x Nidhi	-9.20*	-0.57	-3.64**	0.88	92.03**	-1.10	0.34	-2.42	0.05	-0.27*	0.07
Anagha x BT 118-4-1-1	7.50	2.68	0.55	0.83	-57.02**	-0.70	-1.23	3.54	0.00	0.33*	0.18*
Anagha x Sun 7611	-0.31	2.05	-1.26	0.60	39.25**	-0.40	2.76*	-6.29*	0.15	-0.14	-0.27**
Anagha x TH 977	-0.41	-1.60	-4.11**	-2.68**	29.50**	0.91	-3.08*	1.04	0.30**	-0.29*	0.06
Anagha x Nidhi	-6.78	-3.12*	4.82**	1.25	-11.73	0.20	1.54	1.71	-0.45**	0.10	0.04
SE (Sij)	3.87	1.30	0.85	0.66	9.06	0.59	1.15	2.05	0.09	0.11	0.06
SE (Sij - Sik)	5.47	1.84	1.20	0.93	12.81	0.83	1.63	2.89	0.13	0.16	0.08

* Significant at 5% level

** Significant at 1% level

sca effects for days to fruitset were observed in Anagha x TH 977 (-4.11). Mukthi x Nidhi (-3.64), Sakthi x TH 977 (-3.21) and Mukthi x Sun 7611 (-2.17).

Days to first harvest

Significantly high positive gca effects were observed in Mukthi (1.41). Significant negative gca effects for days to first harvest were observed in Anagha (-1.32). Mukthi x TH 977 (3.19) and Sakthi x BT 118-4-1-1 (1.51) showed significantly high positive sca effects. Anagha x TH 977 (-2.68) and Mukthi x BT 118-4-1-1 (-2.34) showed significant negative sca effects. These F_1 hybrids had significantly negative sca effects for days to flowering and days to fruitset.

Fruit yield per plant

BT 118-4-1-1 (59.10) and Sakthi (19.86) showed significantly high positive gca effects for fruit yield per plant. Hybrids Mukthi x Nidhi (92.03), Sakthi x BT 118-4-1-1 (62.77), Anagha x Sun 7611 (39.25), Sakthi x TH 977 (32.24) and Anagha x TH 977 (29.50) showed significant positive sca effects.

Fruits per plant

The highest positive gca effects for fruits per plant was observed in BT 118-4-1-1 (0.65). Among the hybrids, Sakthi x Nidhi (0.91) and Anagha x TH 977 (0.91) recorded the highest sca effects.

Average fruit weight

The genotypes Sakthi (6.83) and BT 118-4-1-1 (5.50) showed highly significant positive gca effects for average fruit weight. Significant negative gca effects were observed in Sun 7611 (-5.13), Anagha (-4.39) and Mukthi (-2.44). The hybrids Mukthi x TH 977 (4.62), Sakthi x Sun 7611 (2.78) and Anagha x Sun 7611 (2.76) expressed significant positive sca effects.

Crop duration

Significant positive gca effects for crop duration were observed in Anagha (5.62), TH 977 (5.33) and Sakthi (3.12). The genotypes Mukthi (-8.75) and Nidhi (-6.83) showed significant negative gca effects. The hybrid Mukthi x Sun 7611 (6.58) showed significant positive sca effects.

Locules per fruit

Maximum positive gca effect for locules per fruit was observed in Sakthi (0.10). The hybrids Sakthi x Nidhi (0.40) and Anagha x TH 977 (0.30) showed highly significant positive sca effects while Anagha x Nidhi (-0.45) and Sakthi x TH 977 (-0.35) showed highly significant negative sca effects.

Fruit flesh thickness

The genotypes Anagha (0.62), Nidhi (0.34) and Sakthi (0.15) showed significant positive gca effects for fruit flesh thickness. Significant positive sca effects were expressed by Mukthi x Sun 7611 (0.60) and Anagha x BT 118-4-1-1 (0.33).

TSS

Nidhi (0.15) and Sakthi (0.09) showed significant positive gca effects. Significant positive sca effects were observed in Mukthi x Sun 7611 (0.30), Sakthi x BT 118-4-1-1 (0.27) and Anagha x BT 118-4-1-1 (0.18).

4.3.2 Heterosis

The mean performance of lines, testers and F_1 hybrids for different characters is given in Table 6, 7, 8, 9, 10 and 11.

Plant height

The estimate of heterobeltiosis and relative heterosis ranged from 4.71 to 66.62 per cent and 10.21 to 60.63 per cent respectively. The highest positive heterosis was shown by Sakthi x Nidhi (66.62%) followed by Sakthi x TH 977 (43.19%). Maximum negative heterosis was shown by Sakthi x BT 118-4-1-1 (-4.71%). Sakthi x BT 118-4-1-1 (62.65 cm) was the dwarfest hybrid and Sakthi x Nidhi (109.55 cm) was the tallest hybrid.

Days to flowering

The heterobeltiosis and relative heterosis for days to flowering ranged from -26.18 per cent to 2.55 per cent and -26.58 per cent to -0.35 per cent

Table 6. Mean performance of lines, testers and F_1 hybrids for plant height and days to flowering

Parents/F_1 hybrids	Plant height			Days to flowering		
	Mean (cm)	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	65.75			50.80		
Mukthi	69.30			49.00		
Anagha	74.55			51.65		
BT 118-4-1-1	73.80			51.35		
Sun 7611	71.40			51.85		
TH 977	89.00			50.50		
Nidhi	70.65			50.90		
F_1 hybrids						
Sakthi x BT 118-4-1-1	62.65	-4.71	-10.21	37.50	-26.18**	-26.58**
Sakthi x Sun 7611	78.30	19.09	14.18	50.65	-0.30	-1.32
Sakthi x TH 977	94.15	43.19	21.68*	43.65	-13.56*	-13.82**
Sakthi x Nidhi	109.55	66.62**	60.63**	48.65	-4.23	-4.33
Mukthi x BT 118-4-1-1	90.15	30.09	26.00*	43.30	-11.63**	-13.70**
Mukthi x Sun 7611	72.25	4.26	2.70	50.25	2.55	-0.35
Mukthi x TH 977	75.50	8.95**	-4.61	49.50	1.02	-0.50
Mukthi x Nidhi	76.90	10.97	9.90	49.75	1.53	-0.40
Anagha x BT 118-4-1-1	90.00	21.95	21.33**	39.15	-23.76**	-23.98**
Anagha x Sun 7611	77.15	8.05	5.72	48.25	-6.58	-6.76
Anagha x TH 977	86.55	16.10	5.85	38.90	-22.97**	-23.84**
Anagha x Nidhi	85.40	20.88	17.63	39.25	-22.89**	-23.45**

HB - Heterobeltiosis
RH - Relative Heterosis

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

Table 7. Mean performance of lines, testers and F_1 hybrids for Days to fruit set and Days to first harvest

