RELATIVE ADVANTAGES OF F_1 HYBRIDS AND 50:50 PHYSICAL MIXTURES IN TOMATO

By

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THESIS

submitted in partial fulfilment of
the requirement for the degree of

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Department of Olericulture
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DECLARATION

I hereby declare that this thesis entitled "Relative advantages of F_1 hybrids and 50:50 physical mixtures in tomato" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
28.6.1986.

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CERTIFICATE

Certified that this thesis entitled "Relative advantages of F_1 hybrids and 50:50 physical mixtures in tomato" is a record of research work done independently by Miss Sheela A.G., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith, is the most serious disease of tomato (*Lycopersicon esculentum* Mill.) in many tropical, sub-tropical and warm temperate regions of the world. In many areas where the disease is prevalent, losses are so serious that commercial tomato production is not economic. Attempts on disease management and control have not made substantial impact, necessitating development of resistant lines to bacterial wilt. In breeding for disease resistance, extensive programmes were undertaken in North Carolina (U.S.A.), Puerto Rico and the Philippines, but linking of satisfactory levels of resistance with commercial fruit size and quality was proved very difficult. Two sources of resistance and a large number of resistant lines have been reported. The breaking down of resistance is a serious constraint in breeding bacterial wilt resistant tomatoes. The resistance is not stable during warm weather at low elevations, the apparently resistant plants eventually die from the disease (Krauss and Thurston, 1975).

Studies on genetics of wilt resistance showed that resistance is controlled mainly by recessive genes. Digat and Derieux (1968) reported partial dominance of resistance. Crosses involving resistant varieties were more resistant than the resistant cultivars themselves. So development of F_1 hybrids carrying different resistant gene systems would be a desirable step in resistance breeding. Alternatively, the development of physical mixtures could also minimise crop damage considering the 'obstruction' given by the component lines. Attempts on these aspects are limited in tomato. The present study was formulated with the following objectives

1. to compare F_1 hybrids and 50:50 physical mixtures in terms of resistance to bacterial wilt, fruit yield and yield components,

2. to compare F_1 hybrids and 50:50 physical mixtures in terms of specific combining ability and specific associative ability for yield and yield components,

3. to identify specific physical mixtures with near normal agronomic uniformity and field resistance to bacterial wilt,

4. to evaluate two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and yield components,

5. to study maternal effects for certain quantitative characters in tomato and

6. to evaluate a set of tomato lines for resistance to bacterial wilt and economic characters.

Review of Literature

REVIEW OF LITERATURE

Bacterial wilt caused by *Pseudomonas solanacearum* is one of the destructive plant diseases in the warm humid regions of the world. The disease was first reported in Italy in 1882 (Walker, 1952). Smith (1896) described the disease and its causal agent and observed the disease in potato, tomato and brinjal. The first report on bacterial wilt of tomato in India was by Hedayathullah and Saha (1941) from West Bengal.

1. *Pseudomonas solanacearum* E.F. Smith - Complexity of the pathogen

Pseudomonas solanacearum is a complex species consisting of different races differing in host range and pathogenicity (Hayward, 1964). Tremendous geographical variation occurs in the organism. Several races and strains occur in the same area, although they usually attack different hosts (French and Sequeira, 1970). The pathogen attacks more than 200 plant species belonging to 33 families. Kelman (1953) reported that the major susceptible hosts belong to Solanaceae.

Buddenhagen (1960) found that the race of pathogen affecting banana is not related ecologically or etiologically to the race causing bacterial wilt in the dicotyledonous plants. Okabe and Goto (1961) conducted detailed studies on the strains of <u>Pseudomonas solanacearum</u> and reported that the isolates from many solanaceous hosts could be separated into 40 or more groups on the basis of biochemical properties, serological reaction, sensitivity to virulent and temperate phages, and on lysogenicity and bacteriocinogenicity. They reported three types of strains - strains specialised in pathogenicity, strains specialised in pathogenicity, and other physiological and morphological characters, and strains specialised in bacteriological characters only.

A tentative classification scheme of <u>Pseudomonas solanacearum</u> by Okabe and Goto (1961) is summarised here.

Bacterial types	Race 1			Race 2			Race 3
	Str. α	Str. β	Str. γ	Str. ∂	Str. ϵ	Str. η	Etc.
Pathotype	A, C	C, D	A, E	B	F	G, H	I
Colony type	a c	a c	a	bd	Sfr	b	e
Biochemical type	I III	I	IV	III	I III	IV	II

Buddenhagen <u>et al</u>. (1962) classified 4000 isolates from Central and South America into 3 races based broadly on their pathogenicity. Race 1 affects tobacco, tomato, many solanaceous and other weeds and certain diploid bananas. Race 2 is pathogenic to triploid bananas, Heliconias or both. Race 3 affects potato and tomato, but is not highly virulent on other solanaceous crops.

Hayward (1964) classified a collection of 185 isolates of Pseudomonas solanacearum into four biotypes according to their capacity to oxidise three dissaccharides (lactose, maltose and cellobiose) and three hexose alcohols (manitol, sorbitol and dulcitol). Biotype II was obtained solely from potato and tomato, so it is similar to race 3 of Buddenhagen et al. (1962). Buddenhagen et al. (1966) studied the carbohydrate catabolism in different pathogenic strains of Pseudomonas solanacearum. They found that T strain of race 1 was different from B and SFR strains of race 2, the two strains of race 2 being similar metabolically. Zehr (1970) reported a strain of Pseudomonas solanacearum from ginger, virulent to tomato but avirulent to potato and brinjal. But the isolates from tomato, potato and brinjal were not virulent to ginger on artificial inoculation. Pegg et al. (1974) reported two biotypes of the pathogen, one (biotype III) causing common tomato wilt, but only non-significant and slow wilt in ginger and other one (biotype IV) causing very rapid and severe wilt resulting heavy losses in ginger. Keshwal and Joshi (1976) studied ten isolates of Pseudomonas solanacearum and found that the isolate G 5/73 could infect ageratum, tomato and brinjal, but not other solanaceous hosts. Rath and Addy (1977) studied ten isolates causing wilt of tomato and found, based on pathogenicity and hypersensitive reactions that they belong to race 1. Though morphologically alike, they exhibited variations for biochemical properties like gelatin liquefaction, action on litmus, milk, starch hydrolysis etc. Serologically six of the isolates could be grouped into one and it was well correlated with the biochemical properties. Rao (1977) observed that isolates from the hills belonged to race 3 and those from plains to race 1. Ramadevi (1978) reported, after studying different isolates from many parts of Kerala, that *Pseudomonas solanacearum* existed in different races or strains coming under either race 1 or race 3 and race 2 is non-existent. Yi *et al.* (1982) studied 14 isolates virulent to tobacco selected from tobacco plants and classified into 2 races based on reactions in egg plant, tomato, capsicum, potato and tobacco and classified into biochemical type I and type IV, according to physiological characteristics.

2. Genetics of resistance

Two primary sources of resistance were reported (Russel, 1978). The first being the North Carolina type expressed by derivatives of Louisiana Pink is inherited as a recessive character and is controlled by polygenes (Singh, 1961). A second source of resistance derived from *Lycopersicon pimpinellifolium* (PI 127805A) is partially dominant in the seedling stage. In mature plants, resistance was controlled by recessive genes and that the expression of the resistant variety is a function of the age of plant and changes in temperature (Acosta *et al.*, 1964). Acosta (1964) stated that resistance in *Lycopersicon pimpinellifolium* is controlled by a single pair of genes. He also reported linkage between sp^+, the gene for indeterminate plant habit and wilt resistance. No association was observed between the gene 'u' controlling immature fruit colour and the wilt resistance (Acosta *et al*., 1964). Suzuki *et al*. (1964) stated that resistance to *Pseudomonas solanacearum* was quantitatively inherited. Digat and Derieux (1968) made several crosses between resistant and susceptible cultivars and F_2 field data suggested partial dominance of resistance. A close linkage between recessive genes for resistance and genes for poor fruit characteristics was observed (University of West Indies, 1968-'69). AVRDC (1975) reported that resistance to bacterial wilt is controlled by multiple recessive genes acting additively. Ferrer (1976) crossed wilt resistant, PI 126408 with susceptible, Bonny Best and Floradel. Segregating ratios in F_2s suggested that resistance was polygenically inherited and reciprocal crosses showed that no extra chromosomal inheritance was involved. The genes involved were additive and no dominance was observed. Variance component analysis of the P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of a cross between a resistant (VC-4) and susceptible (Walter) tomato cultivars indicated a narrow sense heritability of 42% and a broad sense heritability of 53% with a degree of dominance of 75% for wilt resistance. Inheritance of resistance was mainly due to additive gene action (Graham and Yap, 1976). Kann and Laterot (1977) demonstrated that resistance to *Pseudomonas solanacearum* and *Fusarium oxysporum* f.sp. *lycopercisi* were under multifactorial control and it was suggested that the association between them was due to pleiotrophy rather than linkage. Mew and Ho (1977) observed that polygenic inheritance was modified by changes in temperature. Villareal and Lal (1978) supported the hypothesis of additive gene action in the inheritance of disease resistance. Sreelathakumary (1983) used two distinct sources of resistance, one derived from Louisiana Pink possessing North Carolina type of gene system and another derived from *Lycopersicon pimpinellifolium*. Crosses were made to find out inheritance of combined wilt resistance to bacterial wilt. Studies with the parental lines, F_1s and F_2s indicated a complimentary and hypostatic type of digenic recessive gene system responsible for combined wilt resistance. No F_1 hybrids involving 10 lines from *Lycopersicon esculentum* as female and *Lycopersicon pimpinellifolium* as male showed resistance indicating the recessive type of gene action for resistance. Tikoo *et al.* (1983) observed presence of two independent gene systems for wilt resistance. In CRA-66 Sel-A from Hawaii, the resistance was governed by multiple recessive genes and the genotype 663-12-3 from Taiwan had a monogenic dominant reaction.

Resistant host reaction to the complex bacteria

Breeding for bacterial wilt resistant tomatoes by crossing wild tomato strains with commercial varieties was started at North Carolina Agricultural Experiment Station as early as 1944 (Weaver, 1944). Crosses between Louisiana Pink and T414 showed good resistance to bacterial wilt. Aberdeen (1946) found that the strain derived from Louisiana Pink and T414 were resistant in Queensland also. The two cultivars Sensation and Marvel, possessing good resistance to Pseudomonas solanacearum, had poor fruit quality. Annual Report of School of Agriculture, North Carolina State College (1950-'51) had reports on lines with good field resistance to bacterial wilt but only a few bore fruits of marketable size. Abeygunawardena and Siriwardena (1963) tested 49 tomato varieties and hybrids. The North Carolina lines 1960-s, 1960-2a, 1962-B2, 1961-57-55M, Masterglobe and Kahangula Selection II were the most resistant. The North Carolina lines were superior in wilt resistance to the local cultivated varieties and outyielded the commercial varieties, Masterglobe and Pearson. Acosta et al. (1964) observed resistance in Lycopersicon pimpinellifolium (PI 127805 A). Suzuki et al. (1964) developed tomato varieties OTB_1 and OTB_2 with improved resistance to bacterial wilt by selection from tomato lines NC 1953-60N and NC 1953-64N respectively. Annual Report of the

Agricultural Experiment Station, University of Florida (1967) carried reports on a few bacterial wilt resistant lines resulting from crosses involving popular varieties of USA, Manalucie and Floradel with a resistant stock from North Carolina. Resistance to bacterial wilt in Venus and Saturn was observed by Henderson and Jenkins (1971). Both the varieties were derived from crosses among Louisiana Pink, Beltsville 3814, Pan America, Rutgers, Marglobe, STEP 174 and Manalucie at different levels. Akiba et al. (1972) observed high levels of resistance in three tomato introductions 65 S_2, 66 S 52 and 68 S_4 from USA. The resistance in Venus, Saturn and in local lines IRAT and OTB-2 were confirmed by Daly (1973). Chetia and Kakati (1973) observed resistance to Pseudomonas solanacearum in Oxheart under natural infection. Best Of All and Marglobe Supreme were moderately susceptible. Anaya and Waite (1974) observed more than 90% resistance in BWN 5, BWN 514, BWN 16, BWN 17 and BWN 7755. In a screening programme conducted at the Asian Vegetable Research and Development Centre, Taiwan in 1975 involving 247 cultivars, two additional sources of resistance, accessions 1737 and 1937, were isolated (AVRDC, 1975). Rao et al. (1975) tested 23 wilt resistant cultivars and lines from the U.S.A. and the Philippines for their reaction to an Indian isolate of Pseudomonas solanacearum. Only one line CRA 66 Selection A from Hawaii was resistant.

Daly (1976) observed wilt resistance in IRAT-L3 with a disease incidence of 15%, 80 days after planting in infected soil. Hsu (1976) studied four varieties, all were susceptible following inoculation of the stem or top leaf, but A 95-6 and UP 1167 were comparatively resistant following root inoculation. Mew and Ho (1976) evaluated 43 tomato selections and cultivars, only Accession 33 (Vc 8-1-2-1) was consistently resistant. Jenkins and Nesmith (1976) evaluated the resistant cultivars Venus and Saturn to Indian and American isolates of *Pseudomonas solanacearum*. They found that both the cultivars were highly susceptible to American isolates at 2 to 4 weeks of age when both stem and root were inoculated. They found that the Indian isolate was more virulent than the American isolate. Bedekar (1977) tested four tomato cultivars for their reaction to different isolates of *Pseudomonas solanacearum*. He found that disease reaction varied from cultivar to cultivar and among isolate mixtures. Saturn and PI 303811 withstood only weakly virulent isolates and their mixtures and succumbed to all highly virulent isolates and their mixtures. VC 9-1 UG and VC 11-1 UG showed resistance to eight isolates and various mixtures of them.

Graham *et al.* (1977) observed resistance in a line Cranita, which has Mi for resistance to *Meloidogyne incognita*. The line VC 48-1 was resistant in Taiwan (AVRDC, 1978).

Of the 25 lines tested, L 3972, L 3987 and CL 8d-0-7-1 were moderately resistant in Nigeria (IITA, 1978). Sonoda (1977) evaluated 121 lines for resistance to Pseudomonas solanacearum and found that the cultivars Venus and Saturn and line PI 126408 were more resistant than commercial Florida cultivars. Sonoda and Augustine (1977) isolated Hawaiian Selection 7997 as resistant out of 72 tomato lines screened against bacterial wilt. The lines FP-1, FP-2 and FP-5 were observed tolerant to bacterial wilt (University of Malaya, 1977). Messiaen et al. (1978) reported that INRA 518, with determinate growth habit was resistant to Pseudomonas solanacearum and Meloidogyne spp. Evaluation of tomato lines against bacterial wilt conducted at Agricultural College, Vellayani, Trivandrum indicated wilt incidence of $< 30\%$ in Venus, Saturn and CRA 66 selection A (Remadevi, 1978). Sonoda and Augustine (1978) observed high tolerance in the accessions PI 126408, PI 212441, PI 263722, PI 365930, Hawaii 7981, Hawaii 7997 and CRA 66 (Selections A, D and E). Villareal and Lal (1978) reported that the lines VC 11-1 and Kewalo, derived their resistance from Lycopersicon pimpinellifolium, "PI 127805 A" and the two and three way crosses exhibited comparable resistance. Sonoda et al. (1980) confirmed resistance in the lines Hawaii 7997, CRA 66 and PI 126408. Bissonauth (1980) evaluated four cultivars, of which Vc / Nova was the most resistant. Ramachandran et al. (1980) evaluated 36 tomato lines for their resistance to bacterial wilt under warm humid tropical conditions of Kerala. They observed resistance in La Bonita and CL 32 d-0-1-19 GS. Sunarjono (1980) reported that the breeding lines AVRDC 33 and AVRDC 15 were resistant to bacterial wilt. CL 32 d-0-1-25 appeared promising for resistance. Hawaii 7996 was resistant under low land conditions. Hoque *et al*. (1981) observed high resistance in the lines CL 8d-0 and CL 143-0-13. Celine (1981) reported field tolerance in the line CL 32d-0-1-19 GS. The line CL 2728-0-3-2-2 was the best of nine lines in terms of marketable yield, fruit size and bacterial wilt resistance. CL 2729-1-1-5-5-0-4 had the highest yield and was resistant but had small fruits (AVRDC, 1982). Lin and Chen (1982) reported that TSS1 derived from a cross between the F_1's of Break O' day x Vc 8-1-2-1 and Manapal x Vc 8-1-2-1, was highly resistant. Goth *et al*. (1983) tested selected tomato lines and cultivars to eight isolates of *Pseudomonas solanacearum* collected from diverse locations (K 60, A 21, TFP 12, TFP 13, 126408-1 and Tifton 80-1 belonging to race 1, W 82 belonging to race 3 and FF, an unknown race). They found that line CL 32d-0-1-19 GS was resistant to three isolates K 60, 126408-1 and Tifton 80-1 of race 1. Venus was resistant only to the isolate 126408-1 of race 1. Peterson *et al*. (1983) observed high resistance in the cultivar Scorpio in South Eastern Queensland. Sreelathakumari

(1983) evaluated 10 dervatives of Louisiana Pink and one line derived from *Lycopersicon pimpinellifolium*. The line LE 217 had a disease score of 2 indicating high field resistance.

Genetic and physical manipulation of host to thwart the onslaught of the pathogen

Various methods are used to control bacterial wilt. Crop rotations are of limited value unless long rotations with non-susceptible crops are followed. (Ashrafuzzaman and Islam, 1975). In tomatoes, rotation with *Vigna* sp. followed by maize and cabbage/okra followed by *Vigna* sp. and maize gave effective control of the disease (Sohi *et al*., 1981). Reduction in wilt was obtained by covering the test plants with black plastic films and fumigating with DCB, nomex and vordex (Jones *et al*., 1966).