Parents/F_1 hybrids	Days to fruit set			Days to first harvest		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	71.25			86.60		
Mukthi	67.75			83.65		
Anagha	70.25			85.75		
BT 118-4-1-1	72.75			88.50		
Sun 7611	73.00			85.50		
TH 977	70.65			86.00		
Nidhi	68.50			83.25		
F_1 hybrids						
Sakthi x BT 118-4-1-1	70.50	-1.05	-2.08	86.75	0.17	-0.91
Sakthi x Sun 7611	76.15	6.88	5.58	85.35	-0.18	-0.81
Sakthi x TH 977	67.00	-5.17	-5.57	85.15	-9.99	-1.33
Sakthi x Nidhi	69.25	1.09	-0.89	84.00	0.90	-1.09
Mukthi x BT 118-4-1-1	69.15	2.07	-1.57	84.40	0.90*	-1.95
Mukthi x Sun 7611	71.65	5.76	1.81	84.00	0.42	-0.68
Mukthi x TH 977	78.65	16.09**	13.66**	90.35	8.01*	6.51**
Mukthi x Nidhi	67.90	0.22	-0.33	88.50	6.31*	6.05**
Anagha x BT 118-4-1-1	66.25	-5.69*	-7.34*	84.85	-1.05	-2.61
Anagha x Sun 7611	67.60	-3.77*	-5.62	83.60	-2.22	-2.36
Anagha x TH 977	62.25	-11.39**	-11.64**	81.75	-4.66*	-4.80*
Anagha x Nidhi	71.40	4.23	2.92	86.15	3.48	1.95

HB - Heterobeltiosis * Significant at 5% level
RH - Relative Heterosis ** Significant at 1% level

Table 8. Mean performance of lines, testers and F_1 hybrids for fruit yield per plant and fruits per plant

Parents/F_1 hybrids	Fruit yield per plant			Fruits per plant		
	Mean (g)	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	238.35			10.40		
Mukthi	204.60			7.90		
Anagha	330.00			13.25		
BT 118-4-1-1	210.00			8.00		
Sun 7611	207.90			7.65		
TH 977	172.50			4.85		
Nidhi	257.50			6.75		
F_1 hybrids						
Sakthi x BT 118-4-1-1	422.50	101.19**	88.47**	12.00	50.00	30.43*
Sakthi x Sun 7611	247.50	19.05	10.92	9.85	28.76	9.14
Sakthi x TH 977	333.35	93.25**	62.27**	10.00	106.19	31.15*
Sakthi x Nidhi	199.15	-16.45*	-19.67*	11.90	76.30	38.78**
Mukthi x BT 118-4-1-1	322.10	57.43**	55.38**	12.10	53.16**	52.20**
Mukthi x Sun 7611	205.80	0.59	-0.22	11.15	45.75**	43.41**
Mukthi x TH 977	207.50	20.29	10.05	11.25	131.56*	76.47**
Mukthi x Nidhi	339.60	65.98**	46.98**	10.10	49.63	37.88
Anagha x BT 118-4-1-1	275.00	30.95*	1.85	11.35	41.88	6.82
Anagha x Sun 7611	273.75	31.67*	1.78	10.25	33.99**	-1.91
Anagha x TH 977	302.90	75.59	20.56*	12.35	154.64	36.46**
Anagha x Nidhi	240.00	-6.80**	-18.30**	11.65	72.59	16.50

HB - Heterobeltiosis
RH - Relative Heterosis

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

Table 9. Mean performance of lines, testers and F_1 hybrids for Average fruit weight and crop duration

Parents/F_1 hybrids	Average fruit weight			Crop duration		
	Mean (g)	HB (%)	RH (%)	Mean (days)	HB (%)	RH (%)
Parents						
Sakthi	39.25			106.50		
Mukthi	34.15			105.00		
Anagha	36.15			105.00		
BT 118-4-1-1	41.00			111.00		
Sun 7611	42.90			132.50		
TH 977	40.15			104.00		
Nidhi	48.30			108.00		
F_1 hybrids						
Sakthi x BT 118-4-1-1	53.15	35.41**	32.46**	122.50	15.02*	12.64**
Sakthi x Sun 7611	44.65	13.76	8.70	125.00	17.37	4.60**
Sakthi x TH 977	43.40	10.57	9.32	134.00	28.85**	27.32**
Sakthi x Nidhi	46.80	19.24	6.91	119.00	11.74*	10.96**
Mukthi x BT 118-4-1-1	43.80	28.26	16.57**	115.00	9.52	6.48
Mukthi x Sun 7611	27.05	-20.79**	-29.79**	120.00	14.29**	1.05
Mukthi x TH 977	40.30	18.01	8.48	114.00	9.62*	9.09*
Mukthi x Nidhi	39.75	16.40**	-3.58	104.00	-0.95	-2.35
Anagha x BT 118-4-1-1	40.05	01.79	3.82	132.50	26.19**	22.69**
Anagha x Sun 7611	33.40	-7.61**	-15.50*	121.50	15.71*	2.32
Anagha x TH 977	30.65	-15.21**	-19.66**	134.00	28.85**	28.23**
Anagha x Nidhi	39.00	7.88**	-7.64	122.50	13.43**	15.02**

HB - Heterobeltiosis
RH - Relative Heterosis

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

Table 10. Mean performance of lines, testers and F_1 hybrids for Locules per fruit and fruit flesh thickness

Parents/F_1 hybrids	Locules per fruit			Fruit flesh thickness		
	Mean	HB (%)	RH (%)	Mean (mm)	HB (%)	RH (%)
Parents						
Sakthi	3.15			3.95		
Mukthi	2.90			3.90		
Anagha	3.15			3.75		
BT 118-4-1-1	3.00			4.25		
Sun 7611	3.15			3.55		
TH 977	3.25			3.95		
Nidhi	3.00			4.60		
F_1 hybrids						
Sakthi x BT 118-4-1-1	3.25	8.33	5.69	4.70	18.99	14.63
Sakthi x Sun 7611	3.15	0.00	0.00	3.45	-2.82	-8.00
Sakthi x TH 977	3.00	-4.76	-6.25	4.65	17.72*	17.72**
Sakthi x Nidhi	3.65	21.67	18.70	4.95	25.32	15.79*
Mukthi x BT 118-4-1-1	2.90	0.00	-1.69	3.25	-16.67	-20.25**
Mukthi x Sun 7611	3.15	8.62	4.13	3.60	1.41	-3.36
Mukthi x TH 977	3.25	12.07	5.69	3.65	-6.41	-7.01
Mukthi x Nidhi	3.15	8.62	6.78	3.60	-7.69**	-15.29**
Anagha x BT 118-4-1-1	3.00	-4.76	-2.44	5.40	44.00**	35.00**
Anagha x Sun 7611	3.30	4.76	4.76	4.25	19.72	16.44*
Anagha x TH 977	3.50	11.11	9.37	4.65	24.00*	20.78**
Anagha x Nidhi	2.65	-11.67	-13.82	5.35	42.67*	28.14**