Grafting to resistant root stocks of tomato enables tomatoes to be successfully cultivated in infested soil. By grafting tomato scions to resistant stock *Solanum diversifolium*, complete control was obtained. The crop species were highly compatible and the root stock was also resistant to root-knot nematode, *Meloidogyne incognita* (Reyes, 1967). Bacterial wilt incidence was brought down from 60 to 6% in infested soils by grafting commercial tomato line N-52 on a resistant stock Selection 5808-2 (*Lycopersicon* pimpinellifolium) (Oberero, 1969). Satisfactory control of bacterial wilt was obtained by grafting 3 weeks old tomato scions on resistant tomato stocks, Selection 1169 and Hawaii-2. Felix (1973) found that tomato scions tongue-grafted on Solanum torvum root stocks were resistant to both bacterial wilt and root-knot nematodes. When tomato scions were grafted on resistant brinjal stocks, bacterial wilt incidence was reduced below 10% (Lam and Wong, 1976). Kaan (1977) reported five small fruited tomato lines with good resistance to bacterial wilt as suitable stocks for grafting. Russel (1978) reported that the disease is very difficult to be controlled by chemical or cultural methods and accordingly there were many programmes for resistance breeding.

a) Broad based F_1 hybrids

Four F_7 lines from a cross UPR 199 x Floradel showed good tolerence to Pseudomonas solanacearum (IRAT, 1970). Anaya and Waite (1974) tested 13 lines and F_1 hybrids for resistance to bacterial wilt. The lines BWN 5, BWN 514, BWN 16, BWN 17 and BWN 7755 were resistant to an extent of more than 90%. Three tomato cultivars (VC 11-1, Saturn and Kewalo) resistant to bacterial wilt and the corresponding F_1 progeny of the two way and three way crosses were inoculated with a weak isolate and a virulent isolate of Pseudomonas solanacearum. The progeny was more resistant than the parents (AVRDC, 1975). Graham and Yap (1976) performed a diallel cross among six cultivars Walter, CRA 66, H 7741, Venus, VC-4 and Llanos de Colce, representing a range of susceptibility/resistance of 99.5 to 20.8 on a disease resistant scale. They reported that wilt resistance could attain a high level in a breeding procedure of repeated selfing and selection followed by intercrossing of resistant selections. Chumvisoot and Lambeth (1983) crossed twelve accessions as female to three tester lines Saturn, Venus and Kewalo. Seedlings of parents and hybrids were leaf or stem inoculated with *Pseudomonas solanacearum*. Five accessions and their hybrids with Kewalo had low tolerance. Sreelathakumary (1983) reported that no F_1 hybrids involving 10 lines from *Lycopersicon esculentum* as female and *Lycopersicon pimpinellifolium* as male showed resistance. Out of the four non-segregating (Saturn, LE 79, Pusa Ruby and Pusa Ruby x LE 79 F_1) and two segregating (Pusa Ruby x LE 79 F_2, Saturn x LE 79 F_2) evaluated, the F_2 hybrids of Saturn and LE 79 were found resistant (Narayanankutty, 1985). In a repeated trial F_3s were evaluated along with the F_2s and non-segregating populations (Saturn and LE 79). Resistance was observed in Saturn x LE 79 F_3 (percentage of wilt, 10.7) and Saturn x LE 79 F_2 (percentage of wilt 18.23). Pusa Ruby x LE 79 F_2s and F_3s were susceptible to moderately susceptible.

b) Multilines and Physical mixtures

The multiline theory for the production of composite varieties is one of the truly new concepts in breeding self pollinated crops. The idea of multiline varieties was put forward by Jenson (1952) for use in cereals. In 1953, Borlaug clearly outlined the procedure to develop multiline cultivars to control stem rust of wheat. He suggested that several purelines with different resistant genes should be developed through backcross programme using one recurrent parent. This is done by transferring disease resistance genes from several donor parents carrying different resistance genes to a single recurrent parent. Each donor parent is used in a separate backcross programme so that each line has a different resistance gene or genes. Five to ten of these lines may be mixed to produce a multiline variety. The lines to be mixed in a multiline would be determined by the races of the pathogen prevalent in the area. If a line or lines become susceptible, they would be replaced by the resistant lines. Only one or a few lines of the mixture would become susceptible to the pathogen in any one season i.e. only a small proportion of the plants would be infected by the pathogen. Consequently the disease would spread more slowly than when the entire population was under a single line. This would reduce the damage to the susceptible lines as well (Singh, 1983).

two were highly resistant. Fifteen possible mixtures were developed in 50:50, 75:25, 25:75 ratios and a race mixture was sprayed. The results indicated that the development of rust was slow in mixtures as compared to the pure cultures even when the seeds of the most susceptible parents were mixed and grown. Chin and Husin (1982) reported that rice variety mixtures could effectively control *Pyricularia oryzae* and produce highly stable yields. Disease levels were reduced to one third of the mean severity in purestands.

The resistance of multilines is due to a variety of mechanisms. A proportion of initial inoculam falls on the resistant lines, reducing theinitial inoculam. Of the spores produced by the infected susceptible lines, only a proportion would fall on other susceptible plants, thus reducing the rate of multiplication (Chaudhary, 1982).

The multiline concept is not restricted to a true multiline variety, based on the near isogenic components carrying different race-specific resistant genes. It also comprises variety or line mixtures were the component genotypes differ for the race-specific resistant genes they contain (Parlevliet, 1979). Shorter and Frey (1979) reported the advantages of mixtures over monocultures.

They are,

i) more stable resistance to diseases

ii) greater stability of performance across diverse environments and

iii) higher yield through more efficient utilization of environmental resources

Effect of heterogeneous oat populations on the epiphytotic development of Victoria blight was reported by Ayanru and Browning (1977). When mixtures of the highly resistant line x 424-III and the highly susceptible near isogenic line x 424-10729 were grown in the field and inoculated with *Cochliobolus victoriae* grain yield, bundle weight and weight of 500 cc of grains were significantly higher than for purestands of highly susceptible plants. Weerapat *et al.* (1977) reported that when seedlings of the highly susceptible variety RD 7, the resistant variety RD 9 and various mixtures of the two, were infested at the two leaf stage with first instar individuals of *Nilaparvatha lugens* RD 7, RD 9 and a 50:50 mixture of RD 7:RD 9 showed 100%, nil and 18% damage respectively. They concluded that by planting 50% of an area with a resistant variety, the damage resulting from the attack was reduced to levels lower than those expected on the basis of the ratio of the varieties used. When barley varieties Hassan, Midas and Wing were grown in mixtures, the infection with *Erysiphe graminis* was reduced by half and the yields were upto 11% higher than the means of the component varieties grown alone (Harvey, 1978). The effect of mixtures to reduce powdery mildew was reported by Wolfe (1977), Stolen *et al.* (1980), Day (1981), Stolen (1982), White (1982) and Welling *et al.* (1983).

Pande (1978) reported that mixtures of bengal gram involving resistant components generally showed a reduction in wilt. Gill *et al.* (1981) studied the progression of yellow rust in mixtures of isogenic lines of wheat in varying proportions. Of the six component lines, two were highly susceptible, two were moderately susceptible and two were highly resistant. Fifteen possible mixtures were developed in 50:50, 75:25, 25:75 ratios and a race mixture was sprayed. The results indicated that the development of rust was slow in mixtures as compared to the pure cultures even when the seeds of the most susceptible parents were mixed and grown. Chin and Husin (1982) reported that rice variety mixtures could effectively control _Pyricularia oryzae_ and produce highly stable yields. Disease levels were reduced to one third of the mean severity in purestands.

Materials and Methods

MATERIALS AND METHODS

The present investigations were carried out at the Instructional Farm, College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur during July-November, 1985. The farm is located at an altitude of 22.25 m above MSL, at 10° 32'N latitude and 76° 16'E longitude. The area enjoys a typical warm humid tropical climate. The soil of the experimental site is a deep, well drained and moderately acidic laterite loam fairly rich in organic matter. The soil is highly infested with the bacterium, *Pseudomonas solanacearum* E.F. Smith causing heavy crop damage to Solanaceous vegetables.

The studies consisted mainly of four parts

A. Evaluation of six specific lines of tomato, their F_1 hybrids and 50:50 physical mixtures for resistance to bacterial wilt, fruit yield and yield components

B. Evaluation of two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and yield components

C. Maternal effects for certain quantitative characters in tomato

D. Evaluation of a set of tomato lines for bacterial wilt resistance and economic characters

A. Evaluation of six specific lines of tomato, their F_1 hybrids and 50:50 physical mixtures for resistance to bacterial wilt, fruit yield and yield components.

1) Materials

Six genetically divergent tomato lines possessing different resistant gene systems were used to develop fifteen one way F_1 hybrids and fifteen 50:50 physical mixtures. Physical mixtures were developed through alternate planting in the mainfield.

The six tomato lines were LE 79 LFF, LE 214, LE 217, IIHR Bwr 93, IIHR Bwr 34A and LE 206. The lines IIHR Bwr 93 and IIHR Bwr 34A carried dominant type of resistant genes. All these six genotypes will be designated hereafter as 1, 2, 3, 4, 5 and 6 respectively.

Fifteen one way F_1 hybrids were developed by crossing the above six lines. The hybrids were

i)	1 x 2	vi)	2 x 3	xi)	3 x 5
ii)	1 x 3	vii)	2 x 4	xii)	3 x 6
iii)	1 x 4	viii)	2 x 5	xiii)	4 x 5
iv)	1 x 5	ix)	2 x 6	xiv)	4 x 6 and
v)	1 x 6	x)	3 x 4	xv)	5 x 6

The 50:50 physical mixtures were

i)	1 + 2	vi)	2 + 3	xi)	3 + 5
ii)	1 + 3	vii)	2 + 4	xii)	3 + 6
iii)	1 + 4	viii)	2 + 5	xiii)	4 + 5
iv)	1 + 5	ix)	2 + 6	xiv)	4 + 6
v)	1 + 6	x)	3 + 4	xv)	5 + 6

Pusa Ruby was used as the susceptible check for evaluation of bacterial wilt resistance.

2) Lay out and experimental design

The experiment was conducted during July-November, 1985 in a uniformly fertile and wilt sick soil. The six parental lines, fifteen one way F_1 hybrids and fifteen 50:50 physical mixtures were grown in three replications. The parental lines, the F_1 hybrids and the mixtures were grown separately in each block. Randomisation was resorted within each group within each block. There were two rows of 10 plants each/ entry/replication. Spacing was 70 cm x 60 cm. Pusa Ruby was spot planted to confirm presence of virulent inoculam in each and every planting spot. The plants were observed for incidence of bacterial wilt. Wilting of the susceptible check indicated presence of virulent inoculam in the soil. Bacterial ooze test was also done to confirm bacterial wilt. The disease rating was done as per the scale suggested by

Mew and Ho (1976), R = resistant ($<$ 20% plants wilted, MR = moderately resistant (20 to 40% plants wilted), MS = moderately susceptible (40 to 60% plants wilted) and S = susceptible ($>$60% plants wilted).

Five plants each from parental lines and F_1 hybrids and five plants each from each component lines of a physical mixture were selected randomly and the following observations were made.

a) Vegetative characters

i) Plant height - observed at second harvest

ii) Primary branches/plant - observed at second harvest

b) Productive characters

i) Days to fruit set

ii) Days to fruit harvest

iii) Fruit set (%)

iv) Fruits/plant

v) Fruit yield/plant

c) Disease scoring : Number of plants survived where Pusa Ruby wilted.

3) Statistical analysis of data

a) Analysis of variance

The data were subjected to analysis of variance as described by Ostle (1966). The variance due to treatment was further partitioned.

The line LE 79 LFF was missing in the first replication and hence missing plot technique was followed.

b) Combining ability analysis

The data from the parents and F_1 hybrids were analysed for combining ability effects and heterosis.

Combining ability analysis was carried out according to Model 1, Method 2 of Griffing (1956).

Yij = m + gi + gj + sij + eij

where Yij = mean of $(ixj)^{th}$ F_1 hybrid

m = the population mean

gi = general combining ability (gca) effect of i^{th} parent

gj = gca effect of j^{th} parent

sij = specific combining ability effect (sca) of $(ixj)^{th}$ cross

eij = error associated with ij^{th} cross

The sum of squares (SS) were calculated as follows:

$$\text{SS due to gca} = \frac{1}{n+2} \left\{ \sum (Yi. + Y_{ii})^2 - \frac{6}{n} \; Y..^2 \right\}$$

$$\text{SS due to sca} = \sum\sum Yij^2 - \frac{1}{n+2} \sum (Yi. + Yii)^2 + \frac{2}{(n+1)\;(n+2)} \; Y..^2$$

where n = number of parents

Yi. = total of the array of i^{th} parent summed over j direct crosses

Yii = mean value of i^{th} parent

Yij = mean value of ixj^{th} cross

Y.. = grand total of $\frac{n(n-1)}{2}$, progenies and 'n' parental lines.

The analysis of variance table was set up as follows:

Sources	Degree of freedom	Sum of squares	Mean squares
Gca	5	Sg	Mg
Sca	15	Ss	Ms
Error	39	Se	Me'

$$Me' = \frac{\text{Error mean square (Me)}}{\text{Number of replications}}$$

To test the variance due to general combining ability effect

$$F_{(5,\ 39)} = \frac{Mg}{Me'}$$

To test the variance due to specific combining ability effect

$$F_{(15,\ 39)} = \frac{Ms}{Me'}$$

gca effects (gi) and sca effects (sij) were estimated as follows:

$$gi = \frac{1}{n+2} \left\{ \sum (Yi. + Yii) - \frac{2}{n} Y.. \right\}$$

$$sij = Yij - \frac{1}{n+2} (Yi. + Yii + Y.j + Yjj) + \frac{2}{(n+1)(n+2)} Y..$$

n, Yi.., Yii, Yij and Yjj were the same as explained earlier.

Variances, standard errors and critical differences were estimated

$$\text{Var (gi)} = (n-1)\ \sigma^2 e/n(n+2)$$

$$\text{Var (sij)} = n(n-1)\ \sigma^2 e/(n+1)\ (n+2)$$

$$\text{Var (gi-gj)} = 2\ \sigma^2 e/(n+2)$$

$$\text{Var (sij-sik)} = 2(n+1)\ \sigma^2 e/(n+2)$$

$$\text{Var (sij-skl)} = 2\ n\ \sigma^2 e/(n+2)$$

The above estimates were used to calculate the critical differences for making comparisons between different effects.

c) Heterosis

Heterosis was calculated as percentage increase or decrease of the F_1s over the better parent (Hayes <u>et al</u>., 1965) and over mid-parent (Briggle, 1963).

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

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

Heterobeltiosis was tested using standard error

$$SE = \sqrt{\frac{2\sigma^2 e}{r}} \qquad \sigma^2 e = \text{error mean square}$$

r = number of replications

Relative heterosis was tested using standard error

$$SE = \frac{3}{2} \frac{\sigma^2 e}{r}$$

d) Associative ability analysis

Data from monocultures and physical mixtures were analysed to find out general associative ability and specific associative ability.

Associative ability analysis was done according to Model 1, method 1 of Griffing (1956) as follows:

$$Yij = m + gi + gj + sij + rij + eij$$

where Yij = mean of i + jth physical mixture

m = population mean

gi = general associative ability effect (gaa) of ith parent

gj = gaa effect of jth parent

sij = specific associative ability effect (saa) of (i+j)th physical mixture

rij = difference in performance of ith line with jth line and jth line with ith line

eij = error associated with i+jth physical mixture.

The sum of squares (SS) were calculated as follows:

$$\text{SS due to gaa} = \frac{1}{2n} \sum (Yi. + Y.j)^2 - \frac{2}{n^2} Y..^2$$

$$\text{SS due to saa} = \frac{1}{2} \sum\sum Yij\ (Yji + Yji) - \frac{1}{2n} \sum (Y.j + Y.j)^2 + \frac{1}{n^2} Y..^2$$

$$\text{SS due to differences} = \frac{1}{2} \sum\sum (Yij - Yji)^2$$

where n = number of parents

Yi. = Total of the array of i^{th} parent summed over j mixtures

Y.j = Total of the array of j^{th} parent summed over i mixtures

Yij = Performance of i^{th} line with j^{th} line

Yji = Performance of j^{th} line with i^{th} line

Y.. = Grand total of n + (n-1)n entries.

The analysis of variance table was set up as follows:

Sources	Degree of freedom	Sum of squares	Mean squares
Gaa	5	Sg	Mg
Saa	15	Ss	Ms
Differences	15	Sr	Mr
Error	69	Se	Me'

$$Me' = \frac{\text{Error mean square (Me)}}{\text{Number of replications}}$$

To test the variance due to general associative ability effect

$$F\ (5,\ 69) = \frac{Mg}{Me},$$

To test the variance due to specific associative ability effect

$$F\ (15,\ 69) = \frac{Ms}{Me},$$

To test the variance due to reciprocal effect

$$F\ (15,\ 69) = \frac{Mr}{Me},$$

Estimates of general and specific associative ability effects and reciprocal effects were calculated as follows:

$$gi = \frac{1}{2n}\ (Yi. + Y.i) - \frac{1}{2}\ Y..$$

$$sij = \frac{1}{2}\ (Yij + Yji) - \frac{1}{2n}\ (Yi. + Y.i + Yj. + Y.j) + \frac{1}{n^2}\ Y..$$

$$rij = \frac{1}{2}\ (Yij - Yji)$$

n, Yi., Y.j, Yji, Yij and Y.. were the same as explained earlier.

Variances, standard errors and critical differences were estimated

$$\text{Var (gi)} = \frac{n-1}{2n^2} \sigma^2 e$$

$$\text{Var (sij)} = \frac{1}{2n^2} (n^2-2n+2) \sigma^2 e$$

$$\text{Var (rij)} = \frac{1}{2} \sigma^2 e$$

$$\text{Var (gi - gj)} = \frac{1}{n} \sigma^2 e$$

$$\text{Var (sij - sik)} = \frac{(n-1)}{n} \sigma^2 e$$

$$\text{Var (sij - skl)} = \frac{(n-2)}{n} \sigma^2 e$$

$$\text{Var (rij - rkl)} = \sigma^2 e$$

These values were used to calculate critical differences to compare different effects.

●) General coexistence ability index

General coexistence ability index of a genotype refers to the ratio of its average performance in the mixture to its performance in purestand.

$$GC_o A(i) = \frac{\overline{Mi}}{\overline{M}}$$

where $GC_o A(i)$ = the general coexistence ability of i^{th} genotype in various combinations

$\overline{M}$ = mean performance of the i^{th} genotype in purestand

$\overline{M_i}$ = mean performance of the i^{th} genotype in various mixture combinations

If $GC_oA(i)$ is

a) < 1, the genotype is a poor competitor

b) equal to 1, the genotype is not being affected by other varieties

c) > 1, the genotype dominates over other and therefore, it is a better competitor

f) Association among root characteristics and yield

The correlation coefficient 'r' was calculated using the formula

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left\{\sum x^2 - \frac{(\sum x)^2}{n}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{n}\right\}}}$$

where x = length/volume of root

y = yield

n = number of observations (plants)

g) Observation on root galls caused by root knot nematode, *Meloidogyne incognita*.

All the parents, F_1 hybrids and physical mixtures were observed for galls caused by root knot nematodes.

E. Evaluation of two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and its components

1) Materials

Three tomato lines were used to develop the two way and three way physical mixtures. They were LE 206, LE 212 and IIHR Bwr 34A. The genotypes are designated hereafter as 1, 2 and 3 respectively.

The physical mixtures were

i) 1 + 2

ii) 1 + 3

iii) 2 + 3

iv) 1 + 2 + 3

2) Layout and experimental design

The experiment was conducted during July-November, 1985 in a uniformly fertile and wilt sick soil. The three parental lines and the various physical mixtures were grown in a completely randomised design. There were 60 plants for each entry. Where two and three varieties were involved, each variety constituted respectively about 50 and 33.3% of total plants.

The plants were observed for incidence of bacterial wilt. Bacterial ooze test was done to confirm wilt reaction. The disease rating was according to Mew and Ho (1976).

Five plants from parental line and five plants each from each component line of a physical mixture were selected randomly and the following observations were made:

Productive characters

i) days to fruit set

ii) days to fruit harvest

iii) fruit set (%)

iv) fruits/plant

v) fruit yield/plant

3) Statistical analysis of data

a) Analysis of variance

The data were analysed for analysis of variance for a completely randomised design.

b) General coexistence ability index

General coexistence ability index was calculated as in the previous experiment.

C. Maternal effects for certain quantitative characters in tomato

1) Materials

Five tomato lines, LE 79 LFF(1), LE 214(2), LE 217(3), IIHR Bwr 93(4) and LE 206(5) were crossed in all possible combinations. The various direct and reciprocal hybrids were

Direct F_1 hybrids				Reciprocal F_1 hybrids			
i)	1 x 2	vi)	2 x 4	i)	2 x 1	vi)	4 x 3
ii)	1 x 3	vii)	2 x 5	ii)	3 x 1	vii)	5 x 1
iii)	1 x 4	viii)	3 x 4	iii)	3 x 2	viii)	5 x 2
iv)	1 x 5	ix)	3 x 5	iv)	4 x 1	ix)	5 x 3
v)	2 x 3	x)	4 x 5	v)	4 x 2	x)	5 x 4

2) Lay out and experimental design

The direct and reciprocal F_1 hybrids were grown during July-November, 1985 in a randomised block design with three replications. There were two rows of 10 plants each/entry/replication. Spacing was 70 x 60 cm. Pusa Ruby was spot-planted. The plants were observed for incidence of bacterial wilt. Five plants were selected randomly from each line/replication for taking observations.

a) Vegetative characters

i) Plant height - observed at second harvest

ii) Primary branches/plant - observed at second harvest

b) Productive characters

i) days to fruit set

ii) days to fruit harvest

iii) fruit set (%)

iv) fruits/plant

v) fruit yield/plant

c) Disease scoring - number of survived plants where Pusa Ruby wilted.

3) Statistical analysis of data

a) Analysis of variance

The data were analysed for analysis of variance as described by Cochran and Cox (1966). The variance due to F_1 hybrids was partitioned into variance due to direct hybrids, reciprocal hybrids and direct vs. reciprocal hybrids.

b) Combining ability analysis

Combining ability analysis was carried out according to Model 1, Method 3 of Griffing (1956).

The sum of squares (SS) were calculated as follows:

$$\text{SS due to gca} = \frac{1}{2(n-2)} \sum (Yi. + Y.i)^2 - \frac{2}{n(n-2)} Y..^2$$

$$\text{SS due to sca} = \frac{1}{2} \sum \sum (Yij + Yji)^2 - \frac{1}{2(n-2)} \sum (Yi. + Y.j)^2 + \frac{1}{(n-1)(n-2)} Y..^2$$

$$\text{SS due to reciprocals} = \frac{1}{2} \sum \sum (Yij - Yji)^2$$

where

n = number of parents

Yi. = total of the array of i^{th} parent summed over j direct crosses

Y.j = total of the array of j^{th} parent summed over j indirect crosses

Yij = mean value of ixj^{th} cross

Yji = mean value of jxi^{th} cross

Y.. = grand total of n(n-1) entries

Analysis of variance for combining ability

Sources	Degree of freedom	Sum of squares	Mean squares
Gca	4	Sg	Mg
Sca	5	Ss	Ms
	10	Sr	Mr
Error	38	Se	Me'

$$Me' = \frac{\text{Error mean squares (Me)}}{\text{Number of replications}}$$

To test the variance due to gca effect $F_{(4,\ 38)} = \frac{Mg}{Me'}$

To test the variance due to sca effect $F_{(5,\ 38)} = \frac{Ms}{Me'}$

To test the variance due to reciprocal effect $F_{(10,38)} = \frac{Mr}{Me'}$

General and specific combining ability effects and reciprocal effects were estimated

$$gi = \frac{1}{2n(n-2)} \left\{ n\ (Yi. + Y.i) - 2\ Y.. \right\}$$

$$sij = \frac{1}{2}\ (Yij + Yji) - \frac{1}{2(n-2)}\ (Yi. + Y.i + Yj. + Y.j) + \frac{1}{(n-1)(n-2)}\ Y..$$

$$rij = \frac{1}{2}\ (Yij - Yji)$$

n, Y.i, Y.j, Yji, Yij and Y.. were the same as explained earlier.

Variances, standard errors and critical differences were estimated

$$\text{Var } (gi) = (n-1)\ \sigma^2 e/2n(n-2)$$

$$\text{Var } (sij) = (n-3)\ \sigma^2 e/2(n-1)$$

$$\text{Var } (rij) = \sigma^2 e/2$$

$$\text{Var } (gi - gj) = \sigma^2 e/(n-2)$$

$$\text{Var } (sij - sik) = (n-3)\ \sigma^2 e/(n-2)$$

$$\text{Var } (sij - skl) = (n-4)\ \sigma^2 e/(n-2)$$

These values were used to calculate critical differences to compare different effects.

D. Evaluation of a set of tomato lines for resistance to bacterial wilt and economic characters

1) Materials

The tomato lines LE 206, LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 214, LE 217, LE 79 LFF, LE 79 LFG, LE 79 DG, IIHR Bwr 93 and IIHR Bwr 34A were evaluated (Table 1). Pusa Ruby was spot-planted to confirm presence of virulent inoculam in the soil.

2) Lay out and experimental design

The plants were grown in a randomised block design with 20 plants/line/replication during August-November, 1985. Spacing was 70 cm x 60 cm. The lines were genetically catalogued (Tomato Genetics Cooperative, 1980) (Table 2). The plants were evaluated for wilt incidence. The wilting of the susceptible check indicated the presence of virulent pathogen in the soil. Bacterial ooze test was also carried out. Five plants were randomly selected from each line/replication and the following observations were taken:

a) Vegetative characters

i) plant height - observed at second harvest
ii) primary branches/plant - observed at second harvest

Table 1. Accession number, name, pedigree and source of tomato lines

Accession number	Name	Pedigree	Source
Lycopersicon esculentum			
LE 206	CL 9-0-0-1-30-4	Vc-11-1-2-1B/Saturn	AVRDC, Taiwan
LE 208	CL 143-0-10-3-1-2	Vc-48-1/Tamuchico III	- do -
LE 209	CL 1104-0-0-71-4-2	Vc-9-1-ug/Saturn/ah Tm-2a/ Vc-11-1-Ug	- do -
LE 210	CL 1131-00-38-40	Vc-48-1/Tamu chico III ah Tm-2a/Vc-11-1-Ug	- do -
LE 211	CL 1351-1-6	Carorich/Vc-11-1-Ug/Vc-11 1-Ug BC2///(ah Tm-2a/ Vc-8-1-2-1)-4-4-0	- do -
LE 212	CL 1351-1-9	Carorich/Vc-11-1-Ug/Vc-11 1-Ug BC_2 (ah Tm-2a/Vc- 8-1-2-98/Vc-9-1-2-9B)	- do -
LE 213	CL 1219-0-6-2	71-483 N/Vc-9-1-2-9B// Vc-9-1-2-9B///Vc-9-1-2-9B	- do -
LE 214	CL 948-0-20-2	KL 1/Vc-11-3-4//1339/ Ottawa 66 (F_3)	- do -

Table 1. (Contd.)

Accession number	Name	Pedigree	Source
LE 217	Louisiana Pink	P.I. 143572/PI 270196	Vegetable Laboratory, USDA, BARC-W USA
LE 79 LFG	CL 32d-0-1-1-1-1-19 GS	Vc-9-1-2-3/Venus	KAU, Vellanikkara
LE 79 DG	CL 32d-0-1-1-1-1-19 GS	Vc-9-1-2-3/Venus	- do -
LE 79 LFF	CL 32d-0-1-1-1-1-19 GS	Vc-9-1-2-3/Venus	- do -
IIHR Bwr 93	-	-	IIHR Banglore
IIHR Bwr 34A	-	-	- do -
LE 5	Pusa Ruby	Improved Meeruti x Sioux	IARI New Delhi

b) Productive characters

i) days to fruit set

ii) days to fruit harvest

iii) fruit set (%)

iv) fruits/plant

v) fruit yield/plant

c) Disease scoring - number of normal plants were Pusa Ruby wilted.

3) Statistical analysis

Data were analysed as in a randomised block design. The line LE 209 was missing in one replication and missing plot technique was followed.

Table 2. Gene list of characters

Gene	Name	Phenotype	Locus	
			Chromosome	Site
a	Anthocyaninless	Completely anthocyaninless	IIL	68
c	Potato leaf	Fewer leaf segments	6L	104
dp	Drooping leaf	Leaf drooping, elongate, dark green, stem weak, slender and prostrate	-	-
f	Fasciated	Fruits fasciated, many loculed	11L	95
n	Nipple tip	At stylar end of the fruit	5	-
o	Ovate	Fruits ovate	2L	55
pst	Persistant style	Developing into beak	7S	5
sp	Self pruning	Determinate habit	6L	-
u	Uniform ripening	Unripe fruits lack bicolour pigmentation	10S	14

Results

RESULTS

The results in the present investigations are presented under the following heads.

A. Evaluation of six specific lines of tomato, their F_1 hybrids and 50:50 physical mixtures for resistance to bacterial wilt, fruit yield and yield components

B. Evaluation of two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and yield components

C. Maternal effects for certain quantitative characters in tomato

D. Evaluation of a set of tomato lines for economic characters and resistance to bacterial wilt

A. Evaluation of six specific lines of tomato, their F_1 hybrids and 50:50 physical mixtures for resistance to bacterial wilt, fruit yield and yield components

During July to November, 1985, six lines of tomato - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93, IIHR Bwr 34A and LE 206 -, their one way F_1 hybrids and 50:50 physical mixtures were evaluated under field conditions for their bacterial wilt reaction. The susceptible check Pusa Ruby succumbed to wilt confirming presence of virulent inoculam in the field. The hybrids and lines were classified for wilt reaction according to Mew and Ho (1976) (Table 3). LE 214 and LE 217 were resistant with a wilt reaction of 11.67% and 13.33% respectively. IIHR Bwr 93 (21.67%) and IIHR Bwr 34A (20.69%) were moderately resistant. The lines LE 79 LFF (56.67%) and LE 206 (43.10%) were moderately susceptible. All F_1 hybrids except IIHR Bwr 93 x IIHR Bwr 34A and IIHR Bwr 34A x LE 206 were resistant. LE 214 x IIHR Bwr 34A had a disease incidence of only 5%. LE 214 + LE 217, LE 214 + IIHR Bwr 93, LE 214 + IIHR Bwr 34A, LE 217 + IIHR Bwr 93, LE 217 + IIHR Bwr 34A and IIHR Bwr 93 + IIHR Bwr 34A were resistant with a disease reaction of 16.67%, 18.33%, 10.00%, 15%, 15% and 13.33% respectively. LE 79 LFF + LE 217 (31.67%), LE 214 + LE 206 (25%), LE 217 + LE 206 (28.33%), IIHR Bwr 93 + LE 206 ([illegible]%) and IIHR Bwr 34A + LE 206 (25%) were moderately resistant. LE 79 LFF + LE 214, LE 79 LFF + IIHR Bwr 93, LE 79 LFF + IIHR Bwr 34A and LE 79 LFF + LE 206 were moderately susceptible with a wilt reaction of 43.33%, 41.66%, 40% and 50% respectively.

1) Analysis of variance for yield and yield components

Data on plant height, primary branches/plant, days to fruit set, days to fruit harvest, fruit set (%), fruits/plant and fruit yield/plant were analysed (Table 4). Variance due to genotypes were significant for all the

Table 3. Evaluation of six specific tomato lines, their F_1 hybrids and 50:50 physical mixtures for resistanteto bacterial wilt

Entry	Total number of plants	No. of plants wilted	Wilt reaction (%)
Lines			
LE 79 LFF	60	34	56.67 (MS)
LE 214	60	7	11.67 (R)
LE 217	60	8	13.33 (R)
IIHR Bwr 93	60	13	21.67 (MR)
IIHR Bwr 34A	58	12	20.69 (MR)
LE 206	58	25	43.10 (MS)
F_1 hybrids			
1 x 2	58	5	8.60 (R)
1 x 3	58	3	5.17 (R)
1 x 4	58	6	10.35 (R)
1 x 5	58	3	5.17 (R)
1 x 6	58	10	17.24 (R)
2 x 3	58	4	6.90 (R)
2 x 4	60	9	15.00 (R)
2 x 5	60	3	5.00 (R)
2 x 6	60	8	13.33 (R)
3 x 4	60	4	6.67 (R)
3 x 5	60	5	8.33 (R)
3 x 6	60	4	6.67 (R)
4 x 5	51	18	35.29 (MR)
4 x 6	60	8	13.33 (R)
5 x 6	60	18	30.00 (MR)

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

Table 3. (Contd.)

Entry	Total number of plants	No. of plants wilted	Wilt reaction (%)
Physical mixtures			
1 + 2	60	26	43.33 (MS)
1 + 3	60	19	31.67 (MR)
1 + 4	60	25	41.66 (MS)
1 + 5	60	24	40.00 (MS)
1 + 6	60	30	50.00 (MS)
2 + 3	60	10	16.67 (R)
2 + 4	60	11	18.33 (R)
2 + 5	60	6	10.00 (R)
2 + 6	60	15	25.00 (MR)
3 + 4	60	9	15.00 (R)
3 + 5	60	9	15.00 (R)
3 + 6	60	17	28.33 (MR)
4 + 5	60	8	13.33 (R)
4 + 6	60	18	30.00 (MR)
5 + 6	60	15	25.00 (MR)

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

characters. The six parental lines were different for plant height, days to fruit set, days to fruit harvest, fruits/plant and fruit yield/plant. The mean squares due to hybrids and physical mixtures were significant for all the characters. The hybrids were not significantly different for primary branches/plant, days to fruit set, days to fruit harvest and fruits/plant. Mean squares due to physical mixtures were significant for plant height, primary branches/plant, days to fruit set, days to fruit harvest and fruits/plant. Variance due to hybrids vs physical mixtures were significant for all the characters except primary branches/plant. Mean squares due to parent vs. hybrids and physical mixtures were significant for days to fruit set, fruit set (%), and fruit yield/plant.

Among F_1 hybrids, LE 214 x LE 217 had the maximum plant height at second harvest (104.2 cm). LE 79 LFF + LE 217 was the tallest among physical mixtures (87 cm). LE 79 LFF x LE 206 had the highest number of primary branches/plant at second harvest (8.3). Among mixtures, LE 79 LFF + LE 217 had the maximum primary branches/plant (8.75) at second harvest. The line IIHR Bwr 93 was earlier both for days to fruit set and fruit harvest (60.67 and 86.73 days respectively) (Table 5). Among F_1 hybrids LE 214 x IIHR Bwr 34A was earlier for days to fruit set (56.8) and days to fruit harvest (84.47). Among physical mixtures IIHR Bwr 93 + LE 206 was earlier, which took

Table 4. General analysis of variance

Sources of variation	df	Mean squares: Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Replications	2	123.14**	6.65**	10.73	15.77*	14.51	120.12**	38935.15*
Genotypes	35	298.04**	2.50**	72.39**	62.79**	55.63**	74.00**	85829.86**
Parents	5	383.68**	1.37	37.87**	33.09**	15.13	129.87**	24546.97*
Hybrids and physical mixtures	29	293.30**	2.71**	79.61**	69.62**	61.43**	66.70**	96089.41**
Hybrids	14	322.03**	1.52	5.85	5.30	51.68**	27.06	163038.45**
Physical mixtures	14	177.85**	4.03**	13.39**	11.61**	6.83	47.35**	10386.83
Hybrids vs physical mixtures	1	1507.27**	1.02	2039.37**	1782.15**	962.36**	486.64**	358638.98**
Parents vs hybrids and physical mixtures	1	7.42	2.02	35.67*	13.41	90.02**	6.25	94717.35**
Error	69	22.03	0.84	7.14	4.71	7.24	17.45	9866.98

* P = 0.05

** P = 0.01

Table 5. Mean performance of six specific tomato lines, their F_1 hybrids and 50:50 physical mixtures

Entry	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant (g)
Lines							
LE 79 LFF	78.93	6.78	68.90	92.63	51.68	20.59	474.62
LE 214	93.70	6.77	66.93	92.71	63.29	28.53	621.42
LE 217	89.87	7.80	67.47	95.63	54.10	32.33	700.00
IIHR Bwr 93	67.02	5.87	60.67	86.73	54.53	16.25	489.17
IIHR Bwr 34A	67.63	6.07	61.00	88.60	58.39	16.22	655.75
LE 206	85.76	6.59	63.00	93.58	57.43	21.38	583.66
F_1 hybrids							
1 x 2	88.77	7.15	58.00	87.03	77.07	30.42	758.67
1 x 3	88.93	7.13	57.00	85.40	81.21	33.07	887.17
1 x 4	75.20	6.88	57.67	86.33	68.53	26.32	877.92
1 x 5	69.60	5.85	56.87	85.47	63.04	23.20	908.02
1 x 6	80.92	8.30	57.33	85.33	66.80	29.55	889.00
2 x 3	104.20	7.60	60.93	89.80	65.77	26.93	551.33
2 x 4	87.63	6.73	56.93	86.13	68.84	27.60	887.33
2 x 5	87.57	6.93	56.80	84.47	58.40	22.43	820.83
2 x 6	91.87	7.83	57.80	85.00	70.31	27.15	921.75

Table 5. (Contd.)

Entry	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant (g)
3 x 4	88.03	8.13	57.80	85.26	60.96	24.27	802.44
3 x 5	87.94	6.67	58.73	85.67	68.96	24.65	880.67
3 x 6	93.73	7.93	59.87	86.87	64.44	28.55	836.58
4 x 5	68.33	6.93	60.65	87.90	58.09	17.60	739.75
4 x 6	77.00	6.47	59.27	86.47	62.50	23.53	801.35
5 x 6	68.35	6.27	59.53	86.60	59.26	17.67	821.67
Physical mixtures							
1 + 2	81.85	8.32	67.94	96.10	55.88	19.52	465.94
1 + 3	87.00	8.75	69.17	96.43	53.77	21.28	454.54
1 + 4	70.83	6.45	67.29	93.55	58.50	14.67	398.22
1 + 5	71.72	7.64	68.11	96.67	50.93	15.38	414.38
1 + 6	79.34	6.68	67.41	96.62	59.69	20.93	498.27
2 + 3	86.32	8.00	71.47	98.47	56.33	26.87	562.32
2 + 4	73.28	7.28	66.87	94.82	57.28	24.07	600.38
2 + 5	74.23	7.28	66.83	94.31	57.27	23.39	585.35
2 + 6	85.72	8.13	68.33	96.33	58.54	25.51	552.96

Table 5. (Contd.)

Entry	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant (g)
3 + 4	74.36	5.87	69.60	96.63	53.99	23.65	481.09
3 + 5	73.34	5.93	70.73	96.42	52.61	22.67	537.11
3 + 6	81.55	7.31	69.19	93.00	54.83	24.76	535.18
4 + 5	61.55	5.09	65.50	93.80	51.40	17.54	497.57
4 + 6	67.92	5.50	62.86	91.08	53.99	16.24	492.77
5 + 6	66.27	5.43	66.69	93.01	56.44	16.68	538.38
CD for comparing treatment with no missing value (P = 0.05)	7.65	1.49	4.35	3.55	4.38	6.80	161.72
CD for comparing treatment with one missing value (P = 0.01)	8.58	1.68	4.88	3.99	4.92	7.63	181.50
Sem ±	2.70	0.53	1.54	1.26	1.55	2.41	57.34

62.86 days to fruit set and 91.08 days to fruit harvest. LE 79 LFF x LE 217 had the highest per cent of fruit set (81.21). Among mixtures, LE 79 LFF + LE 206 had the highest per cent of fruit set (59.69). LE 79 LFF x LE 217 had the highest number of fruits/plant (33.07). LE 214 x LE 206 yielded 921.75 g/plant followed by LE 79 LFF x IIHR Bwr 34A (908 g/plant). Among physical mixtures, LE 214 + LE 217 had the highest number of fruits/plant (26.87) while LE 214 + IIHR Bwr 93 had the maximum yield (600.38 g/plant) (Table 5).

2) Analysis of variance for combining ability

The combining ability analysis was done for each of the quantitative characters studied (Table 6). The general and specific combining ability effects were estimated.

Plant height

Variances due to gca and sca were significant (Table 7). LE 214 had the maximum gca effect (8.39) and IIHR Bwr 34A had the minimum gca effect (-7.91). The highest sca effect was recorded in LE 214 x LE 217 (5.13). IIHR Bwr 34A x LE 206 had the minimum sca effect (-7.02) (Table 7).

Primary branches/plant

Only variance due to gca was significant (Table 6). The maximum gca effect was manifested by LE 217 (0.52) and the minimum in IIHR Bwr 34A (-0.51). LE 79 LFF x LE 206

Table 6. Analysis of variance for combining ability effects

Source of variation	df	Mean squares						
		Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant (g)
Gca	5	381.60**	1.00*	4.74**	6.17**	14.90**	44.85*	2850.00
Sca	15	18.90*	0.35	15.85**	11.60**	22.16**	19.45**	26157.10**
Error	39	1.73	0.35	1.34	0.71	2.57	6.97	4773.66

* P = 0.05

** P = 0.01

expressed the maximum sca effect (1.18) and the minimum was expressed by LE 79 LFF x IIHR Bwr 34A (-0.62) (Table 8).

Days to fruit set

Variance due to gca and sca were significant (Table 6). In the study of combining ability effects, positive values indicated tendency towards more days to fruit set and negative values indicated tendency towards earliness. LE 217 had the highest gca effect (1.03). The lowest gca effect was recorded in IIHR Bwr 93 (-0.92). IIHR Bwr 93 x IIHR Bwr 34A had the highest sca effect (2.23). The lowest sca effect was manifested by LE 79 LFF x LE 217 (-4.63) (Table 9).

Days to fruit harvest

Variances due to gca and sca were significant (Table 6). LE 217 had the highest gca effect (1.22). The lowest gca effect was expressed by IIHR Bwr 93 (-1.12). The highest sca effect was recorded in IIHR Bwr 34A x LE 206 (6.33). LE 79 LFF x LE 214 expressed the minimum sca effect (-3.65) (Table 10).