HB - Heterobeltiosis
RH - Relative Heterosis

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

Table11. Mean performance of lines, testers and F_1 hybrids for TSS

Partens/F_1 hybrids	TSS		
	Mean (°Brix)	HB (%)	RH (%)
Parents			
Sakthi	4.00		
Mukthi	4.15		
Anagha	4.10		
BT 118-4-1-1	3.85		
Sun 7611	4.10		
TH 977	4.05		
Nidhi	4.00		
F_1 hybrids			
Sakthi x BT 118-4-1-1	4.15	7.79	5.73
Sakthi x Sun 7611	3.90	-2.50	-3.70
Sakthi x TH 977	3.80	-5.00	-5.59
Sakthi x Nidhi	4.00	0.00	0.00
Mukthi x BT 118-4-1-1	3.25	-15.58**	-18.75*
Mukthi x Sun 7611	4.05	-1.22	-1.82
Mukthi x TH 977	3.85	-4.94	-6.10
Mukthi x Nidhi	4.00	0.00	-1.84
Anagha 415 x BT 118-4-1-1	3.95	2.60	-0.63
Anagha x Sun 7611	3.55	-13.41**	-13.41**
Anagha x TH 977	3.90	-3.70	-4.29
Anagha x Nidhi	4.05	1.25	0.00

HB - Heterobeltiosis * Significant at 5% level
RH - Relative Heterosis ** Significant at 1% level

respectively. Among the F_1 hybrids, Sakthi x BT 118-4-1-1 (37.5 days) was the earliest to flower, followed by Anagha x TH 977 (38.9 days), Anagha x BT 118-4-1-1 (39.15 days) and Anagha x Nidhi (39.25 days). Heterobeltiosis for Sakthi x BT 118-4-1-1 was -26.18 per cent and relative heterosis was -26.58 per cent.

Days to fruit set

The estimate of heterobeltiosis and relative heterosis for days to fruit set ranged from -5.69 per cent to 16.09 per cent and -11.64 per cent to 13.66 per cent respectively. Earliest fruit set was observed in Anagha x TH 977 (62.25 days), followed by Anagha x BT 118-4-1-1 (66.25 days). Heterobeltiosis for the hybrid Anagha x TH 977 was -11.39 per cent and relative heterosis was -11.64 per cent.

Days to first harvest

Anagha x TH 977 (81.75 days) was the earliest to harvest among the hybrids and parents tested. This hybrid had a heterobeltiosis of -4.66 per cent and a relative heterosis of -4.80 per cent. Mukthi x TH 977 took the maximum days to harvest (90.35 days).

Fruit yield per plant

Highest fruit yield was given by Sakthi x BT 118-4-1-1 (422.5 g $plant^{-1}$) while the lowest yield was from Sakthi x Nidhi (199.15 g $plant^{-1}$). The hybrid Sakthi x BT 118-4-1-1 had a heterobeltiosis of 101.19 per cent and a relative heterosis of 88.47 per cent.

Fruits per plant

Maximum number of fruits were produced by the hybrid Anagha x TH 977 (12.35 fruits). Heterobeltiosis was 155.64 per cent and relative heterosis was 36.46 per cent, for this hybrid.

Average fruit weight

The maximum sized fruits were produced by Sakthi x BT 118-4-1-1 (53.15 g) followed by Sakthi x Nidhi (46.8 g). The heterobeltiosis and relative

heterosis for Sakthi x BT 118-4-1-1 was 35.41 per cent and 32.46 per cent respectively. Sakthi x Nidhi had a heterobeltiosis of 19.24 per cent and relative heterosis of 6.91 per cent. The minimum sized fruits were produced by the hybrid Mukthi x Sun 7611 (27.05 g).

Crop duration

The heterobeltiosis and relative heterosis for crop duration ranged from 0.95 per cent to 28.85 per cent and 2.35 per cent to 28.23 per cent respectively. Among the F_1 hybrids, longest duration was for Sakthi x TH 977 and Anagha x TH 977 (134 days). The shortest duration was for Mukthi x Nidhi (104 days).

Locules per fruit

The estimate of heterobeltiosis and relative heterosis for locules per fruit ranged from 11.67 per cent to 21.67 per cent and 13.82 per cent to 18.7 per cent respectively. The maximum number of locules per fruit was recorded for the hybrid Sakthi x Nidhi (3.65). This hybrid had a heterobeltiosis of 21.67 per cent and a relative heterosis of 18.7 per cent.

Fruit flesh thickness

The heterobeltiosis and relative heterosis ranged from 16.67 per cent to 42.67 per cent and 20.25 per cent to 35 per cent respectively. Maximum fruit flesh thickness was recorded in Anagha x BT 118-4-1-1 (5.40 mm). This hybrid had a heterobeltiosis of 44 per cent and a relative heterosis of 35 per cent. This was followed by the hybrid Anagha x Nidhi (5.35 mm). Minimum fruit flesh thickness was observed in the hybrid Mukthi x BT 118-4-1-1 (3.25 mm).

TSS

Among the hybrids, Sakthi x BT 118-4-1-1 had the maximum TSS (4.15°Brix). This hybrid had a heterobeltiosis and relative heterosis of 7.79 per cent and 5.73 per cent respectively. The lowest TSS was recorded in the hybrid Mukthi x BT 18-4-1-1 (3.25°Brix).

4.4 EVALUATION OF F_2 POPULATION FOR RESISTANCE TO BACTERIAL WILT AND INDETERMINATE CHARACTERISTICS

The F_2 population of the twelve crosses were raised in a wilt sick field to evaluate for bacterial wilt resistance and indeterminate growth habit. The performance of indeterminate F_2 progenies resistant to bacterial wilt is given in Table 12.

Among the F_2 progenies, Anagha x Sun 7611 F_2 - 16 was the tallest. Anagha x TH 977 F_2 - 5, Sakthi x Nidhi F_2 - 19 and Sakthi x TH 977 F_2 - 9 were the earliest to flower. Anagha x BT 118-4-1-1 F_2 - 13, Anagha x BT 118-4-1-1 F_2 - 14, Anagha x Sun 7611 F_2 - 7, Mukthi x Nidhi F_2 - 13, and Mukthi x Nidhi F_{12} - 16 were the earliest to harvest. Maximum fruits per plant was observed in Anagha x BT 118-4-1-1 F_2 - 12. Maximum fruit yield per plant was observed in Mukthi x BT 118-4-1-1 F_2 - 8 (1.35 kg plant^{-1}) (Plate 3a), Sakthi x Nidhi F_2 - 7 (1.3 kg plant^{-1}) and Anagha x Nidhi F_2 - 3 (1.275 kg plant^{-1}). Average fruit weight was maximum in Anagha x Nidhi F_2 - 3 (65 g) (Plate 3b). Sakthi x Nidhi F_2 - 7 (145 days) showed highest crop duration.

Table 12. Performance of indeterminate F_2 progenies resistant to bacterial wilt

Sl. No.	Genotype	Growth habit	Plant height (cm)	Days to flower-ing	Days to fruit set	Days to first harvest	Fruits per plant	Fruit yield per plant (g)	Average fruit weight (g)	Crop durat-ion (days)	Fruit shape index	Locules per fruit	Fruit flesh thick-ness (mm)	TSS (°Brix)
1	Anagha x BT 118-4-1-1 F_2 - 11	I	64.0	52	69	117	26	820	31.5	137	0.94	5	4.0	3.8
2	Anagha x BT 118-4-1-1 F_2 - 12	I	68.5	52	70	112	34	1020	30.0	125	0.98	4	6.0	4.0
3	Anagha x BT 118-4-1-1 F_2 - 13	I	62.0	54	69	108	17	528	31.0	129	0.83	3	5.0	3.2
4	Anagha x BT 118-4-1-1 F_2 - 14	I	71.5	52	72	108	25	812	32.5	126	0.98	4	5.0	3.8
5	Anagha x BT 118-4-1-1 F_2 - 17	I	73.0	52	70	112	32	1024	32.0	126	0.91	4	4.0	4.2
6	Anagha x TH 977 F_2 - 5	I	72.0	50	72	115	20	640	32.0	138	0.98	5	5.0	4.2
7	Anagha x TH 977 F_2 - 7	I	84.0	54	72	117	28	880	31.5	138	0.89	5	4.0	4.2
8	Anagha x TH 977 F_2 - 14	I	78.5	54	72	115	31	960	31.0	130	0.94	3	4.0	3.8
9	Anagha x TH 977 F_2 - 17	I	68.5	54	72	117	26	835	32.0	136	1.03	4	5.0	4.2
10	Anagha x Nidhi F_2 - 3	I	73.5	55	72	117	20	1275	65.0	135	0.85	4	5.0	3.8
11	Anagha x Nidhi F_2 - 6	I	80.5	54	68	112	26	835	32.0	130	0.81	5	6.0	3.2
12	Anagha x Nidhi F_2 - 4	I	77.0	52	70	123	24	732	30.5	140	0.91	5	4.0	4.2
13	Anagha x Nidhi F_2 - 18	I	72.0	54	70	112	32	1000	31.5	128	0.81	5	4.0	4.2
14	Anagha x Sun 7611 F_2 - 7	I	74.0	62	72	108	21	650	31.0	130	0.88	4	6.0	3.8
15	Anagha x Sun 7611 F_2 - 8	I	68.5	52	72	117	22	715	32.5	135	1.02	2	5.0	4.0

Contd.

Table 12. Continued

Sl. No.	Genotype	Growth habit	Plant height (cm)	Days to flower-ing	Days to fruit set	Days to first harvest	Fruits per plant	Fruit yield per plant (g)	Average fruit weight (g)	Crop durat-ion (days)	Fruit shape index	Locules per fruit	Fruit flesh thick-ness (mm)	TSS (°Brix)
16	Anagha x Sun 7611 F_2 - 16	I	89.0	65	79	112	23	725	31.5	132	0.95	4	6.0	3.8
17	Anagha x Sun 7611 F_2 - 17	I	70.0	54	68	120	22	670	30.5	140	1.13	4	5.0	4.2
18	Anagha x Sun 7611 F_2 - 18	I	84.0	62	80	128	21	1050	50.0	142	1.01	2	5.0	3.8
19	Anagha x Nidhi F_2 - 24	I	72.5	52	70	120	32	1000	31.5	135	0.89	3	5.0	4.0
20	Sakthi x BT 118-4-1-1 F_2 - 18	I	78.5	62	78	120	28	938	33.5	138	0.92	5	4.0	4.2
21	Mukthi x Nidhi F_2 - 7	I	78.0	62	78	120	20	1000	50.0	140	1.1	2	6.0	3.8
22	Mukthi x Nidhi F_2 - 9	I	72.5	62	70	115	28	924	33.0	135	0.85	4	6.0	4.2
23	Mukthi x Nidhi F_2 - 13	I	80.0	52.0	68	108	27	810	30.0	126	1.1	4	5.0	4.0
24	Mukthi x Nidhi F_2 - 16	I	68.5	52	68	108	27	875	32.5	128	0.84	2	5.0	4.0
25	Mukthi x Nidhi F_2 - 18	I	74.0	54	69	112	23	724	31.5	132	1.02	4	4.0	4.0
26	Mukthi x Nidhi F_2 - 19	I	71.5	60	72	125	22	605	27.5	140	0.88	4	5.0	4.0
27	Mukthi x Nidhi F_2 - 20	I	77.0	62	72	125	27	756	28.0	140	1.0	5	5.0	4.0
28	Sakthi x Nidhi F_2 - 2	I	80.5	54	68	128	27	1200	45.0	142	0.9	4	5.0	4.2
29	Sakthi x Nidhi F_2 - 7	I	74.5	62	72	128	26	1300	50.0	145	0.95	4	6.0	3.2
30	Sakthi x Nidhi F_2 - 10	I	76.5	62	72	117	22	627	28.5	132	1.12	4	5.0	4.0

Contd.

Table 12. Continued

Sl. No.	Genotype	Growth habit	Plant height (cm)	Days to flower-ing	Days to fruit set	Days to first harvest	Fruits per plant	Fruit yield per plant (g)	Average fruit weight (g)	Crop durat-ion (days)	Fruit shape index	Locules per fruit	Fruit flesh thick-ness (mm)	TSS (°Brix)
31	Sakthi x Nidhi F_2 - 17	I	68.5	52	68	128	27	800	29.5	142	1.1	3	4.0	3.8
32	Sakthi x Nidhi F_2 - 18	I	62.5	62	72	125	31	945	30.5	140	1.1	2	5.0	4.2
33	Sakthi x Nidhi F_2 - 19	I	79.0	50	68	128	20	700	35.0	142	0.95	4	5.0	3.8
34	Sakthi x TH 977 F_2 - 9	I	78.5	50	68	117	12	410	34.0	132	0.89	3	6.0	4.0
35	Mukthi x BT 118-4-1-1 F_2 - 3	I	72.5	65	78	115	26	858	33.0	132	0.89	4	5.0	3.8
36	Mukthi x BT 118-4-1-1 F_2 - 8	I	77.0	62	72	112	31	1350	45.0	130	1.1	5	5.0	3.6
37	Mukthi x BT 118-4-1-1 F_2 - 10	I	74.5	60	70	117	26	820	31.5	135	1.02	5	4.0	4.2
38	Mukthi x BT 118-4-1-1 F_2 - 11	I	80.0	68	72	117	30	855	28.5	135	0.85	4	5.0	4.0
39	Mukthi x BT 118-4-1-1 F_2 - 14	I	71.0	54	69	112	21	690	33.0	125	1.02	5	5.0	4.0
40	Mukthi x BT 118-4-1-1 F_2 - 15	I	68.0	52	68	112	19	700	37.0	128	1.0	3	50	4.0
41	Mukthi x BT 118-4-1-1 F_2 - 16	I	82.5	60	70	112	20	610	30.5	125	0.95	3	6.0	4.0
42	Mukthi x Sun 7611 F_2 - 3	I	76.5	54	69	117	21	640	30.5	132	0.85	4	5.0	4.0

a) Mukthi x BT 118-4-1-1 F_2-8

b) Anagha x Nidhi F_2-3

Plate 3. Promising F_2 segregants

Discussion

5. DISCUSSION

Bacterial wilt caused by *Ralstonia solanacearum* Yabuuchi *et al.* is the main constraint for the tomato cultivation in Kerala. The acidic soil conditions and warm humid tropical climate favour the incidence of this disease in the state. Attempts on disease management and control have not made substantial impact necessitating the development of resistant varieties to this pathogen. Resistance breeding taken up in Kerala Agricultural University, Vellanikkara has resulted in the development and release of resistant varieties like Sakthi, Mukthi and Anagha. All these genotypes are determinate or semi determinate and their yield level ranges from 30 - 35.5 t ha^{-1}.