Fruit set (%)

Variances due to gca and sca were significant (Table 6). LE 214 had the highest gca effect (1.63) and the lowest gca effect was expressed by IIHR Bwr 34A (-1.6). The highest

Table 7. General and specific combining ability effects for plant height

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	-2.38	-0.14	0.63	0.94	-3.01	0.02
P_2		8.39	5.13	2.60	4.19	0.20
P_3			7.18	3.61	5.16	2.68
P_4				-6.26	-0.40	-0.02
P_5					-7.91	-7.02
P_6						0.38

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.43	-
sca (sij)	0.96	-
gi - gj	0.66	1.34
sij - sik	1.74	3.52
sij - skl	1.61	3.26

P_1 - LE 79 LFF

P_2 - LE 214

P_3 - LE 217

P_4 - IIHR Bwr 93

P_5 - IIHR Bwr 34A

P_6 - LE 206

gca - diagonal

sca - above diagonal

Table 8. General and specific combining ability effects for primary branches/plant

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	-0.003	0.06	-0.37	0.15	-0.62	1.18
P_2		0.11	-0.02	-0.11	0.35	0.60
P_3			0.52	0.88	-0.32	0.29
P_4				-0.25	0.71	-0.40
P_5					-0.51	-0.34
P_6						0.14

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.19	-
sca (sij)	0.43	-
gi - gj	0.30	0.61
sij - sik	0.78	1.58
sij - skl	0.73	1.47

Table 9. General and specific combining ability effects for days to fruit set

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	0.45	-3.01	-4.63	-2.01	-2.93	-3.12
P_2		0.41	-0.66	-2.71	-2.95	-2.61
P_3			1.03	-2.46	-1.64	-1.16
P_4				-0.92	2.23	0.20
P_5					-0.81	0.34
P_6						-0.16

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.37	-
sca (sij)	0.85	-
gi - gj	0.58	1.17
sij - sik	1.53	3.10
sij - skl	1.42	2.87

Table 10. **General and specific combining ability effects for days to fruit harvest**

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	0.04	-1.21	-3.65	-0.38	-1.46	-2.86
P_2		0.41	0.38	-0.96	-2.84	-3.57
P_3			1.22	-2.63	-2.44	-2.50
P_4				-1.12	2.13	0.70
P_5					0.90	6.33
P_6						0.36

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.27	-
sca (sij)	0.62	-
gi - gj	0.42	0.85
sij - sik	1.12	2.26
sij - skl	1.03	2.07

Table 11. General and specific combining ability effects for fruit set (%)

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	1.41	5.41	9.55	2.88	-0.18	0.95
P_2		1.63	-0.80	2.79	-3.19	2.90
P_3			0.41	-0.72	4.37	0.53
P_4				-1.30	-0.44	1.12
P_5					-1.60	-0.50
P_6						-0.60

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.52	-
sca (sij)	1.17	-
gi - gj	0.80	1.62
sij - sik	2.12	4.29
sij - skl	1.96	3.97

Table 12. General and specific combining ability effects for fruits/plant

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	1.37	2.01	3.35	2.88	1.49	3.96
P_2		2.34	-3.78	3.18	-0.26	0.56
P_3			3.67	-1.46	0.64	0.64
P_4				-2.62	-0.12	-3.95
P_5					-4.35	1.49
P_6						-0.44

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.85	-
sca (sij)	1.93	-
gi - gj	1.32	2.67
sij - sik	3.49	7.07
sij - skl	3.23	6.54

Table 13. General and specific combining ability effects for fruit yield/plant

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	-4.01	20.22	126.72	151.36	132.10	119.19
P_2		-14.98	-198.15	171.74	55.39	162.91
P_3			7.01	64.86	93.73	55.75
P_4				-26.87	-13.30	54.39
P_5					22.48	25.37
P_6						16.37

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	21.94	-
sca (sij)	49.75	-
gi - gj	33.99	68.69
sij - sik	89.92	181.73
sik - skl	83.25	168.25

sca value was recorded in LE 79 LFF x LE 217 (9.54). LE 214 x IIHR Bwr 34A had the lowest sca effect (-3.19) (Table 11).

Fruits/plant

Variances due to gca and sca were significant (Table 6). LE 217 had the highest gca effect (3.67). The lowest gca effect was expressed by IIHR Bwr 34A (-4.35). The highest sca effect was expressed by LE 79 LFF x LE 206 (3.94) followed by LE 79 LFF x LE 217 (3.35) and the lowest by IIHR Bwr 93 x LE 206 (-3.95) (Table 12).

Fruit yield/plant

Only variance due to sca was significant (Table 6). The highest gca value was manifested by IIHR Bwr 34A (22.48) followed by LE 217 (7.01) and IIHR Bwr 93 had the lowest gca (-26.87). LE 214 x LE 206 had the highest sca effect (162.91) followed by LE 79 LFF x IIHR Bwr 93 (151.36) (Table 13).

3) Extent of heterosis in a set of tomato F_1 hybrids

Differences between parents and F_1 hybrids were substantial for most of the characters studied (Table 14).

Plant height

Six F_1 hybrids were taller than their respective taller

Table 14. General analysis of variance

Sources of variation	df	Mean squares: Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Replications	2	544.59**	4.58*	77.25**	48.77**	33.25*	79.08*	42190.45
Genotypes	20	328.66**	1.55	39.21**	30.64**	60.92**	77.38**	60788.30**
Parents	5	383.68**	1.37	37.87**	33.09**	15.13	129.81**	24546.97
F_1 hybrids	14	322.03**	1.52	5.83	5.30*	51.68**	27.06	26096.59
Parents vs F_1 hybrids	1	147.45**	2.88	512.81**	374.69**	421.63**	115.15*	727678.76**
Error	39	5.19	1.04	4.03	2.14	7.71	20.90	14320.98
CD for comparing treatments with no missing value (P=0.05)		3.76	1.68	3.31	2.41	4.58	7.54	197.47
CD for comparing treatments with one missing value (P=0.05)		4.25	1.90	3.74	2.73	5.18	8.53	223.20

parents (Table 15). Twelve hybrids were taller than their respective mid-parents. Heterobeltiosis ranged from -20.3% in IIHR Bwr 34A x LE 206 to 11.21% in LE 214 x LE 217 and relative heterosis from -10.9% in IIHR Bwr 34A x LE 206 to 13.52% in LE 214 x LE 217. LE 214 x LE 217 had 104.2 cm height, 11.21% higher than its better parent and 13.52% higher than its mid-parents.

Primary branches/plant

LE 79 LFF x LE 206 had the maximum primary branches/plant (8.3), 22.42% more than the better parent and 24.07% more than the mid-parent (Table 16). Heterobeltiosis ranged from -13.72% in LE 79 LFF x IIHR Bwr 34A to 22.42% in LE 79 LFF x LE 206. LE 79 LFF x IIHR Bwr 34A had the minimum relative heterosis of -9.02% and the maximum of 24.07% in LE 79 LFF x LE 206. Nine hybrids had more number of primary branches than their respective better parent.

Days to fruit set

All hybrids were earlier than their respective parents (Table 17). LE 214 x IIHR Bwr 34A produced first fruit 56.8 days after sowing, expressing a heterobeltiosis of -6.89% and a relative heterosis of -11.21%. LE 79 LFF x IIHR Bwr 34A and LE 214 x IIHR Bwr 93 were early hybrids (56.87 and 56.9 days respectively).

Table 15. F_1 heterosis for plant height

Parents and F_1 hybrids		Plant height (cm)	Increase or decrease over(%)	
			Mid-parent	Better parent
LE 79 LFF	(1)	78.93		
LE 214	(2)	93.70		
LE 217	(3)	89.87		
IIHR Bwr 93	(4)	67.02		
IIHR Bwr 34A	(5)	67.63		
LE 206	(6)	85.76		
1 x 2		88.77	2.84	-5.26**
1 x 3		88.93	5.37*	-1.05
1 x 4		75.20	3.04	-4.73*
1 x 5		69.60	-5.02	-11.82**
1 x 6		80.92	-1.74	2.52
2 x 3		104.20	13.52**	11.21**
2 x 4		87.63	9.05**	-6.48**
2 x 5		87.57	8.55**	-6.54**
2 x 6		91.87	2.39	-1.95
3 x 4		88.03	12.21**	-2.05
3 x 5		87.93	11.66**	-2.16
3 x 6		93.73	6.73*	4.30*
4 x 5		68.33	1.49	1.04
4 x 6		77.00	7.99**	-10.22**
5 x 6		68.35	-10.90**	-20.30**
CD for comparing treatment with no missing value (P = 0.05)		3.76	Se = 1.61	Se = 1.86
CD for comparing treatment with one missing value (P = 0.05)		4.25		

Table 16. F_1 heterosis for primary branches/plant

Parents and F_1 hybrids		Primary branches/ plant	Increase or decrease over (%) Mid-parent	Better parent
LE 79 LFF	(1)	6.78		
LE 214	(2)	6.77		
LE 217	(3)	7.80		
IIHR Bwr 93	(4)	5.87		
IIHR Bwr 34A	(5)	6.08		
LE 206	(6)	6.59		
1 x 2		7.15	5.46**	5.46**
1 x 3		7.13	-2.20**	-8.59**
1 x 4		6.88	8.69**	1.48
1 x 5		5.85	-9.02**	-13.72**
1 x 6		8.30	24.07**	22.42**
2 x 3		7.60	4.25**	-2.56**
2 x 4		6.73	6.49**	-0.59
2 x 5		6.93	7.78**	2.36**
2 x 6		7.83	17.22**	15.66**
3 x 4		8.13	18.86**	4.23**
3 x 5		6.67	-3.89**	9.70**
3 x 6		7.93	10.14**	1.67*
4 x 5		6.93	15.89**	13.98**
4 x 6		6.47	3.85**	-1.82*
5 x 6		6.27	1.10	-4.86**
CD for comparing treatment with no missing value (P = 0.05)		1.68	Se =0.72	Se =0.83
CD for comparing treatment with one missing value (P = 0.05)		1.90		

Table 17. F_1 heterosis for days to fruit set

Parents and F_1 hybrids		Days to fruit set	Increase or decrease over (%) Mid-parent	Better parent
LE 79 LFF	(1)	68.90		
LE 214	(2)	66.93		
LE 217	(3)	67.47		
IIHR Bwr 93	(4)	60.67		
IIHR Bwr 34A	(5)	61.00		
LE 206	(6)	63.00		
1 x 2		58.00	-14.61**	-13.34**
1 x 3		57.00	-16.41**	-15.52**
1 x 4		57.67	-10.99**	-4.95**
1 x 5		56.87	-12.44**	-6.77**
1 x 6		57.33	-13.07**	-9.00**
2 x 3		60.93	-9.33**	-8.97**
2 x 4		56.93	-10.77**	-6.16**
2 x 5		56.80	-11.21**	-6.89**
2 x 6		57.80	-11.04**	-8.25**
3 x 4		57.80	-9.79**	-4.73**
3 x 5		58.73	-8.58**	-3.72*
3 x 6		59.87	-8.23*	-4.97**
4 x 5		60.65	-0.31	-0.03
4 x 6		59.27	-4.12*	-2.31
5 x 6		59.53	-3.98	-2.41
CD for comparing treatment with no missing value ($P = 0.05$)		3.31	Se = 1.42	Se = 1.64
CD for comparing treatment with one missing value ($P = 0.05$)		3.74		

Days to fruit harvest

All hybrids produced fruits early compared to their mid-parents (Table 18). All the F_1s except IIHR Bwr 93 x IIHR Bwr 34A produced fruits early compared to their respective better parents. Heterobeltiosis ranged from 1.35 to -8.32% and relative heterosis, from -0.26% to -9.27%. The earlier hybrids were LE 214 x IIHR Bwr 34A (84 days) and LE 214 x LE 206 (85 days).

Fruit set (%)

The percentage fruit set was more than their respective better parents in 13 hybrids (Table 19). Heterobeltiosis ranged from -7.37% in LE 214 x IIHR Bwr 34A to 50.11% in LE 79 LFF x LE 217. Relative heterosis ranged from -4.01% in LE 214 x IIHR Bwr 34A to 53.52% in LE 79 LFF x LE 217. LE 79 LFF x LE 217 had the highest percent of fruit set (81.21%) followed by LE 79 LFF x LE 214 (77.07%). LE 79 LFF x LE 217 manifested heterobeltiosis to the extent of 50.11% and relative heterosis to 53.52%. Heterobeltiosis in LE 79 LFF x LE 214 was 21.77% and relative heterosis, 34.06%.

Fruits/plant

Seven hybrids had more fruits than their better parents and twelve had more fruits than their mid-parents (Table 20). Heterobeltiosis ranged from -24.93% to 27.83% and relative heterosis, from -11.5% to 42.89%. LE 79 LFF x LE 217 had

Table 18. F_1 heterosis for days to fruit harvest

Parents and F_1 hybrids		Days to fruit harvest	Increase or decrease over (%)	
			Mid-parent	Better parent
LE 79 LFF	(1)	92.63		
LE 214	(2)	92.71		
LE 217	(3)	95.63		
IIHR Bwr 93	(4)	86.73		
IIHR Bwr 34A	(5)	88.60		
LE 206	(6)	93.58		
1 x 2		87.03	-6.09**	-6.05**
1 x 3		85.40	-9.27**	-7.81**
1 x 4		86.33	-3.74**	-0.46
1 x 5		85.47	-5.68**	-3.53**
1 x 6		85.33	-8.55**	-7.88**
2 x 3		89.80	-4.64**	-3.14*
2 x 4		86.13	-4.00**	-0.69
2 x 5		84.47	-6.83**	-4.66**
2 x 6		85.00	-8.95**	-8.32**
3 x 4		85.26	-6.49**	-1.70
3 x 5		85.67	-7.00**	-3.31**
3 x 6		86.87	-8.38**	-7.17**
4 x 5		87.90	-0.26	1.35
4 x 6		86.47	-4.31**	-0.30
5 x 6		86.60	-5.15**	-2.26
CD for comparing treatments with no missing value (P = 0.05)		2.41	Se = 1.07	Se = 1.19
CD for comparing treatments with one missing value (p = 0.05)		2.73		

Table 19. F_1 heterosis for fruit set (%)

Parents and F_1 hybrids		Fruit set (%)	Increase or decrease over (%) Mid-parent	Increase or decrease over (%) Better parent
LE 79 LFF	(1)	51.69		
LE 214	(2)	63.29		
LE 217	(3)	54.10		
IIHR Bwr 93	(4)	54.53		
IIHR Bwr 34A	(5)	58.39		
LE 206	(6)	57.43		
1 x 2		77.07	34.06**	21.77**
1 x 3		81.21	53.52**	50.11**
1 x 4		68.53	29.03**	25.67**
1 x 5		63.04	14.54**	7.96**
1 x 6		66.80	22.43**	16.32**
2 x 3		65.77	12.04**	3.92
2 x 4		68.84	16.86**	8.77**
2 x 5		58.40	-4.01	-7.73**
2 x 6		70.31	16.48**	11.09**
3 x 4		60.96	12.22**	11.79**
3 x 5		68.96	22.60**	18.10**
3 x 6		64.44	15.55**	12.21**
4 x 5		58.09	2.89	-0.51
4 x 6		62.50	11.65**	8.83**
5 x 6		59.26	2.33	1.49
CD for comparing treatments with no missing value ($P = 0.05$)		4.58	Se = 1.96	Se = 2.27
CD for comparing treatments with one missing value ($P = 0.05$)		5.18		

Table 20. F_1 heterosis for fruits/plant

Parents and F_1 hybrids		Fruits/ plant	Increase or decrease over (%) Mid-parent	Better parent
LE 79 LFF	(1)	20.59		
LE 214	(2)	28.53		
LE 217	(3)	32.33		
IIHR Bwr 93	(4)	16.25		
IIHR Bwr 34A	(5)	16.22		
LE 206	(6)	21.38		
1 x 2		30.42	23.86**	6.63
1 x 3		33.07	24.98**	2.29
1 x 4		26.32	42.89**	27.83**
1 x 5		23.20	26.02**	12.68**
1 x 6		29.55	40.78**	25.96**
2 x 3		26.93	-11.50**	-16.70**
2 x 4		27.60	23.27**	-3.26
2 x 5		22.43	0.22	-21.38**
2 x 6		27.15	8.77**	-4.84
3 x 4		24.27	-0.08	-24.93**
3 x 5		24.67	1.61	23.69**
3 x 6		28.55	6.29	-11.69**
4 x 5		17.60	8.37**	8.31*
4 x 6		23.53	25.03**	10.06**
5 x 6		17.67	-6.01	-17.35**
CD for comparing treatments with no missing value (P = 0.05)		7.54	Se =3.23	Se = 3.73
CD for comparing treatments with one missing value (P = 0.05)		8.53		

Table 21. F_1 heterosis for fruit yield/plant

Parents and F_1 hybrids		Fruit yield/ plant	Increase or decrease over (%)	
			Mix-parent	Better parent
LE 79 LFF	(1)	474.62		
LE 214	(2)	621.42		
LE 217	(3)	700.00		
IIHR Bwr 93	(4)	489.17		
IIHR Bwr 34A	(5)	655.75		
LE 206	(6)	583.66		
1 x 2		758.67	38.44	22.09
1 x 3		887.17	51.06	26.74
1 x 4		877.92	82.18	79.47
1 x 5		908.02	60.66	38.47
1 x 6		889.00	68.00	52.32
2 x 3		551.33	-16.56	-21.24
2 x 4		887.33	59.82	42.79
2 x 5		820.83	28.54	25.17
2 x 6		921.75	52.98	48.33
3 x 4		802.44	34.96	14.63
3 x 5		880.67	29.92	25.81
3 x 6		836.58	30.34	19.51
4 x 5		739.75	29.22	12.81
4 x 6		801.33	49.39	37.29
5 x 6		821.67	32.59	25.30
CD for comparing treatments with no missing value (P = 0.05)		197.47	Se=84.62	Se = 97.71
CD for comparing treatments with one missing value (P = 0.05)		223.20		

33.07 fruits/plant, followed by LE 79 LFF x LE 214 (30.42). LE 79 LFF x LE 214 manifested heterobeltiosis to the extent of 2.29% and relative heterosis to the tune of 24.98%. Heterobeltiosis in LE 79 LFF x LE 214 was 6.63% and relative heterosis was 23.86%.

Fruit yield/plant

Fruit yield/plant was more than their respective better parents in fourteen hybrids (Table 21). Heterobeltiosis ranged from -21.24% in LE 214 x LE 217 to 79.47% in LE 79 LFF x IIHR Bwr 93. The best F_1 hybrid LE 214 x LE 206 yielded 921.75 g/plant. This was 48.33% more than the better parent, LE 206 (655.75 g) and 52.98% more than the mid-parent. Relative heterosis ranged from -16.56% in LE 214 x LE 217 to 82.18% in LE 79 LFF x IIHR Bwr 93.

4) Associative ability analysis in a set of 50:50 physical mixtures

The associative ability analysis was done for each of the quantitative characters studied (Table 22, 23). The general associative ability (gaa) effects, specific associative ability (saa) effects and performance differences were estimated.

Plant height

Variances due to gaa, saa and performance differences were significant (Table 23). The highest gaa effect was

Table 22. General analysis of variance

Source of variation	df	Mean squares						
		Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant
Replications	2	92.54	5.74	23.52	24.81	80.52	61.87	4696.17
Genotypes	35	353.91	5.80	33.80	28.85	54.75	92.57	17884.61
Error	69	25.90	1.08	12.15	6.82	36.48	22.81	6153.02

Table 23. General analysis of variance for associative ability

Sources of variation	df	Mean squares						
		Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
gaa	5	424.37**	5.27**	26.07**	20.83**	32.06*	110.51**	19908.60**
saa	15	18.11*	0.90**	7.12	9.47**	10.28	5.73	4327.29*
Differences	15	115.69**	1.86**	10.51**	6.03**	21.63	29.44**	2951.08
Error	69	8.63	0.36	4.05	2.27	12.16	7.60	2051.01

* P = 0.05

** P = 0.01

manifested in LE 217 (5.47) and the lowest in IIHR Bwr 93 (-7.54). saa value was maximum in LE 79 LFF + LE 217 (2.91) and minimum in IIHR Bwr 34A + LE 206 (-4.42) (Table 24).