Indeterminate tomatoes give higher yield over a period of time. The indeterminate types are very much suited to the homesteads of Kerala. As the indeterminate types available in the country are susceptible to bacterial wilt, we cannot grow them in Kerala.

Studies on genetics of bacterial wilt resistance by Sadhankumar (1995) and Kurian and Peter (2001) have shown that the genes for resistance to bacterial wilt in tomato are recessive in nature. Even though Tikoo (1987) has reported dominant sources of resistance to bacterial wilt, the source itself is susceptible to bacterial wilt under Vellanikkara conditions (Sadhankumar, 1995). This may be due to the presence of two biovars (biovar III and biovar V) infecting tomato under Kerala conditions (Mathew *et al.*, 2000). Hence the present study was taken up with a view to generate information on combining ability of selected parents in tomato, heterosis in bacterial wilt resistant lines and to develop bacterial wilt resistant indeterminate types in tomato. The major findings are discussed here under.

5.1 EVALUATION OF F_1 HYBRIDS AND PARENTS FOR BACTERIAL WILT RESISTANCE AND INDETERMINATE CHARACTERS

5.1.1 Evaluation for bacterial wilt resistance

In the present study, all the F_1 hybrids and male parents were susceptible to bacterial wilt. The female parents viz. Sakthi, Mukthi and Anagha were resistant to bacterial wilt. The resistance to bacterial wilt in Sakthi, Mukthi

and Anagha have already been reported by many workers (Kurian and Peter, 1995; Sadhankumar, 1995; Rajan and Sadhankumar, 1998, and Rani, 2000). The F_1 hybrids were susceptible to bacterial wilt as the sources of resistance used in the present study were recessive in nature. While transferring the wilt resistant genes into processing tomatoes. Kurian and Peter (2001) and Devi *et al.* (2002) also got F_1 hybrids which were susceptible to bacterial wilt. Sadhankumar (1995) also got susceptible F_1 hybrids while transferring bacterial wilt resistance to fruit crack resistant genotypes in tomato.

5.1.2 Evaluation for indeterminate character

The bacterial wilt resistant genotypes used in the study viz. Sakthi, Mukthi and Anagha were determinate or semideterminate. All the male parents viz. BT 118-4-1-1, Sun 7611, TH 977 and Nidhi were indeterminate. All the F_1 hybrids except Sakthi x BT 118-4-1-1 were indeterminate in character.

5.2 LINE x TESTER ANALYSIS FOR YIELD ATTRIBUTES

5.2.1 Combining ability

Plant height

Highly significant positive gca effect in Nidhi (7.40) shows that Nidhi is a good general combiner for increased plant height. Highly significant negative gca effects in Sun 7611 (-7.31) and Mukthi (-4.51) indicates that these genotypes can be used as good general combiners for dwarfness. Rani (2000) reported negative gca effect in Mukthi for plant height. Sakthi x Nidhi (109.55) was the tallest among the hybrids (Table 13). It's parents had a height of 65.75 cm (Sakthi) and 70.65 cm (Nidhi).

Days to flowering

BT 118-4-1-1 (-4.92) and Anagha (-3.51) had maximum significant negative gca effect for days to flowering. So they can be used as a good general combiners for early flowering. Highly significant negative sca effect was observed in Anagha x Nidhi (-3.12). This was in confirmation with the study of Rani (2000) who also observed Anagha as a good general combiner for early flowering.

Table 13. Performance of promising F1 hybrids

Characters	Hybrids	sca effect	*per se* performance	Heterobeltiosis(%)	Relative heteroisis(%)
Plant height(cm)	Sakthi x Nidhi	15.98	109.55	66.62	60.63
	Mukthi x BT 118-4-1-1	13.73	90.15	30.09	26.0
	Sakthi x BT 118-4-1-1	-21.23	62.65	-4.71	-10.21
	Mukthi x Nidhi	-9.20	76.90	10.97	9.9
Days to flowering	Anagha x Nidhi	-3.12	39.25	-22.89	-23.45
Days to fruitset	Mukthi x TH 977	7.33	78.65	16.09	13.66
	Anagha x Nidhi	4.82	71.4	4.23	2.92
	Sakthi x Sun 7611	3.44	76.15	6.88	5.58
	Anagha x TH 977	-4.11	62.25	-11.39	-11.64
	Mukthi x Nidhi	-3.64	67.9	0.22	-0.33
	Sakthi x TH 977	-3.21	67.0	-5.17	-5.57
	Mukthi x Sun 7611	-2.17	71.65	5.76	1.81
Days to first harvest	Mukthi x TH 977	3.19	90.35	8.01	6.51
	Sakthi x BT 118-4-1-1	1.51	86.75	0.17	-0.91
	Anagha x TH 977	-2.68	81.75	-4.66	-4.8
	Mukthi x BT 118-4-1-1	-2.34	84.4	0.9	-1.95
	Sakthi x Nidhi	-2.12	84.0	0.9	-1.09
Fruit yield per plant (g)	Mukthi x Nidhi	92.03	339.6	65.98	46.98
	Sakthi x BT 118-4-1-1	62.77	422.5	101.19	88.47
	Anagha x Sun 7611	39.25	273.75	31.67	1.78
	Sakthi x TH 977	32.24	333.35	93.25	62.27
Average fruit weight (g)	Mukthi x TH 977	4.62	40.30	18.01	8.48
	Sakthi x Sun 7611	2.78	44.65	13.76	8.70
	Anagha x Sun 7611	2.76	33.40	-7.61	-15.50
Crop duration (days)	Mukthi x Sun 7611	6.58	120.00	14.29	1.05
	Anagha x Sun 7611	-6.29	121.50	15.71	2.32
	Mukthi x TH 977	-4.58	114.00	9.62	9.09
Locules per fruit	Sakthi x Mukthi	0.40	3.65	21.67	18.70
	Anagha x TH 977	0.30	3.50	11.11	9.37
	Anagha x Nidhi	-0.45	2.65	-11.67	-13.82
	Sakthi x TH 977	-0.35	3.00	-4.76	-6.25
Fruit flesh thickness (mm)	Mukthi x Sun 7611	0.60	3.6	1.41	-3.36
	Anagha x BT 118-4-1-1	0.33	5.4	44.00	35.00
	Sakthi x Sun 7611	-0.46	3.45	-2.62	-8.00
	Mukthi x BT 118-4-1-1	-0.43	3.25	-16.67	-20.25
TSS	Mukthi x Sun 7611	0.30	4.05	-1.22	-1.82
	Sakthi x BT 118-4-1-1	0.27	4.15	7.79	5.73
	Mukthi x BT 118-4-1-1	-0.45	3.25	-15.58	-18.75

Days to fruitset

Anagha (-2.94) had maximum significant negative gca effect for days to fruitset. So this variety can be used as a good general combiner for early fruitset. Maximum negative significant sca effect was observed in Anagha x TH 977 (-4.11). Both these parents had negative gca effect for this character. Similar to this study Rani (2000) has already reported that Anagha is a good general combiner for earliness.

Days to harvest

Anagha (-1.32) showed maximum significant negative gca effect for days to harvest. So this variety can be used as a good general combiner for early harvest. Highly significant negative sca effect was observed in Anagha x TH 977 (-2.68), followed by Mukthi x BT 118-4-1-1 (-2.34). Anagha as a good general combiner for days to harvest has been reported earlier by Rani (2000).