Primary branches/plant

Variances due to gaa, saa and performance differences were significant (Table 23). gaa value was maximum in LE 214 (0.76) and minimum in IIHR Bwr 93 (-0.88). The highest saa effect was recorded in LE 79 LFF + LE 217 (0.98) and the lowest in LE 217 + IIHR Bwr 34A (-0.75) (Table 25).

Days to fruit set

Variance due to gaa was significant. Variance due to saa was not significant (Table 23). LE 217 had the highest gaa value (2.06) and the lowest value was in IIHR Bwr 93 (-1.99). The highest saa effect was manifested by IIHR Bwr 34A + LE 206 (2.19). IIHR Bwr 93 + LE 206 had the lowest saa effect (-1.79) (Table 26).

Days to fruit harvest

Variances due to gaa, saa and performance differences were significant (Table 23). The highest gaa value was recorded in LE 217 and the lowest in IIHR Bwr 93 (-1.8). The highest saa effect was recorded in LE 79 LFF + IIHR Bwr 34A (2.6) and the lowest in LE 217 + LE 206 (-1.85) (Table 27).

Fruit set (%)

Only variance due to gca was significant (Table 23). LE 214 recorded the highest gca (2.62) and LE 217 the lowest (-1.26). sca effect was maximum in LE 79 LFF + LE 206 (3.83) and minimum in LE 79 LFF + IIHR Bwr 34A (-3.89) (Table 28).

Fruits/plant

Variances due to gca and performance differences were significant (Table 23). LE 217 had the highest gca effect (3.96) and the lowest was expressed by IIHR Bwr 34A (-2.66). LE 79 LFF + LE 206 expressed the highest sca effect (2.16) and the lowest by LE 214 + LE 217 (-1.94) (Table 29).

Fruit yield/plant

Variances due to gca and sca were significant (Table 23). LE 214 had the highest gca value (44.16) and the lowest gca value was in LE 79 LFF (-68.17). Maximum sca effect was recorded in LE 214 + IIHR Bwr 93 (61.77) and the lowest in LE 79 LFF + IIHR Bwr 34A (-55.64) (Table 30).

5) General coexistence ability index of selected tomato lines

For plant height, the GCoA estimate of only LE 79 LFF was greater than unity (1.03). The GCoA estimates of other lines were LE 214 (0.93), LE 217 (0.95), IIHR Bwr 93 (0.92),

Table 24. General associative ability (gaa), specific associative ability (saa) and performance differences for plant height

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	**2.02**	-2.65	2.91	-0.84	2.76	-0.45
P_2	-5.89	**5.93**	-1.67	-2.08	-1.25	2.03
P_3	2.25	-0.14	**5.47**	-0.21	-1.69	-1.68
P_4	6.40	10.82	13.84	**-7.54**	-0.47	-2.30
P_5	8.81	12.48	10.67	-1.80	**-7.04**	-4.42
P_6	3.00	3.15	2.15	-5.52	-8.63	**1.16**

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.77	-
saa (sij)	1.77	-
difference (rij)	2.08	-
gi - gj	1.20	2.39
sij - sik	2.68	5.35
sij - skl	2.40	4.78
rij - rkl	2.94	5.86

gaa - diagonal and underlined

saa - above diagonal

differences - below diagonal

Table 25. General associative ability (gaa), specific associative ability (saa) and performance differences for primary branches/plant

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	0.50	-0.05	0.98	-0.34	0.90	-0.46
P_2	-1.24	0.76	-0.03	0.58	0.28	0.78
P_3	-0.33	-0.13	0.74	-0.53	-0.75	0.26
P_4	0.30	1.28	1.01	-0.88	-0.27	-0.26
P_5	1.06	1.96	1.47	-0.54	-0.58	-0.58
P_6	-0.13	0.96	0.76	-0.72	-0.56	-0.23

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.16	-
saa (sij)	0.36	-
differences (rij)	0.42	-
gi - gj	0.25	0.49
sij - sik	0.55	1.09
sij - skl	0.49	0.98
rij - rkl	0.60	1.20

Table 26. General associative ability (gaa), specific associative ability (saa) and performance differences for days to fruit set

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	<u>0.90</u>	-0.52	-1.63	0.85	0.94	0.68
P_2	-0.98	<u>0.69</u>	1.32	0.76	-0.40	0.70
P_3	-2.25	0.84	<u>2.06</u>	2.12	1.41	-0.84
P_4	-0.07	3.54	1.27	-<u>1.99</u>	0.81	-1.79
P_5	2.41	3.31	1.78	-0.17	-<u>0.73</u>	2.19
P_6	3.06	3.10	1.99	0.66	-3.85	-<u>0.90</u>

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.53	-
saa (sij)	1.21	-
differences (rij)	1.42	-
gi - gj	0.83	1.65
sij - sik	1.84	3.66
sij - skl	1.64	3.28
rij - rkl	2.01	4.01

Table 27. General associative ability (gaa), specific associative ability (saa) and performance differences for days to fruit harvest

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	1.25	-0.70	-1.00	0.98	2.60	1.46
P_2	-0.03	0.86	1.42	0.90	-0.55	2.50
P_3	-1.60	-0.34	1.33	2.25	1.08	-1.85
P_4	-0.48	1.96	1.84	-1.80	1.40	-1.17
P_5	0.84	2.38	1.64	0.60	-0.86	-0.18
P_6	0.92	2.66	3.60	-0.46	-1.58	-0.81

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.40	-
saa (sij)	0.91	-
differences (rij)	1.07	-
gi - gj	0.62	1.23
sij - sik	1.38	2.74
sij - skl	1.23	2.45
rij - rkl	1.51	3.01

Table 28. General associative ability (gaa), specific associative ability (saa) and performance differences for fruit set (%)

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	<u>-0.95</u>	-2.18	0.61	3.38	-3.89	3.83
P_2	-2.58	<u>2.62</u>	-0.34	0.18	0.52	1.27
P_3	3.03	-1.60	<u>-1.26</u>	-0.41	-0.40	-0.73
P_4	-0.12	2.47	7.80	<u>-0.85</u>	-2.03	-1.98
P_5	-2.87	-0.93	4.20	1.15	<u>-1.06</u>	0.67
P_6	-1.57	0.07	-1.18	3.94	5.44	<u>1.47</u>

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.92	-
saa (sij)	2.10	-
differences (rij)	2.47	-
gi - gj	1.42	2.83
sij - sik	3.18	6.34
sij - skl	2.85	5.68
rij - rkl	3.49	6.96

Table 29. **General associative ability (gaa), specific associative ability (saa) and performance differences for fruits/plant**

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	-2.24	-1.83	-1.74	-1.31	-1.03	2.16
P_2	-2.16	3.56	-1.94	1.56	1.18	1.76
P_3	-6.59	-1.71	3.96	0.74	-0.07	0.21
P_4	0.95	5.10	5.48	-2.35	-1.25	1.87
P_5	0.19	6.49	4.99	-0.10	-2.66	1.67
P_6	-0.76	4.51	4.76	-1.21	-0.85	-0.29

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	0.73	-
saa (sij)	1.66	-
differences (rij)	1.95	-
gi - gj	1.13	2.25
sij - sik	2.52	5.02
sij - skl	2.25	4.49
rij - rkl	2.76	5.50

Table 30. General associative ability (gaa), specific associative ability (saa) and performance differences for fruit yield/plant

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	-68.17	-23.13	-22.29	-20.57	-55.64	35.64
P_2	-62.22	44.16	-26.87	61.77	2.00	-25.01
P_3	-55.57	-21.10	23.17	-36.52	-24.25	-21.79
P_4	-23.20	-37.55	-55.67	-27.42	-13.21	-13.61
P_5	-70.21	38.57	14.22	-32.01	16.33	-10.19
P_6	-29.38	-12.74	-0.51	-17.22	26.80	11.94

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gaa (gi)	11.94	-
saa (sij)	27.22	-
differences (rij)	32.03	-
gi - gj	18.49	36.88
sij - sik	41.34	82.46
sij - skl	36.98	73.76
rij - rkl	45.29	90.33

IIHR Bwr 34A (0.92) and LE 206 (0.90). LE 79 LFF (1.09), LE 214 (1.3), LE 217 (1.01) and LE 206 (1.29) had GCoA estimates greater than one, for primary branches/plant. All lines except LE 79 LFF had GCoA values more than one for days to fruit set. LE 79 LFF could maintain its performance in mixtures (1.00). For days to fruit harvest, all lines except LE 206 had GCoA estimates greater than unity. The GCoA value of LE 79 LFF (1.05) and LE 217 (1.03) were greater than one, for fruit set (%) and that of LE 214 (0.91), IIHR Bwr 93 (0.98), IIHR Bwr 34A (0.93) and LE 206 (0.96). For fruits/plant IIHR Bwr 93 and IIHR Bwr 34A had GCoA values more than one (1.04 and 1.03 respectively) and that of LE 79 LFF (0.83), LE 214 (0.96), LE 217 (0.88) and LE 206 (0.92) were less than one. For fruit yield/plant only IIHR Bwr 93 could maintain its performance in mixtures (1.00). The GCoA estimates of LE 79 LFF, LE 214, LE 217, IIHR Bwr 34A and LE 206 were less than unity (0.85, 0.90, 0.78, 0.81 and 0.91 respectively) (Table 31).

6) Performance of pure lines and physical mixtures

The data on plant height, primary branches/plant days to fruit set, days to fruit harvest, fruit set (%), fruits/plant and fruit yield/plant were analysed (Table 32). Variances due to genotypes were significant for all the characters except fruit set (%). The six parental lines were different for plant height, days to fruit set, days to fruit harvest, fruits/plant and fruit yield/plant. The mean

Table 32. General analysis of variance

Sources of variation	df	Mean squares: Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit/ yield/ plant (g)
Replications	2	65.61*	2.19*	1.44	8.34	13.84	28.96	755.82
Genotypes	20	235.21**	3.21**	25.44**	24.28**	8.99	67.40**	17463.76**
Parents	5	383.68**	1.37	37.87**	33.09**	15.13	129.81**	24546.97**
Mixtures	14	177.85**	4.03**	13.39	11.61*	6.83	47.35**	10387.00*
Parents vs. mixtures	1	295.98**	0.88	132.06**	157.65**	8.50	35.88	81122.34**
Error	39	16.01	0.59	8.79	5.47	6.17	13.04	4574.70
CD for comparing treatments with no missing value (P = 0.05)		6.60	1.27	4.89	3.86	4.10	5.96	111.61
CD for comparing treatments with missing value (P = 0.05)		7.46	1.43	5.53	4.36	4.63	6.74	126.15

* P = 0.05

** P = 0.01

squares due to physical mixtures were significant for plant height, primary branches/plant, fruits/plant and fruit yield/plant. Variances due to parents vs. physical mixtures were significant for plant height, days to fruit set, days to fruit harvest and fruit yield/plant.

The expected wilt reaction (%) of mixtures based on parental performance and its deviation from observed values are presented (Table 33). Eight mixtures which showed deviation in the negative direction were IIHR Bwr 93 + IIHR Bwr 34A (-7.85%), IIHR Bwr 34A + LE 206 (-6.9%), LE 214 + IIHR Bwr 34A (-6.18%), LE 79 LFF + LE 217 (-3.33%), LE 217 + IIHR Bwr93(-2.5%), LE 214 + LE 206 (-2.39%), IIHR Bwr 93 + LE 206 (-2.39%) and LE 217 + IIHR Bwr 34A (-2.01%). LE 79 LFF + LE 214 had a wilt reaction of 9.16% more than the expected value. The other mixtures which showed positive deviation over expected values were LE 214 + LE 217 (4.17%), LE 79 LFF + IIHR Bwr 93 (2.49%), LE 79 LFF + IIHR Bwr 34A (1.32%), LE 214 + IIHR Bwr 93 (1.66%), LE 79 LFF + LE 206 (0.11%) and LE 217 + LE 206 (0.11%).

All mixtures except LE 79 LFF + LE 217 had less height than the expected value (Table 34). Nine mixtures produced more primary branches/plant (Table 35). The days to fruit set for all mixtures were more than the expected days to fruit set (Table 36). All mixtures except LE 217 + LE 206 took more days to fruit harvest than the expected value (Table 37).

Table 33. Per cent of observed (M), expected ($\overline{M}C$) death due to wilt and their deviation ($M-\overline{M}C$)

Parents and mixtures		M	$\overline{M}C$	$M-\overline{M}C$
LE 79 LFF	(1)	56.67		
LE 214	(2)	11.67		
LE 217	(3)	13.33		
IIHR Bwr 93	(4)	21.67		
IIHR Bwr 34A	(5)	20.69		
LE 206	(6)	43.10		
1 + 2		43.33	34.17	9.16
1 + 3		31.67	35.00	-3.33
1 + 4		41.66	39.17	2.49
1 + 5		40.00	38.68	1.32
1 + 6		50.00	49.89	0.11
2 + 3		16.67	12.50	4.17
2 + 4		18.33	16.67	1.66
2 + 5		10.00	16.18	-6.18
2 + 6		25.00	27.39	-2.39
3 + 4		15.00	17.50	-2.50
3 + 5		15.00	17.01	-2.01
3 + 6		28.33	28.22	0.11
4 + 5		13.33	21.18	-7.85
4 + 6		30.00	32.39	-2.39
5 + 6		25.00	31.90	-6.90

Table 34. Observed plant height (M), mid-component value ($\overline{MC}$), their deviation (M-$\overline{MC}$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	M-$\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	78.93			
LE 214	(2)	93.70			
LE 217	(3)	89.87			
IIHR Bwr 93	(4)	67.02			
IIHR Bwr 34A	(5)	67.63			
LE 206		85.76			
1 + 2		81.85	86.32	-4.47	-5.18
1 + 3		87.00	84.40	2.60	3.08
1 + 4		70.83	72.98	-2.15	-2.95
1 + 5		71.72	73.28	-1.56	-2.13
1 + 6		79.34	82.35	-3.01	-3.66
2 + 3		86.32	91.79	-5.47	-5.96
2 + 4		73.28	80.36	-7.08	-8.81
2 + 5		74.23	80.67	-6.44	-7.98
2 + 6		85.72	89.73	-4.01	-4.68
3 + 4		74.36	78.45	-4.09	-5.21
3 + 5		73.34	78.75	-5.41	-6.87
3 + 6		81.55	87.82	-6.27	-7.14
4 + 5		61.55	67.33	-5.78	-8.59
4 + 6		67.92	76.39	-8.47*	-11.09
5 + 6		66.27	76.70	-10.43*	-13.60
CD for comparing treatments with no missing value (P = 0.05)		6.60			
CD for comparing treatments with one missing value (P = 0.05)		7.66			

Table 35. Observed primary branches/plant(M), mid-component value ($\overline{MC}$), their deviation ($M-\overline{MC}$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	$M-\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	6.78			
LE 214	(2)	6.77			
LE 217	(3)	7.80			
IIHR Bwr 93	(4)	5.87			
IIHR Bwr 34A	(5)	6.08			
LE 206	(6)	6.59			
1 + 2		8.32	6.78	1.54*	22.71
1 + 3		8.75	7.29	1.46*	20.03
1 + 4		6.45	6.33	0.12	1.90
1 + 5		7.64	6.43	1.21	18.82
1 + 6		6.68	6.69	-0.01	-0.15
2 + 3		8.00	7.29	0.71	9.74
2 + 4		7.28	6.32	0.96	15.19
2 + 5		7.28	6.43	0.85	13.22
2 + 6		8.13	6.68	1.45*	21.71
3 + 4		5.87	6.84	-0.97	-14.18
3 + 5		5.93	6.94	-1.01	-14.55
3 + 6		7.31	7.20	0.11	1.53
4 + 5		5.09	5.98	-0.89	-14.88
4 + 6		5.50	6.23	-0.73	-11.72
5 + 6		5.43	6.34	-0.91	-14.35

CD for comparing treatments with no missing value ($P = 0.05$) 1.27

CD for comparing treatments with one missing value ($P = 0.05$) 1.43

Table 36. Observed days to fruit set(M), mid-component value ($\overline{MC}$), their deviation ($M-\overline{MC}$) and percentage deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	$M-\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	68.90			
LE 214	(2)	66.93			
LE 217	(3)	67.47			
IIHR Bwr 93	(4)	60.67			
IIHR Bwr 34A	(5)	61.00			
LE 206	(6)	63.00			
1 + 2		67.94	67.92	0.02	0.03
1 + 3		69.17	68.19	0.98	1.44
1 + 4		67.29	64.79	2.50	3.86
1 + 5		68.11	64.95	3.16	4.87
1 + 6		67.41	65.95	1.46	2.21
2 + 3		71.47	67.20	4.27	6.35
2 + 4		66.87	63.80	3.07	4.81
2 + 5		66.83	63.97	2.86	4.47
2 + 6		68.33	64.97	3.36	5.17
3 + 4		69.60	64.07	5.53*	8.63
3 + 5		70.73	64.24	6.49*	10.10
3 + 6		69.19	65.24	3.95	6.05
4 + 5		65.50	60.84	4.66	7.66
4 + 6		62.86	61.84	1.02	1.65
5 + 6		66.69	62.00	4.69	7.57
CD for comparing treatments with no missing value ($P = 0.05$)		4.89			
CD for comparing treatments with one missing value ($P = 0.05$)		5.53			

Table 37. Observed days to fruit harvest(M), mid-component value ($\overline{MC}$), their deviation ($M-\overline{MC}$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	$M-\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	92.63			
LE 214	(2)	92.71			
LE 217	(3)	95.63			
IIHR Bwr 93	(4)	86.73			
IIHR Bwr 34A	(5)	88.60			
LE 206	(6)	93.99			
1 + 2		96.10	92.67	3.47	3.70
1 + 3		96.43	94.13	2.30	2.44
1 + 4		93.55	89.68	3.87	4.32
1 + 5		96.67	90.62	6.05*	6.68
1 + 6		96.62	93.31	3.31	3.55
2 + 3		98.47	94.17	4.30*	4.57
2 + 4		94.82	89.72	5.10*	5.68
2 + 5		94.31	90.66	3.65	4.03
2 + 6		96.33	93.35	2.98	3.19
3 + 4		96.63	91.18	5.45*	5.98
3 + 5		96.42	92.12	4.30*	4.67
3 + 6		93.00	94.81	-1.81	1.91
4 + 5		93.80	87.67	6.13*	6.99
4 + 6		91.08	90.36	0.72	0.80
5 + 6		93.01	91.30	1.71	1.87
CD for comparing treatments with no missing value ($P = 0.05$)		3.86			
CD for comparing treatments with one missing value ($P = 0.05$)		4.36			

Table 38. Observed fruit set (%) (M), mid-component value, ($\overline{M}C$), their deviation (M–$\overline{M}C$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{M}C$	M–$\overline{M}C$	Per cent deviation
LE 79 LFF	(1)	51.69			
LE 214	(2)	63.29			
LE 217	(3)	54.10			
IIHR Bwr 93	(4)	54.53			
IIHR Bwr 34A	(5)	58.39			
LE 206	(6)	57.43			
1 + 2		55.88	57.49	–1.61	–2.80
1 + 3		53.77	52.90	0.87	1.65
1 + 4		58.50	53.11	5.39	10.15
1 + 5		50.93	55.04	–4.11	–7.47
1 + 6		59.69	54.36	5.33	9.40
2 + 3		56.33	58.70	–2.37	–4.04
2 + 4		57.28	58.91	–1.63	–2.77
2 + 5		57.27	60.84	–3.57	–5.87
2 + 6		58.54	60.36	–1.82	–3.11
3 + 4		53.99	54.32	–0.33	–0.61
3 + 5		52.61	56.25	–3.64	–6.47
3 + 6		54.83	55.77	–0.94	–1.69
4 + 5		51.40	56.46	–5.06	–8.96
4 + 6		53.99	55.98	–1.99	–3.55
5 + 6		56.44	57.91	–1.47	–2.54
CD for comparing treatments with no missing value (P = 0.05)		5.96			
CD for comparing treatments with one missing value (P = 0.05)		6.74			

Table 39. Observed number of fruits/plant(M), mid-component value ($\overline{MC}$), their deviation ($M-\overline{MC}$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	$M-\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	20.59			
LE 214	(2)	28.53			
LE 217	(3)	32.33			
IIHR Bwr 93	(4)	16.25			
IIHR Bwr 34A	(5)	16.22			
LE 206	(6)	21.38			
1 + 2		19.52	24.56	-5.04	-20.52
1 + 3		21.28	26.46	-5.18	-19.58
1 + 4		14.67	18.42	-3.75	-20.36
1 + 5		15.38	18.41	-3.03	-16.46
1 + 6		20.93	20.99	-0.06	-0.29
2 + 3		26.87	30.43	-3.56	-11.70
2 + 4		24.07	22.39	1.68	7.50
2 + 5		23.39	22.38	1.01	4.51
2 + 6		25.51	24.96	0.55	2.20
3 + 4		23.65	24.29	-0.64	-2.64
3 + 5		22.67	24.28	-1.61	-6.63
3 + 6		24.76	26.86	-2.10	-7.82
4 + 5		17.54	16.24	1.30	8.00
4 + 6		16.24	18.82	-2.58	-13.70
5 + 6		16.68	18.80	-2.12	-11.28
CD for comparing treatments with no missing value ($P = 0.05$)		5.96			
CD for comparing treatments with one missing value ($P = 0.05$)		6.74			

Table 40. Observed fruit yield/plant(M), mid-component value ($\overline{MC}$), their deviation ($M-\overline{MC}$) and per cent deviation over mid-component value

Parents and mixtures		M	$\overline{MC}$	$M-\overline{MC}$	Per cent deviation
LE 79 LFF	(1)	474.62			
LE 214	(2)	621.42			
LE 217	(3)	700.00			
IIHR Bwr 98	(4)	489.17			
IIHR Bwr 34A	(5)	655.75			
LE 206	(6)	583.66			
1 + 2		465.94	548.02	-82.08	-14.98
1 + 3		454.54	587.31	-132.77**	-22.61
1 + 4		398.22	481.90	-83.68	-17.37
1 + 5		414.38	565.19	-150.81*	-26.68
1 + 6		498.27	529.14	-30.87	-5.83
2 + 3		562.32	660.71	-98.39	-14.89
2 + 4		600.38	555.20	45.18	8.13
2 + 5		584.35	638.59	-54.24	-8.49
2 + 6		552.96	602.54	-49.58	-8.23
3 + 4		481.09	594.59	-113.50*	-19.09
3 + 5		537.11	677.88	-140.77*	-20.77
3 + 6		535.18	641.83	-106.65	-16.62
4 + 5		497.57	572.46	-74.89	-13.08
4 + 6		492.77	536.42	-43.65	-8.14
5 + 6		538.38	619.71	-81.33	-13.12

CD for comparing treatments with no missing value (P = 0.05) 111.61

CD for comparing treatments with one missing value (P = 0.05) 126.15

The fruit set (%) was lesser in all mixtures except LE 79 LFF + LE 217, LE 79 LFF + IIHR Bwr 93 and LE 79 LFF + LE 206 (Table 35). The mixtures LE 214 + IIHR Bwr 93, LE 214 + IIHR Bwr 34A and LE 214 + LE 206 had more fruits/plant than the expected number based on parental performance (Table 39). Fruit yield/plant was more than the expected yield only in LE 214 + IIHR Bwr 93 (Table 40).

Number of mixtures showing positive and negative deviations from mid-component (MC), best (BC) and poorest (PC) components for different characters are summarised (Table 41).

None of the mixtures were taller than their better components. LE 79 LFF + LE 217 was taller than the mid-component. Four mixtures were dwarfer than the dwarfest component constituting the mixture. Seven physical mixtures had more primary branches than the better component and nine mixtures had more branches than the mid-components. None of the mixtures were earlier than the earlier parents, for days to fruit set. None of them were earlier than the mid-component also. Seven physical mixtures were later than the later component. None of the mixtures were earlier than the earlier parents, for days to fruit harvest also. Only LE 217 + LE 206 was earlier than the mid-component. All mixtures except IIHR Bwr 93 + LE 206 and IIHR Bwr 34A + LE 206 were later than the later component constituting the respective mixtures. LE 79 LFF + IIHR Bwr 93 and LE 79 LFF +

Table 41. Number of mixtures showing positive(+) and negative(-) deviations from mid-component mean ($\overline{MC}$), best (BC) and poorest (PC) components for various characters

Character	Mean performance			
	+		-	
	BC	$\overline{MC}$	$\overline{MC}$	PC
Days to fruit set	-	15	-	7
Days to fruit harvest	-	14	1	13
Fruits/plant	-	4	11	5
Fruit yield/plant	-	1	14	11
Fruit set (%)	2	3	12	6
Plant height	-	1	14	4
Primary branches/plant	7	9	6	4

LE 206 were better than the better component, for fruit set (%). Six mixtures were poorer than the poorest component. Three mixtures showed positive deviations over mid-component value. No mixture outyielded the better component for fruits/plant and fruit yield/plant. The mixtures LE 214 + IIHR Bwr 93, LE 214 + IIHR Bwr 34A, LE 214 + LE 206 and IIHR Bwr 93 + IIHR Bwr 34A were better than the mid-component for fruits/plant. The remaining mixtures showed negative deviations from mid-component value. Five mixtures were poorer than the poorest components. For fruit yield/plant, only LE 214 + IIHR Bwr 93 was better than the mid-component. Eleven mixtures were poorer than the poorest component.

7) Mean performance of F_1 hybrids and physical mixtures

Mean performances of F_1 hybrids and physical mixtures are presented (Table 42). All F_1 hybrids except LE 79 LFF x IIHR Bwr 34A were taller than the corresponding physical mixtures. The mixture LE 79 LFF + IIHR Bwr 34 A had a height of 71.72 cm while the F_1 hybrid had 69.6 cm. Eight F_1 hybrids had more number of primary branches than the respective mixtures and seven mixtures produced more number of branches than the respective F_1 hybrids. For days to fruit set, all hybrids except IIHR Bwr 93 x LE 206 were significantly earlier than the respective mixtures. All hybrids were significantly earlier than the respective mixtures for days to fruit harvest. All hybrids except

IIHR Bwr 34A + LE 206 had significantly higher fruit set (%). All hybrids except LE 214 x IIHR Bwr 34A had more fruits/ plant. All the F_1 hybrids significantly outyielded the respective mixtures.

8) Association between root characteristics, primary branches/plant, plant height and fruit yield

A significant correlation was observed between root volume and fruit yield (r = 0.58). Correlation between root volume and plant height and root volume and primary branches/plant were not significant (Table 43). Correlation between root length and yield, root length and plant height and root length and primary branches/plant were also not significant.

9) Observations on root galls caused by *Meloidogyne incognita*

All the parental lines, F_1 hybrids and physical mixtures had galls caused by root knot nematodes (Table 44).

Table 43. Correlation between root characteristics, plant height, primary branches/plant and fruit yield/plant

Characters	Root volume	Root length
Plant height	0.33	0.12
Primary branches/plant	0.21	0.20
Fruit yield/plant	0.58*	0.19

Table value t_{34} ($P = 0.05$) = 0.33

Table 44. Preliminary observations on root galls by *Meloidogyne incognita*

Parents/F_1 hybrids/ physical mixtures	Number of plants observed	Number of plants with root galls	Parents/F_1 hybrids/ physical mixtures	Number of plants observed	Number of plants with root galls
Parents					
LE 214	45	6	4 x 5	28	7
LE 217	29	7	4 x 6	35	2
IIHR Bwr 93	24	5	5 x 6	14	1
IIHR Bwr 34A	33	7	Physical mixtures		
LE 206	12	2	1 + 2	26	16
F_1 hybrids			1 + 3	27	12
1 x 2	37	13	1 + 4	10	1
1 x 3	26	6	1 + 5	24	4
1 x 4	37	8	1 + 6	16	2
1 x 5	35	8	2 + 3	46	30
1 x 6	35	9	2 + 4	43	12
2 x 3	43	8	2 + 5	37	13
2 x 4	37	1	2 + 6	44	19
2 x 5	35	3	3 + 4	40	15
2 x 6	37	3	3 + 5	14	7
3 x 4	32	1	3 + 6	8	5
3 x 5	32	14	4 + 5	18	4
3 x 6	44	6	4 + 6	8	6

B. **Evaluation of two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and yield components**

Three lines of tomato LE 206, LE 212 and IIHR Bwr 34A, their two way and three way mixtures were grown in a wilt sick soil during July-November, 1985. The genotypes were classified for their bacterial wilt reaction (Table 45). Complete wilting (100%) was observed in the susceptible check, Pusa Ruby. The component lines LE 206 (26.32%), LE 212 (32.78%) and IIHR Bwr 34A (27.27%) were moderately resistant. The two way mixtures LE 206 + LE 212 (31.67%), LE 206 + IIHR Bwr 34A (26.67%), LE 212 + IIHR Bwr 34A (33.33%) and the three way mixture LE 206 + LE 212 + IIHR Bwr 34A (31.67%) were also moderately resistant.

1) General analysis of variance for yield and yield components

The data on days to fruit set, days to fruit harvest, fruit set (%), fruits/plant and fruit yield/plant were analysed (Table 46). Variances due to genotypes, parents and mixtures were not significant for any of the characters. Mean squares due to parents versus mixtures were significant for days to fruit harvest and fruit yield/plant.

LE 206 was earlier both for days to fruit set (59.9 days) and fruit harvest (104.5 days), among parental lines.

Table 45. Evaluation of three lines of tomato and the physical mixtures for resistance to bacterial wilt

Lines		Total number of plants	Number of plants wilted	Wilt reaction (%)
LE 206	(1)	57	15	26.32 (MR)
LE 212	(2)	55	18	32.78 (MR)
IIHR Bwr 34A	(3)	55	15	27.27 (MR)
1 + 2		60	19	31.67 (MR)
1 + 3		60	16	26.67 (MR)
2 + 3		60	20	33.33 (MR)
1 + 2 + 3		60	19	31.67 (MR)

MR = Moderately resistant, 20 to 40% plants wilted

Table 46. General analysis of variance

Sources of variation	df	Mean squares				
		Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruit/ plant	Fruit yield/ plant(g)
Genotypes	6	5.07	9.72	12.79	46.27	467689.77
Parents	2	6.88	2.49	6.81	57.35	16538.69
Mixtures	3	4.21	1.65	20.81	49.42	1850.94
Parents vs. mixtures	1	3.80	48.39*	0.66	14.66	2767508.40*
Error	7	5.10	2.96	17.64	16.31	5241.16

* P = 0.05

Among physical mixtures LE 206 + IIHR Bwr 34A was earlier for days to fruit set (61.3 days) while LE 212 + IIHR Bwr 34A was earlier for days to fruit harvest (100.73 days). LE 206 + IIHR Bwr 34A had the highest per cent of fruit set (57.99%). LE 212 had the highest fruits/plant (30.9) followed by LE 206 + LE 212 (29.5). IIHR Bwr 34A had the maximum fruit yield/plant (529.34 g) followed by LE 206 + LE 212 (497.13 g) (Table 47).

2) The general coexistence ability index

For days to fruit set, the GCoA estimates were greater than unity for all the parental lines and physical mixtures. The days to fruit harvest were less in mixtures than in purestands, as the GCoA effects were less than one. The GCoA estimates of LE 212 and IIHR Bwr 34A, for per cent of fruit set were greater than one (1.11 and 1.05 respectively), while LE 206 maintained its performance in mixtures (1.00). For fruits/plant, GCoA estimate of LE 212 was equal to one, while LE 206 and IIHR Bwr 34A had GCoA values less than unity. For fruit yield/plant, GCoA estimates were greater than one for all the parental lines and physical mixtures (Table 48).

C. Maternal effects for certain quantitative characters in tomato

The direct and reciprocal F_1 hybrids involving five

Table 47. Mean performance of three tomato lines and their physical mixtures

Entry		Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/plant	Fruit yield/plant(g)
LE 206	(1)	59.90	104.50	53.60	24.60	496.50
LE 212	(2)	63.50	106.60	52.57	30.90	358.00
IIHR Bwr 34A	(3)	62.48	106.20	56.15	20.25	529.34
1 + 2		64.45	102.07	56.56	29.50	497.13
1 + 3		61.30	102.45	57.99	17.35	487.13
2 + 3		62.35	100.73	52.31	22.73	429.38
1 + 2 + 3		63.95	102.80	51.34	23.16	482.84
		N.S.		N.S.	N.S.	
CD (P = 0.05)			3.32			171.22
SEM ±			0.99			41.80

Table 48. General coexistence ability estimates and mean performance of different genotypes in purestands and in mixtures

Genotype	Stand	Days to fruit set		Days to fruit harvest		Fruit set (%)		Fruits/ plant		Fruit yield/ plant(g)	
		Mean	GCoA	Mean	GCoa	Mean	GCoA	Mean	GCoA	Mean	GCoA
LE 206	Pure	59.90		104.50		53.00		24.60		480.00	
			1.06		0.98		1.00		0.86		1.08
	Mixtures	63.37		102.53		52.74		21.17		519.63	
LE 212	Pure	63.50		106.60		50.00		30.90		321.10	
			1.02		0.96		1.11		1.00		1.21
	Mixtures	64.57		101.81		55.24		30.84		388.04	
IIHR Bwr 34A	Pure	62.48		106.20		50.00		19.83		501.00	
			0.97		0.96		1.05		0.81		1.07
	Mixtures	60.60		101.75		52.72		16.05		534.67	

tomato lines - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93 and LE 206 - were evaluated under field conditions along with the susceptible check Pusa Ruby during July to November, 1985 (Table 49). All the direct and reciprocal F_1 hybrids, except LE 206 x IIHR Bwr 93 (28.33%), were resistant to bacterial wilt. Pusa Ruby showed 100% susceptibility.

1) General analysis of variance for yield and yield components

Variances due to genotypes were significant for plant height, days to fruit harvest and per cent of fruit set (Table 50). Mean squares due to direct F_1 hybrids were significant only for plant height and per cent of fruit set. Variances due to reciprocal F_1 hybrids were significant for plant height, days to fruit set, days to fruit harvest and per cent of fruit set. Mean squares due to direct versus reciprocal F_1's were significant for days to fruit set, days to fruit harvest and per cent of fruit set.

Among direct F_1 hybrids, LE 214 x LE 217 was the tallest (104.2 cm) followed by LE 217 x LE 206 (93.73 cm) LE 217 x LE 214 was the tallest among reciprocal F_1 hybrids (104.93 cm) followed by LE 206 x LE 214 (104.87 cm). Among direct F_1 hybrids, LE 79 LFF x LE 206 had the highest number of primary branches/plant (8.3) at second harvest. Among reciprocal F_1 hybrids, LE 206 x LE 217 (8.33) had the highest number of primary branches/plant. LE 214 x IIHR Bwr 93

Table 49. Evaluation of direct and reciprocal F_1 hybrids involving five specific lines of tomato for resistance to bacterial wilt

Lines	Total number of plants	Number of plants wilted	Wilt reaction (%)
1 x 2	58	5	8.60 (R)
1 x 3	58	3	5.17 (R)
1 x 4	58	6	10.35 (R)
1 x 5	58	10	17.25 (R)
2 x 3	58	4	6.90 (R)
2 x 4	60	9	15.00 (R)
2 x 5	60	8	13.33 (R)
3 x 4	60	4	6.67 (R)
3 x 5	60	4	6.67 (R)
4 x 5	60	8	13.33 (R)
2 x 1	58	3	5.17 (R)
3 x 1	60	4	6.67 (R)
3 x 2	60	11	18.33 (R)
4 x 1	60	4	6.67 (R)
4 x 2	60	6	6.67 (R)
4 x 3	50	3	6.00 (R)
5 x 1	60	3	5.00 (R)
5 x 2	60	9	15.00 (R)
5 x 3	60	6	10.00 (R)
5 x 4	60	17	28.33 (MR)

1. LE 79 LFF 3. LE 217 5. LE 206

2. LE 214 4. IIHR Bwr 93

R - Resistant, <20% plants wilted

MR - Moderately resistant, 20-40% plants wilted

Table 50. General analysis of variance

Sources of variation	df	Mean squares: Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Replications	2	195.42**	3.96*	70.42	134.56**	74.06**	219.37**	122336.60**
Genotypes	19	274.26**	0.92	8.16	12.20**	46.42**	36.99	35641.51
Direct F_1's	9	215.16**	1.19	5.26	5.88	49.02**	23.97	34034.23
Reciprocal F_1's	9	355.76**	0.75	6.17	13.31*	47.32**	44.07	38036.96
Direct vs. Reciprocals	1	72.59	-	52.09**	59.10**	14.77**	90.43	28547.99
Error	38	33.77	0.86	4.57	5.19	6.44	26.09	20712.83

* P = 0.05

** P = 0.01

Table 51. Mean performance of direct and reciprocal F_1 hybrids involving five specific lines of tomato

Lines	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Direct F_1 hybrids							
1 x 2	88.77	7.15	58.00	87.03	77.07	30.42	758.67
1 x 3	88.93	7.13	57.00	85.40	81.21	30.07	887.17
1 x 4	75.20	6.88	57.67	86.33	68.53	26.32	877.92
1 x 5	80.92	8.30	57.33	85.33	66.80	29.55	889.00
2 x 3	104.20	7.60	60.93	89.80	65.77	26.93	551.33
2 x 4	87.63	6.73	56.93	86.13	68.84	27.60	887.33
2 x 5	91.87	7.83	57.80	85.00	70.31	27.15	921.75
3 x 4	88.03	8.13	57.80	85.26	60.96	24.27	802.44
3 x 5	93.73	7.93	59.87	86.87	64.44	28.55	836.58
4 x 5	77.00	6.47	59.27	86.47	62.50	23.53	801.33
Reciprocal F_1 hybrids							
2 x 1	88.27	7.07	58.67	86.07	76.41	29.87	916.00
3 x 1	92.60	7.53	58.73	85.53	72.76	30.49	547.78

Table 51. (Contd.)

Lines	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
3 x 2	104.93	7.27	58.60	88.33	66.09	28.84	606.33
4xx 1	74.80	7.27	59.53	88.33	70.14	24.60	867.33
4 x 2	92.93	7.73	61.40	87.13	65.01	21.27	504.17
4 x 3	96.77	7.03	62.07	90.08	63.59	24.23	827.50
5 x 1	83.27	7.00	58.67	86.93	70.65	24.52	745.83
5 x 2	104.87	8.07	60.70	89.53	69.46	23.80	814.00
5 x 3	86.25	8.33	60.93	88.87	64.31	27.35	873.00
5 x 4	73.60	6.80	61.93	92.67	52.49	18.45	668.83
CD (P=0.05	9.61	1.53	3.54	3.77	4.20	8.45	237.96
SEM±	3.36	0.54	1.23	1.32	1.47	2.95	83.09

was earlier for days to fruit set (56.93 days) while for days to fruit harvest LE 214 x LE 206 (85 days) was earlier among direct F_1 hybrids. Among reciprocal F_1 hybrids LE 217 x LE 214 was earlier for days to fruit set (58.6 days). For days to fruit harvest LE 217 x LE 79 LFF (85.53 days) was earlier. LE 79 LFF x LE 217 had the highest per cent of fruit set (81.21%) followed by LE 79 LFF x LE 214 (77.07%) among direct F_1 hybrids. Among reciprocal F_1 hybrids LE 214 x LE 79 LFF had the maximum per cent of fruit set (76.41%). Among direct F_1's, LE 79 LFF x LE 214 had the maximum fruits/plant (30.42) followed by LE 79 LFF x LE 217 (30.07). Among reciprocal F_1's LE 217 x LE 79 LFF had maximum fruits/plant (30.49) followed by LE 214 x LE 79 LFF (29.87). LE 214 x LE 206 had the highest yield of 921.75 g/plant among direct F_1's while LE 214 x LE 79 LFF had the highest yield of 916 g/plant among reciprocal F_1 hybrids (Table 51).

2) Analysis of variance for combining ability

The combining ability analysis was conducted for each of the quantitative characters studied (Table 52). The general and specific combining ability effects and reciprocal effects were estimated.