Fruit yield per plant

Maximum positive significant gca effect for fruit yield per plant was observed in BT 118-4-1-1 (59.10) and Sakthi (19.86). So there can be used as good general combiners for getting higher yields. Maximum positive significant sca effects were observed in Mukthi x Nidhi (92.03), Sakthi x BT 118-4-1-1 (62.77), Anagha x Sun 7611 (39.25), Sakthi x TH 977 (32.24) and Anagha x TH 977 (29.5). Sakthi as a good general combiner for fruit yield per plant has been reported earlier by Kurian (1990). This fact is further evidenced by the high sca effects shown by the crosses Sakthi x BT 118-4-1-1 and Sakthi x TH 977. Maximum positive sca effect was seen in Mukthi x Nidhi. This is also convinced by the per se performance of these hybrids.

Fruits per plant

BT 118-4-1-1 (0.65) and Anagha (0.24) with high positive gca effects were good general combiners for increased fruits per plant. Sakthi x Nidhi (0.91), Anagha x TH 977 (0.91), Mukthi x Sun 7611 (0.45), Sakthi x BT 118-4-1-1 (0.41) and Mukthi x BT 118-4-1-1 (0.30) had maximum positive sca effects. These

hybrids ranked top in per se performance also. High x low gca effects of parents give rise to high sca effects in hybrids. Similar results have already been reported by Rani (2000).

Average fruit weight

One draw back with respect to bacterial wilt resistant varieties is that their fruit size is very low. So this factor is of prime importance in breeding programs involving bacterial wilt resistance. Sakthi (6.83) and BT 118-4-1-1 (5.5) were found to be good general combiners for fruit size as evidenced by the high gca effects for this characters in these genotypes. The cross Mukthi x TH 977 (4.62) is a combination of medium x medium gca combiners which has resulted in maximum positive sca effect for average fruit weight. This suggests a non-additive gene action of complementary nature. Rani (2000) also got hybrids with high sca effects while crossing genotypes with medium gca effect, and thus confirming the present findings.

Crop duration

Anagha (5.62) and TH 977 (5.33) had maximum positive gca effect for increased crop duration. So these can be used as good general combiners for increased duration. Mukthi x Sun 7611 (6.58) showed maximum positive significant sca effects for this character.

Locules per fruit

Sakthi (0.10) was a good general combiner for increased locules per fruit. Among the hybrids, Anagha x TH 977 (0.30) and Sakthi x Nidhi (0.40) had maximum positive significant sca effects for locule number.

Fruit flesh thickness

Anagha (0.62) and Nidhi (0.34) were good general combiners for fruit flesh thickness. The crosses involving Nidhi also showed positive sca effects for this character. Mukthi x Sun 7611 (0.60) showed significantly high positive sca effects.

TSS

The genotypes Sakthi (0.09) was a good general combiner for TSS. Among the hybrids, Mukthi x Sun 7611 (0.30) showed highly significant positive sca effects.

5.2.2 Heterosis

The relative heterosis and heterobeltiosis for eleven characters including yield were estimated. The number of heterotic hybrids for each character was recorded.

Plant height

Sakthi x Nidhi was the tallest among the hybrids (109.55 cm). It was taller than it's parents. It was followed by Sakthi x TH 977 (94.15 cm). There were 4 relatively heterotic and 2 heterobeltiotic hybrids, for increased plant height.

Days to flowering

Sakthi x BT 118-4-1-1 was the earliest to flower (37.5 days). It was closely followed by Anagha x TH 977, Anagha x BT 118-4-1-1 and Anagha x Nidhi. There were 6 relatively heterotic and heterobeltiotic hybrids for days to flowering.

Days to fruitset

Anagha x TH 977 (62.25 days) was the earliest hybrid for fruitset, followed by Anagha x BT 118-4-1-1. There were 3 relatively heterotic hybrids for this character.

Days to first harvest

Anagha x TH 977 (81.75 days) was the earliest to harvest, followed by Anagha x Sun 7611. There were 3 relatively heterotic and 4 heterobeltiotic hybrids.

Fruit yield per plant

For fruit yield per plant, heterosis was significant and positive for Sakthi x BT 118-4-1-1. This is due to high and significant gca effects of parental lines Sakthi and BT 118-4-1-1 for this character.This hybrid had highly significant positive sca effect also. Several workers like Sidhu and Surjansingh (1993), Dev *et al.* (1994), Dod *et al.* (1995), Sadhankumar (1995), Vidyasagar *et al.* (1997), Chaurasia and Kalloo (1998) and Rani (2000) had reported significant heterosis in several parental combinations for fruit yield per plant in tomato. There were 7 relatively heterotic and 8 heterobeltiotic hybrids for this character.

Fruits per plant

Maximum significant relative heterosis (76.47%) was recorded in Mukthi x TH 977. The maximum and significant heterobeltiosis was recorded in Mukthi x BT 118-4-1-1 (53.16%). The *per se* performance of this hybrid was also good. Sidhu and Surjansingh (1993), Dev *et al.* (1994), Dod *et al.* (1995), Hegazi *et al.* (1995), Sadhankumar *et al.* (1995), Vidyasagar *et al.* (1997), Chaurasia and Kalloo (1998) and Rani (2000) had reported significant heterosis in several parental combinations for fruits per plant in tomato. There were 8 relatively heterotic and 4 heterobeltiotic hybrids.

Average fruit weight

There were 5 relatively heterotic and 6 heterobeltiotic hybrids for increased fruit weight. Among the F_1 hybrids, Sakthi x BT 118-4-1-1 produced bigger sized fruits. The highest positive heterosis was observed in this combination. Significant positive heterosis for fruit weight in tomato has already been reported by several workers like Sidhu and Surjansingh (1993), Dev *at al.* (1994), Dod *et al.* (1995), Hegazi *et al.* (1995), Sadhankumar *et al.* (1995), Suresh *et al.* (1995), Vidyasagar *et al.* (1997), Chaurasia and Kalloo (1998), Dhaliwal *et al.* (1998) and Rani (2000).

Crop duration

There were 8 relatively heterotic and 9 heterobeltiotic hybrids for this character. Sakthi x TH 977 and Anagha x TH 977 (134 days) showed increased crop duration.

Locules per fruit

There were no relatively heterotic and heterobeltiotic hybrids for locules per fruit. Sakthi x Nidhi (3.65) was having the maximum number of locules per fruit.

Fruit flesh thickness

The hybrid Anagha x BT 118-4-1-1 (5.40 mm) recorded the maximum fruit flesh thickness. There were 8 relatively heterotic and 5 heterobeltiotic hybrids.

TSS

Maximum TSS was recorded by Sakthi x BT 118-4-1-1 (4.15°Brix). There were 2 relatively heterotic and heterobeltiotic hybrids.

5.3 EVALUATION OF F_2 POPULATION FOR RESISTANCE TO BACTERIAL WILT AND INDETERMINATE CHARACTER

The F_2 population were evaluated for bacterial wilt resistance and indeterminate character. The F_2 segregants of Anagha x BT 118-4-1-1, Anagha x Sun 7611, Anagha x TH 977, Anagha x Nidhi, Sakthi x BT 118-4-1-1, Sakthi x TH 977, Sakthi x Nidhi, Mukthi x BT 118-4-1-1, Mukthi x Sun 7611 and Mukthi x Nidhi were found to be indeterminate in growth habit and resistant to bacterial wilt.