Plant height

Only variance due to gca was significant (Table 52). gca effect was maximum in LE 214 (8.94) and minimum in

Table 52. Analysis of variance for combining ability analysis

Sources of variation	df	Mean squares						
		Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Gca	4	358.00**	0.45	3.63	3.53	54.41**	41.00**	13653.50
Sca	5	24.89	0.33	0.53	2.96	7.04*	1.88	192061.30*
Reciprocals	10	18.05	0.23	3.45*	4.84*	4.11	6.08	7508.95
Error	38	11.26	0.29	1.52	1.73	2.15	8.70	6904.28

IIHR Bwr 93 (-7.31). The highest sca effect was recorded in LE 214 x LE 206 (12.51) and the lowest in LE 217 x LE 206 (-3.29). Reciprocal effect was the highest in LE 206 x LE 217 (3.74) and the lowest in IIHR Bwr 93 x LE 217 (-4.37) (Table 53).

Primary branches/plant

Variances due to gca, sca and reciprocal effect were not significant (Table 52). LE 214 had the highest gca effect (0.28) and IIHR Bwr 93 had the lowest gca effect (-0.38). The maximum sca effect was expressed by LE 214 x LE 206 (0.27) and the minimum by IIHR Bwr 93 x LE 206 (-0.64). LE 206 x LE 79 LFF recorded the highest reciprocal effect (0.65) and IIHR Bwr 93 x LE 214, the lowest (-0.50) (Table 54).

Days to fruit set

Only variance due to reciprocal effect was significant (Table 52). gca effect was maximum in IIHR Bwr 93 (0.51) and minimum in LE 79 LFF (-1.32). The highest sca effect was manifested in LE 206 x IIHR Bwr 93 (0.41) and the lowest in LE 79 LFF x LE 214 (-0.45). LE 217 x LE 214 recorded the highest reciprocal effect (1.17) and IIHR Bwr 93 x LE 214, the lowest (-2.24) (Table 55).

Days to fruit harvest

Variance due to reciprocals was only significant. gca effect was maximum in IIHR Bwr 93 (0.59) and minimum in LE 79 LFF (-1.31). The highest sca effect was recorded in LE 214 x LE 217 (1.47) and the lowest in LE 214 x IIHR Bwr 93 (-1.35). LE 217 x LE 214 expressed the highest reciprocal effect (0.74). LE 206 x IIHR Bwr 93 recorded the lowest reciprocal effect (-3.10) (Table 56).

Per cent of fruit set

Variances due to gca and sca were significant (Table 52). LE 79 LFF had the maximum gca effect (4.25) and the minimum in IIHR Bwr 93 (-3.17). The sca effect was the highest in LE 217 x LE 206 (3.83) and the lowest in LE 214 x LE 217 (-2.51). The highest reciprocal effect was expressed by LE 206 x IIHR Bwr 93 (2.92) and the lowest by LE 206 x LE 79 LFF (-1.20) (Table 57).

Fruits/plant

Variance due to gca was only significant (Table 52). Maximum gca effect was observed in LE 79 LFF (2.71) and minimum in IIHR Bwr 93 (-3.71). LE 217 x LE 206 showed the highest sca effect (1.03) and LE 214 x LE 217 the lowest (-1.20). The highest reciprocal effect was recorded by IIHR Bwr 93 x LE 214 (3.12). The lowest was observed in LE 217 x LE 214 (-0.96) (Table 58).

Table 53. General, specific and reciprocal effects for plant height

	P_1	P_2	P_3	P_4	P_5
P_1	-6.18	-2.97	0.62	-0.23	2.60
P_2	-0.25	8.94	-0.70	-0.08	12.51
P_3	-1.84	-0.37	7.60	3.38	-3.29
P_4	0.20	-2.65	-4.37	-7.31	-3.07
P_5	-1.18	-6.50	-3.74	1.70	-3.05

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	1.23	-
sca (sij)	1.68	-
Reciprocal (rij)	2.37	-
gi - gj	1.94	3.92
sij - sik	2.73	5.55
sij - skl	1.94	3.92

gca - diagonal & underlined

sca - above diagonal

Reciprocal - below diagonal

P_1 - LE 79 LPF

P_2 - LE 214

P_3 - LE 217

P_4 - IIHR Bwr 93

P_5 - LE 206

Table 54. General, specific and reciprocal effects for primary branches/plant

	P_1	P_2	P_3	P_4	P_5
P_1	-0.16	-0.17	-0.20	0.20	0.16
P_2	0.04	0.03	-0.28	0.16	0.27
P_3	-0.20	0.17	0.28	0.26	-0.10
P_4	-0.20	-0.50	0.55	-0.38	-0.64
P_5	0.65	-0.12	-0.20	-0.17	0.24

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.20	-
sca (sij)	0.27	-
Reciprocal (rij)	0.38	-
gi - gj	0.31	0.63
sij - sik	0.44	0.89
sij - skl	0.30	0.63

Table 55. General, specific and reciprocal effects for days to fruit set

Parents	P_1	P_2	P_3	P_4	P_5
P_1	-1.32	-0.45	-0.39	0.23	-0.36
P_2	-0.34	-0.08	0.27	-0.44	-0.35
P_3	-0.87	1.17	0.40	-0.16	0.33
P_4	-0.93	-2.24	-2.14	0.51	0.41
P_5	-0.67	-1.45	-0.53	-1.33	0.50

Effects/ comparison	Standard error	Critical difference ($P = 0.05$)
gca (gi)	0.45	-
sca (sij)	0.62	-
Reciprocal (rij)	0.87	-
gi - gj	0.71	1.40
sij - sik	1.01	2.04
sij - skl	0.71	1.40

Table 56. General, specific and reciprocal effects for days to fruit harvest

Parents	P_1	P_2	P_3	P_4	P_5
P_1	-1.31	0.48	-0.79	0.69	-0.38
P_2	0.48	0.03	1.49	-1.35	-0.59
P_3	-0.07	0.74	0.22	-0.50	-0.18
P_4	-1.00	-0.50	-2.41	0.59	1.15
P_5	-0.80	-2.27	-1.00	-3.10	0.47

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.45	-
sca (sij)	0.62	-
Reciprocal(rij)	0.87	-
gi - gj	0.71	1.40
sij - sik	1.01	2.04
sij - skl	0.71	1.40

Table 57. General, specific and reciprocal effects for fruit set (%)

Parents	P_1	P_2	P_3	P_4	P_5
P_1	<u>4.25</u>	-0.23	1.99	-0.25	-1.51
P_2	0.20	<u>1.62</u>	-2.51	0.91	1.83
P_3	2.90	-0.12	-<u>0.38</u>	0.08	3.83
P_4	0.45	1.14	-0.76	-<u>3.17</u>	-0.74
P_5	-1.20	0.27	0.06	2.92	-<u>2.33</u>

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	0.54	-
sca (sij)	0.73	-
Reciprocal (rij)	1.04	-
gi - gj	0.85	1.71
sij - sik	1.20	2.42
sij - skl	0.85	1.71

Table 58. General, specific and reciprocal effects for fruits/plant

Parents	P_1	P_2	P_3	P_4	P_5
P_1	<u>2.71</u>	0.21	0.63	-0.11	-0.73
P_2	0.28	<u>0.65</u>	-1.20	0.93	0.06
P_3	1.29	-0.96	<u>1.86</u>	-0.47	1.03
P_4	0.86	3.12	0.02	-<u>3.71</u>	-0.36
P_5	2.52	1.97	0.60	2.54	-<u>1.51</u>

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca - (gi)	1.07	-
sca (sij)	1.48	-
Reciprocal (rij)	2.08	-
gi - gj	1.70	3.45
sij - sik	2.41	4.88
sij - skl	1.70	3.45

Table 59. General, specific and reciprocal effects for fruit yield/plant

Parents	P_1	P_2	P_3	P_4	P_5
P_1	65.39	30.65	23.60	19.73	-73.96
P_2	-78.67	-56.28	-135.04	6.19	98.21
P_3	28.03	-27.50	-27.42	54.89	56.57
P_4	5.30	129.92	-12.53	-10.07	-80.80
P_5	71.63	53.88	-18.17	66.25	28.37

Effects/ comparison	Standard error	Critical difference (P = 0.05)
gca (gi)	30.34	-
sca (sij)	41.55	-
Reciprocal (rij)	58.76	-
gi - gj	47.97	97.15
sij - sik	67.84	137.39
sij - skl	47.97	97.15

Fruit yield/plant

Variance due to sca was only significant (Table 52). The highest gca effect was expressed in LE 79 LFF (65.39) and the lowest in LE 214 (-56.28). LE 214 x LE 206 had the maximum sca effect (98.21) and LE 214 x LE 217 had the minimum (-135.04). The highest reciprocal effect was shown by IIHR Bwr 93 x LE 214 (129.92) and the lowest by LE 214 x LE 79 LFF (-78.67) (Table 59).

D. Evaluation of a set of tomato lines for resistance to bacterial wilt and economic characters

Fourteen tomato lines - LE 206, LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 214, LE 217, LE 79 LFF, LE 79 LFG, LE 79 DG, IIHR Bwr 93 and IIHR Bwr 34A were evaluated under field conditions along with the susceptible check Pusa Ruby during July to November, 1985 (Table 60). The lines were genetically catelogued for important morphological characters (Table 61). The lines LE 211 (10%), LE 214 (6.67%), LE 217 (3.51%), LE 79 LFG (5%) and LE 79 DG (15%) were resistant. The lines LE 206 (30%), LE 208 (38.33%), LE 213 (25%), IIHR Bwr 93 (28.81%) and IIHR Bwr 34A (20%) were moderately resistant. LE 210 (43.33%) and LE 212 (41.67%) were moderately susceptible while LE 209 (75%) and LE 79 LFF (60%) were susceptible. The susceptible check, Pusa Ruby showed 100% wilt incidence.

Table 60. Evaluation of tomato lines for their reaction to bacterial wilt

Lines	Total number of plants	Number of plants wilted	Disease reaction (%)
LE 206	60	18	30.00 (MR)
LE 208	60	23	38.33 (MR)
LE 209	60	45	75.00 (S)
LE 210	60	26	43.33 (MS)
LE 211	60	6	10.00 (R)
LE 212	60	25	41.67 (MS)
LE 213	60	15	25.00 (MR)
LE 214	60	4	6.67 (R)
LE 217	57	2	3.51 (R)
LE 79 LFG	60	3	5.00 (R)
LE 79 DG	60	9	15.00 (R)
LE 79 LFF	60	35	60.00 (S)
IIHR Bwr 93	59	17	28.81 (MR)
IIHR Bwr 34A	60	12	20.00 (MR)

R - Resistant, < 20% plants wilted

MR - Moderately resistant, 20-40% plants wilted

MS - Moderately susceptible, 40-60% plants wilted

S - Susceptible, > 60% plants wilted

Table 61. Genetic cataloguing of 14 tomato lines

Lines	Genetic cataloguing							
LE 206	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	uu.,
LE 208	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	oo.,	pst^{+}-.,	sp^{+}-.,	uu.,
LE 209	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	uu.,
LE 210	aa.,	cc.,	dp^{+}-.,	f^{+}-.,	nn.,	oo.,	pst pst.,	sp^{+}-.,	uu.,
LE 211	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 212	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 213	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 214	a^{+}-.,	c^{+}-.,	dpdp.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 217	a^{+}-.,	c^{+}-.,	dpdp.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 79 LFF	a^{+}-.,	c^{+}-.,	dp^{+}-.,	ff.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 79 LFG	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
LE 79 DG	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
IIHR Bwr 34A	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	u^{+}-.,
IIHR Bwr 93	a^{+}-.,	c^{+}-.,	dp^{+}-.,	f^{+}-.,	n^{+}-.,	o^{+}-.,	pst^{+}-.,	sp^{+}-.,	uu.,

Data on plant height, primary branches/plant, days to fruit set, days to fruit harvest, fruit set (%), fruit/plant and fruit yield/plant were analysed (Table 62). Significant differences were observed for plant height, primary branches/plant, fruits/plant and fruit yield/plant. Plant height ranged from 56.62 cm in LE 212 to 98.33 cm in LE 79 DG. The maximum primary branches/plant was produced by LE 214 (9.93) followed by LE 79 LFG (8.8) and the minimum by IIHR Bwr 93 (4.6). Days to fruit set ranged from 58.6 days in LE 211 to 68.73 days in LE 206. The lines LE 209 (59.43 days) and LE 213 (59.4 days) were also early. Days to fruit harvest ranged from 92.33 days in LE 213 to 97.92 days in IIHR Bwr 93. The lines LE 211 (93.47 days), LE 217 (94.2 days) and LE 214 (94.8 days) were also early for fruit harvest. The fruit set (%) was the lowest in LE 208 (45.5%) and the highest in LE 213 (60.58%). The highest fruits/plant was borne by LE 213 (36.00) followed by LE 208 (33.75). LE 210 had the lowest fruits/plant (16.81). The line LE 79 LFG yielded the highest (742.6 g/plant) followed by LE 79 DG (733.0 g/plant). The line LE 209 yielded the lowest (231.67 g/plant) (Table 63).

Table 62. General analysis of variance

Sources of variation	df	Mean squares						
		Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
Replications	2	1242.87**	6.38**	215.58**	737.64**	35.08	34.30	286.80
Genotypes	13	562.19**	7.92**	20.48	7.74	66.25	139.25**	70847.09**
Error	25	64.91	0.87	18.26	10.94	33.61	42.00	20977.39

** P = 0.01

Table 63. Mean performance of tomato lines

Lines	Plant height (cm)	Primary branches/ plant	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)
LE 206	84.53	7.20	68.73	95.93	57.59	21.67	533.17
LE 208	78.57	5.50	62.00	95.30	45.50	33.75	599.00
LE 209	61.42	5.14	59.43	97.83	54.85	18.33	231.67
LE 210	82.49	4.84	63.25	97.27	47.75	16.81	237.50
LE 211	93.63	8.47	58.60	93.47	49.66	32.57	562.33
LE 212	56.62	7.47	63.67	96.00	48.16	31.67	385.33
LE 213	79.08	7.67	59.40	92.33	60.58	36.00	537.33
LE 214	93.93	9.93	64.27	94.80	57.71	31.83	650.33
LE 217	88.60	7.80	65.13	94.20	58.31	25.20	549.83
LE 79 LFG	93.67	8.80	62.87	96.73	58.16	19.67	742.67
LE 79 DG	98.33	8.33	62.53	95.53	51.32	26.03	733.33
LE 79 LFF	70.87	6.51	64.70	94.97	55.04	26.89	598.00
IIHR Bwr 93	63.73	4.60	63.27	97.92	51.11	16.90	539.00
IIHR Bwr 34A	67.60	6.13	62.60	96.20	55.09	18.02	595.08
CD for comparing treatments with no missing value	7.65	1.57				10.88	243.14
CD for comparing treatments with missing value	8.76	1.77	N.S.	N.S.	N.S.	12.31	275.08
SEm±	4.65	0.54				3.74	83.62

Discussion

DISCUSSION

Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith is the most serious disease of tomato in the warm humit tropics. The first report on the disease came from Italy in 1882 (Walker, 1952). In India it was first reported from West Bengal by Hedayathullah and Saha (1941).

Hayward (1964) reported *Pseudomonas solanacearum* as a complex species consisting of several races differing in host range and pathogenicity. More than 200 species of plants are susceptible to the pathogen. The major susceptible species belong to Solanaceae. Tomatoes and egg plants are more susceptible than chillies. Other common hosts include banana, potato, tobacco, peanut, sesamum etc.

The first expression of the disease is wilting of the lower leaves, accompanied usually with yellowing of older leaves. The root system of the wilted plants develop a water soaked appearence. Dark brown to black areas develop due to decay of root system and whole plant dies off. The appearence of bacterial ooze when the vascular system is severed, is the characteristic indication of the disease (Walker, 1952; Chupp and Sherf, 1960). The entry of the pathogen is through injured root system. Wounds caused by nematode injury, mechanical injury and root breakage due to transplanting etc. are considered to be the entry points. Libman *et al.* (1964) reported entry of pathogen through uninfested roots. *Pseudomonas solanacearum* is gram negative, non-spore forming, rod shaped and motile with one or several polar flagella (Kranz *et al.*, 1977). It survives in soil under natural conditions for as long as six years.

Various methods were used to control the disease. Crop rotations are of limited value unless long rotations with non-susceptible crops are followed. Rotation of tomatoes with *Vigna* sp. followed by maize and cabbage/okra followed by *Vigna* sp. and maize gave effective control (Sohi *et al.*, 1981). Control of bacterial wilt was obtained by grafting tomato scions to resistant stocks (Reyes, 1967; Oberero, 1969). Chemical control measures are costly and ineffective. Use of resistant varieties is the only economical and feasible method to control bacterial wilt. Two distinct sources of resistance-one derived from Louisiana Pink (North Carolina Source) and the other from PI 127805 A (*Lycopersicon pimpinellifolium*) were reported (Russel, 1978).

Crosses involving resistant varieties were more resistant than the resistant cultivars themselves. Crosses between Louisiana Pink and T 414 from Puerto Rico were considered as promising sources of resistance (Weaver, 1944). Two way and three way crosses of three tomato cultivars

(VC 11-1, Saturn and Kewalo) were resistant than their parents (AVRDC, 1975). In the present study six tomato lines - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93, IIHR Bwr 34A and LE 206, possessing different gene systems were crossed without reciprocals. All F_1 hybrids except IIHR Bwr 93 x IIHR Bwr 34A and IIHR Bwr 34A x LE 206 were resistant. This confirmed the earlier reports of Weaver (1944) and AVRDC (1975). Salient features of the most promising F_1 hybrids are given (Table 64). LE 214 x LE 206, the highest yielding F_1 hybrid (921.75 g/plant) with 27.15 fruits/plant, was earlier to fruit set (57.8 days) and fruit harvest (85 days).

Various investigations involving mixtures as potential cultivars in field crops like rice, wheat, sorghum, soybean and maize indicated the possibility of some favourable interaction among the mixture components. Such interactions are found useful in achieving greater yield through more efficient use of environment (Donald, 1963). As the different components in a mixture would constitute a barrier to arrest the spread of disease organisms, it appeared possible that heterogeneous populations might act as a non-polluting means of disease control (Vander Plank, 1968, 1975). Among the 15physical mixtures developed from six tomato lines, six were resistant - LE 214 + LE 217, LE 214 + IIHR Bwr 93, LE 214 + IIHR Bwr 34A, LE 217 + IIHR Bwr 93, LE 217 + IIHR Bwr 34A and IIHR Bwr 93 + IIHR Bwr 34A.

Table 64. Prominent F_1 hybrids and their salient features

F_1 hybrids	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)	Wilt reaction (%)
LE 214 x LE 206	57.80	85.00	70.31	27.15	921.75	13.33 (R)
LE 79 LFF x IIHR Bwr 34A	56.87	85.47	63.04	23.20	908.02	5.17 (R)
LE 79 LFF x LE 217	57.00	85.40	81.21	33.07	887.17	5.17 (R)

The component lines forming these resistant mixtures were resistant to moderately resistant. LE 79 LFF + LE 217, LE 214 + IIHR Bwr 34A, LE 214 + LE 206, LE 217 + IIHR Bwr 93, LE 217 + IIHR Bwr 34A, IIHR Bwr 93 + IIHR Bwr 34A, IIHR Bwr 93 + LE 206 and IIHR Bwr 34A + LE 206 had higher level of resistance than the expected values based on parental performances (Fig. 1). The component lines carrying different resistance genes provide obstruction (Harvey, 1978) for the spread of the disease. This confirmed the earlier report of Pande (1978) in bengal gram. The best resistant physical mixture LE 214 + IIHR Bwr 93 (600.38 g/plant) had 24 fruits/plant took 66.87 days to fruit set and 94.82 days to fruit harvest. The most promising resistant physical mixtures and their salient features are given (Table 65). Fifteen F_1 hybrids and 15 physical mixtures were compared for their bacterial wilt resistance (Table 66). All the F_1s except IIHR Bwr 93 x IIHR Bwr 34A and IIHR Bwr 34A x LE 206 had higher level of resistance than their respective mixtures (Table 66). The mixture IIHR Bwr 93 + IIHR Bwr 34A showed only 13.33% susceptibility, while respective F_1 hybrid showed 35.29% susceptibility. IIHR Bwr 34A + LE 206 also showed an increased resistance to bacterial wilt when compared to its respective F_1 hybrid (Table 66). Prominent F_1 hybrids and physical mixtures with respect to economic characters are given (Table 67).