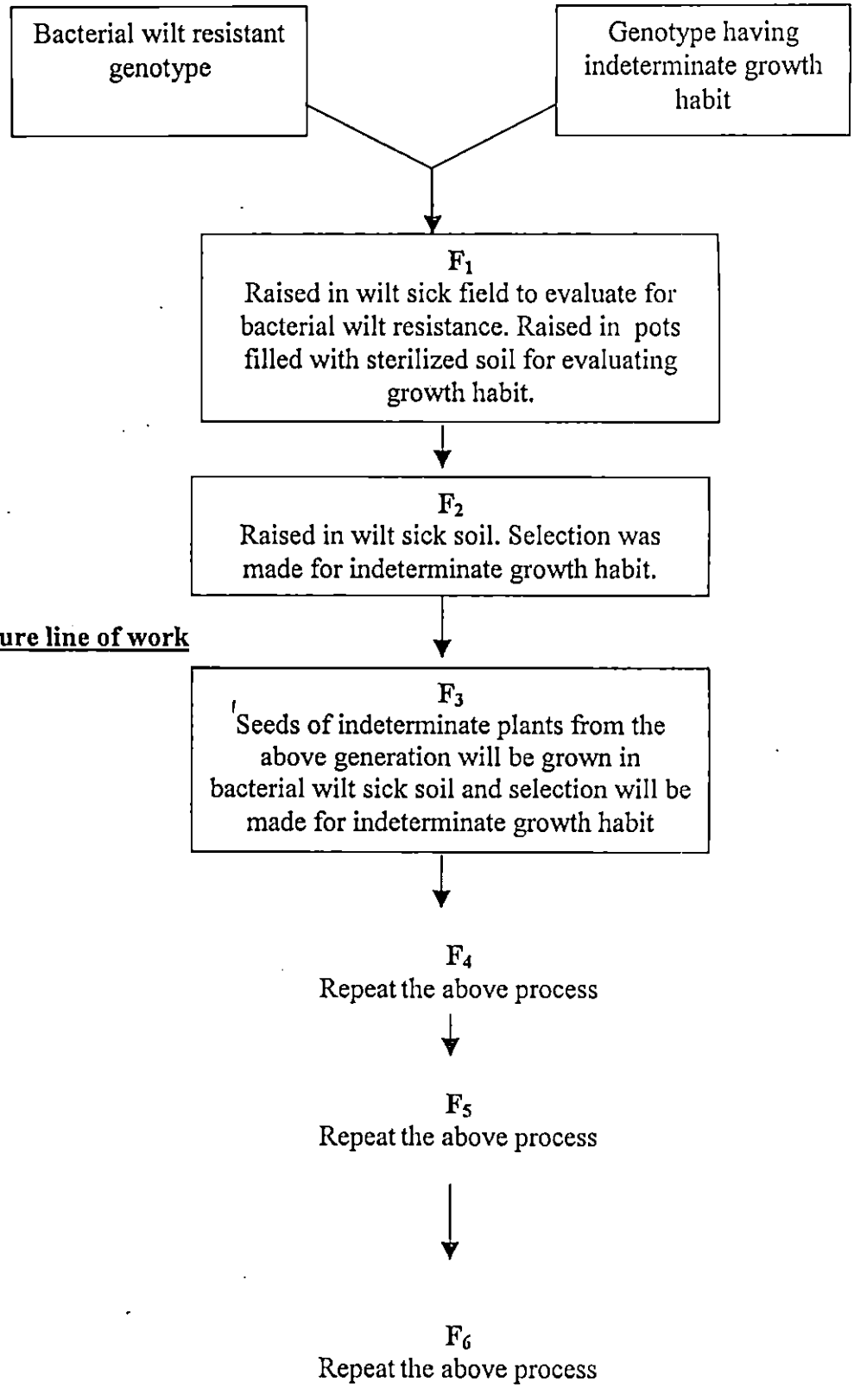
Among the F_2 population, 42 F_2 segregants were found to be having indeterminate growth habit and resistance to bacterial wilt. Among them, maximum yield was recorded by Mukthi x BT 118-4-1-1 F_2-8 (1.35 kg plant^{-1}), Sakthi x Nidhi F_2-7 (1.3 kg plant^{-1}) and Anagha x Nidhi F_2-3 (1.28 kg plant^{-1}). Maximum fruits per plant were observed in the F_2 segregants Anagha x BT 118-4-1-1 F_2-12 (34), Anagha x BT 118-4-1-1 F_2-17 (32), Anagha x Nidhi F_2-18 (32) and Anagha x Nidhi F_2-24 (32). Usually, bacterial wilt resistance is seen associated with small fruit size. So this character is of utmost economic importance. Among the segregants, maximum average fruit weight was recorded in Anagha x Nidhi

F_2-3 (65 g), Anagha x Sun 7611 F_2-18 (50 g), Mukthi x Nidhi F_2-7 (50 g) and Sakthi x Nidhi F_2-7 (50 g).

The earliness of a genotype can be evaluated from factors like days to flowering, fruit set and harvest. The F_2 progenies Anagha x TH 977 F_2-5 (50 days), Sakthi x Nidhi F_2-19 (50 days), Sakthi x TH 977 F_2-9 (50 days) were the earliest to flower and Anagha x BT 118-4-1-1 F_2-13, Anagha x BT 118-4-1-1 F_2-14, Anagha x Sun 7611 F_2-7, Mukthi x Nidhi F_2-13 and Mukthi x Nidhi F_2-16 were the earliest to harvest.

The F_2 progenies having indeterminate growth habit and resistance to bacterial wilt can be progressed to get indeterminate genotypes resistant to bacterial wilt coupled with high yield and good horticultural traits. The schematic representation of the breeding technology followed is given below.

Schematic representation of breeding technology followed



By F_6 generation, uniformity can be obtained.

Summary

6. SUMMARY

The investigation on "Incorporation of resistance to bacterial wilt in indeterminate tomatoes" was carried out during July 2002 - September, 2003 at the Department of Olericulture, College of Horticulture, Vellanikkara. The objectives of the study were development of indeterminate tomatoes resistant to bacterial wilt and estimation of general combining ability, specific combining ability and heterosis in these genotypes.

Three bacterial wilt resistant varieties (Sakthi, Mukthi and Anagha) were crossed with four indeterminate genotypes (BT 118-4-1-1, Sun 7611, TH 977 and Nidhi) in a line x tester fashion to produce twelve F_1 hybrids. These F_1 hybrids along with the parents were grown in a bacterial wilt sick field to evaluate for resistance to bacterial wilt. All the F_1 hybrids and male parents were susceptible to bacterial wilt. Mukthi, Sakthi and Anagha were resistant to this disease with survival percentages of 80, 85 and 87.5 per cent respectively.