Many of the reportedly resistant lines like Venus and Saturn (Henderson and Jenkins, 1971; Sonoda, 1977) wilted

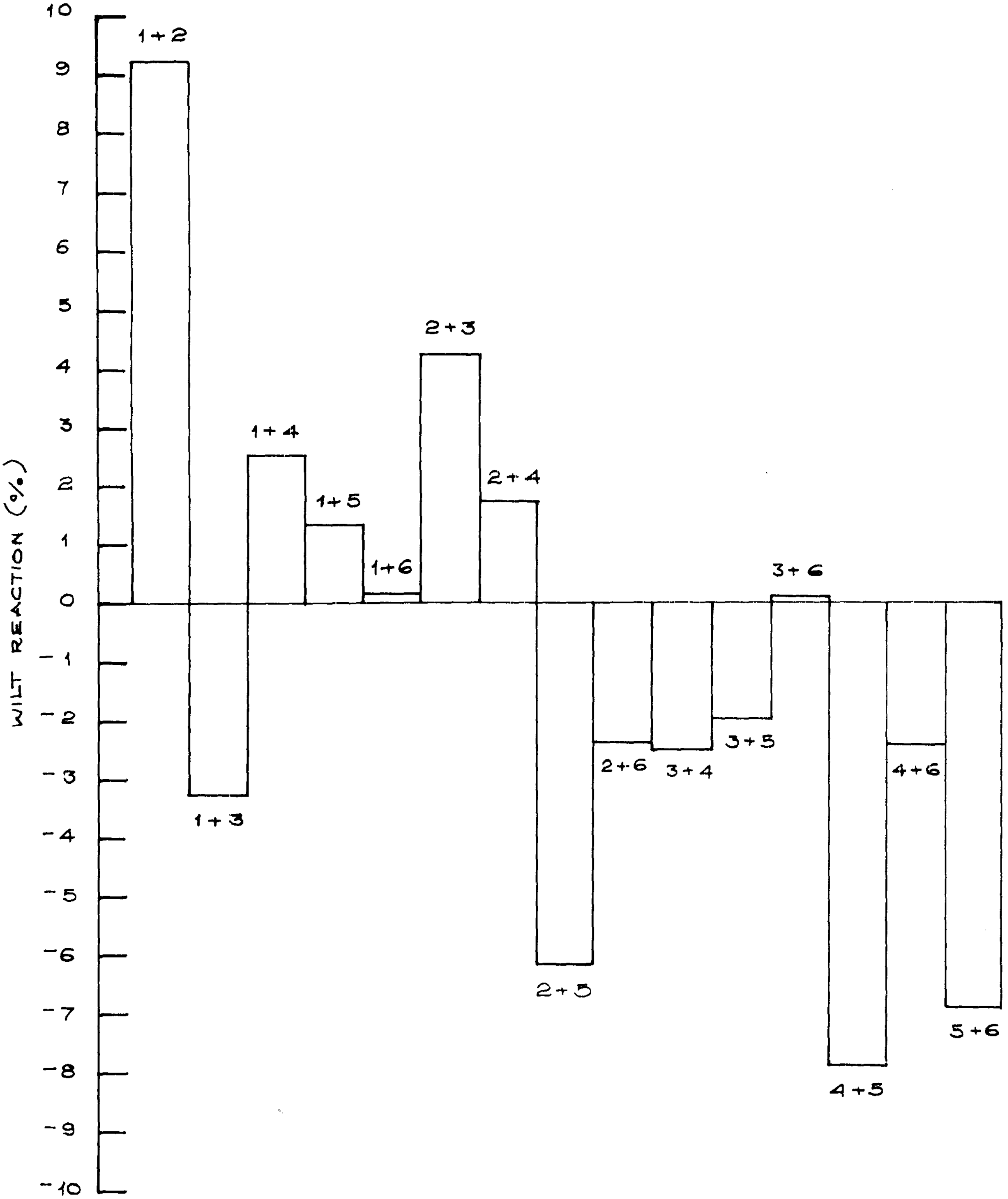

FIG. 1 DEVIATION FROM EXPECTED REACTION OF PHYSICAL MIXTURES TO INCIDENCE OF BACTERIAL WILT

Table 65. Prominent physical mixtures with their salient characteristics

Physical mixtures	Days to fruit set	Days to fruit harvest	Fruit set (%)	Fruits/ plant	Fruit yield/ plant(g)	Wilt reaction (%)
LE 214 + IIHR Bwr 93	66.87 (63.80)	94.82 (89.72)	57.28 (58.91)	24.07 (22.39)	600.38 (555.20)	18.33 (R) (16.67)
LE 214 + LE 217	71.47 (67.20)	98.47 (94.17)	56.33 (58.70)	26.87 (30.43)	562.32 (660.71)	16.67 (R) (12.50)
LE 214 + IIHR Bwr 34A	66.83 (63.97)	94.31 (90.66)	57.27 (60.84)	23.39 (24.96)	584.35 (638.59)	10.00 (R) (16.18)

(Values in parenthesis indicate expected values based on pure stand)

Table 66. Comparison of F_1 hybrids and physical mixtures for resistance to bacterial wilt

Entry	Wilt reaction (%)	Deviation	Entry	Wilt reaction (%)	Deviation
1 x 2	8.6	-34.73	2 x 6	13.33	-11.67
1 + 2	43.33		2 + 6	25.00	
1 x 3	5.17	-26.50	3 x 4	6.67	- 8.33
1 + 3	31.67		3 + 4	15.00	
1 x 4	10.35	-31.31	3 x 5	8.33	- 6.67
1 + 4	41.66		3 + 5	15.00	
1 x 5	5.17	-34.83	3 x 6	6.67	-21.66
1 + 5	40.00		3 + 6	28.33	
1 x 6	17.24	-32.76	4 x 5	35.29	21.96
1 + 6	50.00		4 + 5	13.33	
2 x 3	6.90	-9.77	4 x 6	13.33	-16.67
2 + 3	16.67		4 + 6	30.00	
2 x 4	15.00	-3.33	5 x 6	30.00	5.00
2 + 4	18.33		5 + 6	25.00	
2 x 5	5.00	-5.00			
2 + 5	10.00				

Table 67. Prominent F_1 hybrids and physical mixtures with respect to economic characters

Characters	F_1 hybrids	Physical mixtures
Plant height	LE 214 x LE 217 (104.2 cm)	LE 79 LFF + LE 217 (87 cm)
Primary branches/plant	LE 79 LFF x LE 206 (83 cm)	LE 79 LFF + LE 217 (8.75)
Days to fruit set	LE 214 x IIHR Bwr 34A (56.8 days)	IIHR Bwr 93 + LE 206 (62.86 day)
Days to fruit harvest	LE 214 x IIHR Bwr 34A (94.47 days)	IIHR Bwr 93 x LE 206 (91.08 days)
Fruit set (%)	LE 79 LFF x LE 217 (81.21%)	LE 79 LFF + LE 206 (59.69%)
Fruits/plant	LE 79 LFF x LE 217 (33.07)	LE 214 + LE 217 (26.87)
Fruit yield/plant	LE 214 x LE 206 (921.75 g/plant)	LE 214 + IIHR Bwr 93 (600.38 g/plant)

under warm humid tropical conditions of Kerala, indicating the possible existence of different races of the pathogen and the need to identify field resistant lines. Sreelathakumari (1983) observed resistance in LE 217. Narayanankutty (1985) observed resistance in LE 217 and LE 79 LFG. Resistance in LE 217 and LE 79 LFG were confirmed by spot-planting with the susceptible check, Pusa Ruby during July-November, 1985. High incidence to wilt was observed in LE 208, LE 209, LE 210, LE 212, LE 213, IIHR Bwr 93 and IIHR Bwr 34A. The lines LE 211, LE 214 and LE 79 DG were resistant with wilt incidence of 10%, 6.67% and 15% respectively. These lines could be additional sources of resistance to bacterial wilt (Plate I, II and III).

Heterosis

Earliness of the F_1 hybrids was confirmed taking into consideration constituent characters - days to fruit set and days to fruit harvest. Out of 15 hybrids, 13 hybrids had negative relative heterosis and 12 hybrids showed negative heterobeltiosis for days to fruit set (Table 68). Fourteen hybrids had significantly negative relative heterosis and nine hybrids had significantly negative heterobeltiosis for days to fruit harvest. LE 214 x IIHR Bwr 34A had the first fruit in 56.8 days and took 84.47 days to fruit harvest (Table 67). Earliness in tomato hybrids was reported by Phills (1976), Babu (1978) and Singh _et al_. (1978).

Plate I - LE 79 DG

Plate II - LE 214


L.E. 79 DG


LE 214

Plate III - LE 211


LE 211

Table 68. Number of heterotic hybrids for important economic characters

Characters	Relatively heterotic hybrids	Heterobeltiotic hybrids
Plant height	12 (8)	4 (2)
Primary branches/plant	12 (11)	9 (8)
Days to fruit set	15 (13)	15 (12)
Days to fruit harvest	15 (14)	14 (9)
Fruit set (%)	14 (12)	13 (11)
Fruits/plant	12 (9)	7 (5)
Fruit yield/plant	14 (0)	14 (0)

(Values given in parenthesis indicate significantly heterotic hybrids)

LE 79 LFF x LE 217 had the highest number of fruits/plant (33.07) (Table 67). It expressed heterobeltiosis to the extent of 2.29% and a relative heterosis of 24.98%. Nine hybrids showed significant positive relative heterosis and only five hybrids expressed significant positive heterobeltiosis for fruits/plant. For fruit yield/plant, 14 out of 15 hybrids showed relative heterosis and heterobeltiosis. Heterosis for fruit yield and its components was earlier observed by Babu (1978), Peter and Rai (1978), Singh et al. (1978), Popova et al. (1979), Luk'yan (1980) and Bhutani (1981). The best hybrid in terms of fruit yield/plant was LE 214 x LE 206 (921.75 g) which manifested a heterobeltiosis of 48.33% and a relative heterosis of 52.98%.

Combining ability analysis

Allard (1960) pointed out that the common approach of selecting parents on the basis of per se performance does not necessarily lead to fruitful results. The choice of parents for hybridization has to be based on complete genetic information and the knowledge of combining ability of parents. From the genetical point of view it was inferred that gca and sca could be attributed to additive and non-additive gene action respectively (Sprague and Tatum, 1942). In the present investigation variances due to gca and sca were highly significant for plant height, days to fruit set, days to fruit harvest, fruit set (%)

and fruits/plant. Both additive and non-additive gene action were important in the expression of above characters (Table 69). Singh and Mital (1978) and Peter and Rai (1980) observed both additive and non-additive gene action in the expression of above characters. Variance due to sca was only significant, indicating the role of non-additive gene action for fruit yield/plant. A preponderance of non-additive gene action over additive geneaction for fruit yield/plant was reported by Kaul and Nandpuri (1972), Avarado and Cortazar (1972) and Peter and Rai (1980). For primary branches/plant a preponderance of additive gene action over non additive gene action was observed, as reported by Misra and Khanna (1977).

The best parent for early fruit harvest in present study was IIHR Bwr 93 which had a gca value of -1.12. LE 214 x IIHR Bwr 34A was the earliest hybrid (Table 67). The sca effect of the above cross was -2.84. The gca values of its parents were 0.41 and 0.9 respectively. For fruits/plant, LE 217 had the highest gca effect (3.67) followed by LE 214 (2.34). The sca effect of LE 214 x LE 217 in which two good general combiners were involved as only 3.78. LE 79 LFF x LE 217 had the highest number of fruits/plant (33.07) where sca effect was 3.35. For fruit yield/plant, IIHR Bwr 34A and LE 206 were better parents. The gca was the highest for fruit yield/plant in IIHR Bwr 34A (22.48) followed by LE 206 (16.37). The sca

Table 69. Components of total genetic variances for seven quantitative characters in tomato

Characters	Gene action	
	Additive (A)	Non-additive (N)
Plant height	A	N
Primary branches/plant	A	-
Days to fruit set	A	N
Days to fruit harvest	A	N
Fruit set (%)	A	N
Fruits/plant	A	N
Fruit yield/plant	-	N

effect of the cross IIHR Bwr 34 A x LE 206 was only 25.37. The sca effect of the best hybrid LE 214 x LE 206 was 162.91, whose parents had gca effects of -14.98 and 16.37 respectively. This indicated that hybrids with high *per se* performance may not necessarily have parents with high gca effect.

Maternal effects in the inheritance of quantitative characters

Li (1976) observed cytoplasmic effects for earliness in hybrids between Bonny Best and Immur Prior Beta. Maternal effects for days to flower set was observed by Cuartero and Cubero (1982). In the present investigation, there were significant reciprocal differences for days to fruit set, days to fruit harvest and fruit set (%). There were no reciprocal differences for plant height, primary branches/plant, fruits/plant and fruit yield/plant.

Summary

SUMMARY

The present studies, "Relative advantages of F_1 hybrids and 50:50 physical mixtures in tomato" were carried out during July to November, 1985 at the Instructional Farm of College of Horticulture, Vellanikkara, Trichur. The experiments consisted of four parts.

Evaluation of six specific lines of tomato, their F_1 hybrids and 50:50 physical mixtures for resistance to bacterial wilt, fruit yield and yield components.

Evaluation of two way and three way mixtures involving three lines of tomato for resistance to bacterial wilt, fruit yield and yield components

Maternal effects for certain quantitative characters in tomato

Evaluation of a set of tomato lines for bacterial wilt resistance and economic characters

2) The experimental materials consisted of six specific lines of tomato carrying different resistant gene systems - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93, IIHR Bwr 34A, LE 206 - and eight other reportedly resistant lines of

tomato - LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 79 LFG and LE 79 DG -. Fifteen intervarietal hybrids were developed by crossing six specific lines of tomato in all possible combinations without reciprocals. Fifteen 50:50 physical mixtures were developed by alternate planting in the mainfield.

3) Among the 15 one way F_1 hybrids, all except IIHR Bwr 93 x IIHR Bwr 34A and IIHR Bwr 34A x LE 206 were resistant to bacterial wilt. LE 214 x LE 206, the highest yielder (921.75 g/plant) was earlier to fruit set (57.8 days) and fruit harvest (85 days) followed by LE 79 LFF x IIHR Bwr 34A (908 g/plant). LE 79 LFF x LE 217 had the highest fruit set (%) (81.21%), with the highest fruits/ plant (33.07). Among the 15 physical mixtures, six were resistant - LE 214 + LE 217, LE 214 + IIHR Bwr 93, LE 214 + IIHR Bwr 34A, LE 217 + IIHR Bwr 93, LE 217 + IIHR Bwr 34A, and IIHR Bwr 93 + IIHR Bwr 34A - with a wilt incidence of 16.67%, 18.33%, 10%, 15%, 15% and 13.33% respectively. The best resistant physical mixture, LE 214 + IIHR Bwr 93, had a yield of 600.38 g/plant and produced 24 fruits/plant. It took 66.87 days to fruitset and 94.82 days to fruit harvest.

4) Intervarietal heterosis was calculated as proposed by Hayes *et al*. (1965) and Briggle (1965). Heterosis was observed for plant height, primary branches/plant, days to

fruit set, days to fruit harvest, fruit set (%), fruits/plant and fruit yield/plant.

The best F_1 hybrid LE 214 x LE 206 (921.75 g/plant) had 27.15 fruits/plant, was earlier to fruit set (57.8 days) and fruit harvest (85 days).

5) Combining ability analysis was carried out as suggested by Griffing (1956). Variances due to general combining ability and specific combining ability were significant for plant height, days to fruit set, days to fruit harvest, fruit set (%) and fruits/plant, indicating role of both additive and non-additive gene action in the expression of the above characters. Variance due to general combining ability alone was significant for primary branches/plant, indicating additive type of gene action. Variance due to specific combining ability alone was significant for fruit yield/plant, indicating the role of non-additive gene action.

6) The two way and three way mixtures involving three lines of tomato - LE 206, LE 212 and IIHR Bwr 34A - were only moderately resistant to bacterial wilt. The two way mixtures LE 206 + LE 212, LE 206 + IIHR Bwr 34A, LE 212 + IIHR Bwr 34A and the three way mixture LE 206 + LE 212 + IIHR Bwr 34A had wilt incidence of 31.67%, 26.67%, 33.33% and 31.67% respectively.

7) Five lines of tomato - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93 and LE 206 - were crossed in all possible combinations including reciprocals. All hybrids except LE 206 x IIHR Bwr 93 were resistant. There were significant differences between the direct and reciprocal F_1 hybrids for days to fruit set, days to fruit harvest and fruit set (%), indicating maternal parental effect. There were no reciprocal differences for plant height, primary branches/plant, fruits/plant and fruit yield/plant.

8) Among the 15 lines of tomato evaluated, resistance was observed in LE 211 (10%), LE 214 (6.67%), LE 217 (3.51%), LE 79 LFG (5%) and LE 79 DG (15%). The highest yield was recorded in LE 79 LFG (742.6 g/plant) with 19.67 fruits/plant followed by LE 79 DG (733 g/plant).

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* Originals not seen

RELATIVE ADVANTAGES OF F_1 HYBRIDS AND 50:50 PHYSICAL MIXTURES IN TOMATO

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ABSTRACT OF A THESIS

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ABSTRACT

Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith is the most serious disease limiting the successful cultivation of tomato (*Lycopersicon esculentum* Mill.) in the acidic soils of Kerala. Development of F_1 hybrids possessing different resistant gene systems would be a desirable step in tomato improvement. Development of specific physical mixtures could also minimise crop damage considering the 'obstruction' given by the component lines. Experiments were carried out during 1984-'85, at the Instructionl Farm of College of Horticulture, Vellanikkara, Trichur to identify new sources of resistance to bacterial wilt.

The susceptible check Pusa Ruby showed 100% susceptibility in all the trials. Six specific tomato lines - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93, IIHR Bwr 34A and LE 206 - were crossed in all possible combinations. All F_1 hybrids except IIHR Bwr 93 x IIHR Bwr 34A and IIHR Bwr 34A x LE 206 were resistant to bacterial wilt. LE 214 x LE 206 (921.75 g/plant), the best F_1 hybrid, had 27.15 fruits/plant and was earlier to fruit set (57.8 days) and fruit harvest (85 days). Among the 15 physical mixtures, six were resistant - LE 214 + LE 217 (16.67%), LE 214 + IIHR Bwr 93 (18.33%), LE 214 + IIHR Bwr 34A (10%), LE 217 + IIHR Bwr 93 (15%), LE 217 + IIHR Bwr 34A (15%) and IIHR Bwr 93 + IIHR Bwr 34A (13.33%). LE 214 + IIHR Bwr 93,

the best resistant physical mixture, had 24 fruits/plant weighing 600.38 g/plant.

Intervarietal heterosis was observed for plant height, primary branches/plant, days to fruit set, days to fruit harvest, fruit set (%), fruits/plant and fruit yield/plant. Combining ability analysis indicated the role of both additive and non-additive gene action in the expression of days to fruit set, days to fruit harvest, and plant height. Additive gene action was predominant for primary branches/plant. A preponderance of non-additive gene action over additive gene action was observed for fruits/plant and fruit yield/plant.

To study the maternal parental effect, five lines of tomato - LE 79 LFF, LE 214, LE 217, IIHR Bwr 93 and LE 206 - were crossed in all possible combinations including reciprocals. Maternal parental effect was pronounced for days to fruit set, days to fruit harvest and fruit set (%).

Evaluation of 15 reportedly resistant lines of tomato confirmed resistance in LE 211, LE 214, LE 217, LE 79 LFG and LE 79 DG. The line LE 79 LFG was the highest yield (742.6 g/plant) with 19.67 fruits/plant.