The varieties Sakthi and Anagha were semideterminate, while Mukthi was determinate. The genotypes BT 118-4-1-1, Sun 7611, TH 977 and Nidhi were indeterminate in growth habit. Among the F_1 hybrids, all the hybrids except Sakthi x BT 118-4-1-1 had indeterminate growth habit. Sakthi x BT 118-4-1-1 was semideterminate in growth habit.

Good general combiners for different characters were identified. Anagha was a good general combiner for early flowering, early fruit set and early harvest. BT 118-4-1-1 was a good general combiner for fruit yield per plant, fruits per plant and average fruit weight.

Good specific combiners for different characters were identified. Anagha x Nidhi was a good specific combiner for early flowering. Anagha x TH 977 was a good specific combiner for both early fruit set and early harvest. Mukthi x Nidhi was a good specific combiner for fruit yield per plant, while Sakthi x Nidhi was a good specific combiner for fruits per plant. Mukthi x TH 977 was a good specific combiner for average fruit weight.

The relative heterosis and heterobeltiosis for eleven biometric characters were estimated. There were 2 heterobeltiotic and 4 relatively heterotic hybrids for plant height. For days to flowering, there were 6 heterobeltiotic and relatively heterotic hybrids. There were 4 heterobeltiotic and 3 relatively heterotic hybrids for days to first fruitset, and days to first harvest. For fruit yield per plant, there were 8 heterobeltiotic and 7 relatively heterotic hybrids. The F_1 hybrid Sakthi x BT 118-4-1-1 recorded the highest fruit yield per plant. For fruits per plant, there were 4 heretobeltiotic and 8 relatively heterotic hybrids. There were 6 heterobeltiotic and 5 relatively heterotic hybrids for average fruit weight. For crop duration, there were 9 heterobeltiotic and 8 relatively heterotic hybrids. For locules per fruit, none of the hybrids were relatively heterotic or heterobeltiotic. There were 5 heterobeltiotic and 8 relatively heterotic hybrids for fruit flesh thickness while there were 2 relatively heterotic and heterobeltiotic hybrids for TSS.

The F_2 segregants were evaluated for bacterial wilt resistance and growth habit. There were 42 indeterminate F_2 segregants resistant to bacterial wilt. Among the F_2 progenies, Anagha x BT 118-4-1-1 F_2 - 13, Angha x BT 118-4-1-1 F_2 - 14 and Anagha x Sun 7611 F_2 - 7 were the earliest to harvest. Fruit yield per plant was maximum in Mukthi x BT 118-4-1-1 F_2 - 8, Sakthi x Nidhi F_2 - 7 and Anagha x Nidhi F_2 - 3. Average fruit weight was maximum in Anagha x Nidhi F_2 - 3.

Segregants having indeterminate growth habit and resistance to bacterial wilt were selected for further studies.

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* Originals not seen

Appendices

APPENDIX-I

ANOVA for line x tester analysis for yield and it's components

Source	df	Plant height	Days to flowering	Days to 1st fruit set	Days to 1st harvest	Fruit yield per plant	Fruits per plant	Average fruit weight	Crop duration	Locules per fruit	Fruit flesh thickness	TSS
Parents	6	110.55	1.81	7.81	6.31	5216.24**	14.6**	42.47**	202.97**	0.029	0.234	.0.0195
Hybrids	11	295.75**	53.0**	38.49**	10.61*	8911.54**	1.61	102.96**	156.0**	0.140*	1.16**	0.123**
Parent vs Hybrids	1	835.31**	314.54**	5.38	0.352	21414.3**	67.48**	0.0957	1213.33**	0.052	0.789**	0.240*
Lines	2	39.17	3.65	6.48	4.61	8421.03	14.33	13.19	1.50	0.042	0.0216	0.0116
Testers	3	148.96	0.68	8.82	9.28**	2434.19**	3.98	26.79*	324.79**	0.030	0.3979**	0.0233
Line x testers	1	138.06	1.52	7.46	0.785	7152.75**	47.04**	148.03**	240.48**	0.0038	0.167	0.0238
Error	18	65.22	7.14	5.3	3.22	449.3	1.57	7.04	17.62	.056	.0713	.0318

APPENDIX-II

Components of additive and non additive variances and heritability for yield and it's components

Source	df	Mean squares										
		Plant height	Days to flowering	Days to 1st fruit set	Days to 1st harvest	Fruit yield per plant	Fruits/ plant	Average fruit weight	Crop duration	Locules/ fruit	Fruit flesh thickness	TSS
Parents	6	110.55	1.81	7.81	6.31	5216.24**	14.60**	42.47**	202.97	0.029	0.234	0.0195
Hybrids	11	295.75**	53.00**	38.49**	10.61*	8911.54**	1.61	102.96**	156.00**	0.140*	1.16**	0.123**
Parent vs Hybrids	1	835.31**	314.54**	5.38	0.352	21414.30**	67.48**	0.0957	1213.33**	0.052	0.789**	0.240**
Lines	2	39.17	3.65	6.48	4.61	8421.03**	14.33**	13.19	1.50	0.042	0.0216	0.0116
Testers	3	148.96	0.68	8.82	9.28**	2434.19**	3.98	26.79*	324.79**	0.030	0.3979**	0.0233
Line x testers	1	138.06	1.52	7.46	0.785	7152.75**	47.04**	148.03**	240.48**	0.0038	0.167	0.0238
Error	18	65.22	7.14	5.30	3.22	449.30	1.57	7.04	17.62	0.056	0.0713	0.0318

INCORPORATION OF RESISTANCE TO BACTERIAL WILT IN INDETERMINATE TOMATOES

By
GUDI JACOB

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

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ABSTRACT

Investigations on "Incorporation of resistance to bacterial wilt in indeterminate tomatoes" was carried out during July 2002 - September 2003 at the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara. The salient findings are mentioned below:

Three bacterial wilt resistant varieties (Sakthi, Mukthi and Anagha) were crossed with four indeterminate genotypes (BT 118-4-1-1, Sun 7611, TH 977 and Nidhi) in a line x tester fashion to produce twelve F_1 hybrids. The F_1 hybrids were found to be susceptible to bacterial wilt. All the hybrids except Sakthi x BT 118-4-1-1 were indeterminate in growth habit.

The general combining ability of the parents and specific combining ability of the crosses were estimated. Anagha was a good general combiner for earliness in flowering, fruit set and harvest. BT 118-4-1-1 was a good general combiner for fruit yield per plant, fruits per plant and average fruit weight. Mukthi x Nidhi was the best specific combiner for fruit yield per plant. Sakthi x Nidhi was a good specific combiner for fruits per plant and Mukthi x TH 977 was a good specific combiner for average fruit weight.

The relative heterosis and heterobeltiosis for different biometric characters were estimated. Sakthi x BT 118-4-1-1 was the best F_1 hybrid for fruit yield per plant (422.5 g plant^{-1}) and average fruit weight (53.15 g). Mukthi x BT 118-4-1-1 was the best hybrid for fruits per plant (12.10).

The F_2 segregants were evaluated for bacterial wilt resistance and growth habit. There were 42 indeterminate F_2 segregants resistant to bacterial wilt. Among these Anagha x BT 118-4-1-1 F_2-13 was the earliest to harvest. Maximum fruit yield was obtained in the F_2 segregant Mukthi x BT 118-4-1-1 F_2-8. These indeterminate F_2 segregants were selected for further improvement.