EVALUATION OF A SET OF NON-SEGREGATING AND SEGREGATING POPULATIONS OF TOMATO FOR FIELD RESISTANCE TO BACTERIAL WILT

By
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THESIS

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To

my

Friends

DECLARATION

I hereby declare that this thesis entitled "Evaluation of a set of non-segregating and segregating populations of tomato for field resistance to bacterial wilt" 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,
13 June, 1985.

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CERTIFICATE

Certified that this thesis entitled "Evaluation of a set of non-segregating and segregating populations of tomato for field resistance to bacterial wilt" is a record of research work done independently by Sri. Narayanan Kutty C., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara,
12 June, 1985.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Sri. Narayanan Kutty C., a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Evaluation of a set of non-segregating and segregating populations of tomato for field resistance to bacterial wilt" may be submitted by Sri. Narayanan Kutty C., in partial fulfilment of the requirement for the degree.

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INTRODUCTION

Bacterial wilt caused by Pseudomonas solanacearum E.F. Smith is the most serious disease affecting successful cultivation of tomato (Lycopersicon esculentum L.) in the warm humid tropics. Conventional plant protection methods have failed to control this disease. Breeding for resistance is the obvious choice left. Two sources of resistance have been reported and a good number of resistant varieties have come up. The breaking down of resistance is the most serious constraint in breeding bacterial wilt resistant tomatoes. The tomato line LE 79 (CL 32d-0-1-19 GS) reported resistant to bacterial wilt in Kerala, was resistant only to three of eight isolates tested. This points to the need for continuous evaluation of varieties for resistance to bacterial wilt. Studies on genetics of wilt resistance showed that resistance is controlled mainly by recessive genes. Crosses involving resistant varieties were more resistant than the resistant cultivars themselves. This fact needs to be investigated.

The reports on undesirable linkage between resistance and poor fruit characteristics present a

grim outlook for bacterial wilt resistance breeding programmes. Lines having good resistance to bacterial wilt associated with appreciable fruit size have to be identified.

The present system of alternate row planting with susceptible check for field screening in resistance breeding programmes is handicapped with high probability of escape. A practical and more feasible method of field screening, if deviced, would enable the continuous evaluation of lines for resistance.

The present study was formulated with the following objectives

1. To evaluate a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt
2. To evaluate newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt
3. To evaluate a set of tomato lines for wilt resistance under two environments
4. To study the genetics of fruit shoulder colour in intervarietal crosses involving Pusa Ruby and LE 79

5. To evaluate the effectiveness of spot - planting as a method for varietal evaluation against bacterial wilt

REVIEW OF LITERATURE

Bacterial wilt caused by Pseudomonas solanacearum E.F. Smith is one of the most destructive plant diseases in the warm humid regions of the world. About 106 species of plants are susceptible to Pseudomonas solanacearum (Young, 1946). According to Kelman (1953) the major susceptible species belong to the family Solanaceae. Among the solanaceous vegetables, tomatoes and egg plants were more susceptible than peppers (Chupp and Sherf, 1960).

A. Origin, races and strains of Pseudomonas solanacearum

It is not known in which continent Pseudomonas solanacearum arose. Majority of evidence indicate that the strains are products of long evolution occuring independantly in different areas on different hosts (Buddenhagen and Kelman, 1964).

Tremendous geographical variation occurs in Pseudomonas solanacearum. Hayward (1964) described the pathogen as complex consisting of different races differing in host range and pathogenicity. Buddenhagen (1960) found that the race affecting banana is not related ecologically or etiologically to the race causing bacterial wilt in the dicotyledenous plants. Okabe and

Goto (1961) conducted detailed studies on the strains of Pseudomonas solanacearum. They seperated isolates from Japan into 40 groups based on biochemical properties, serological reactions and sensitivity to virulent phages. They further recognised three types of strains.

1. strains specialised in pathogenicity
2. strains specialised in pathogenicity and other physiological and morphological characters
3. strains specialised in bacteriological characters only

Buddenhagen et al. (1962) classifed 4000 isolates from Central and South America into 3 races broadly based on their pathogenicity. Race 1 attacked solanaceous crops and certain diploid bananas. Race 2 was pathogenic on bananas and heleconias. Race 3 was pathogenic to potato and tomato but weakly pathogenic on other solanaceous crops. 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. Races 2 and 3 had more agglutinins in common than either has with race 1 (Morton et al., 1966). 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) also studied ten isolates of Pseudomonas solanacearum attacking tomato and found that they all belonged to race 1. They were morphologically alike, but exhibited variations for biochemical properties as gelatin liquefaction, action on milk, starch hydrolysis etc. Serologically six of them could be grouped into one.

B. Symptomatology of the disease

Generally the first expression of the disease is a wilting of the lower leaves of the plant (Walker, 1952; Chupp and Sherf, 1960). The wilting is usually accompanied with yellowing of older leaves. Dwarfing and stunting of the plant may also occur (Young, 1946; Kelman, 1953). A very characteristic and distinct indication of bacterial wilt is the appearance of bacterial coze from the injured vascular regions (Ashrafuzzaman and Islam, 1975). The roots and lower part of the stem appearing normal from outside, show a browning of vascular bundles and a water-soaked appearence in the root (Chupp and Sherf, 1960). Eventually dark brown to black areas develop due to decay of root system and the whole plant dies off.

C. Mechanism of wilting

The pathogen, Pseudomonas solanacearum is aerobic, gram negative, non-spore forming, rod-shaped and motile with one or several polar flagella (Ashrafuzzaman and Islam, 1975; Kranz et al., 1977). It survives in soil under natural conditions for as long as six years. Once a susceptible host is available, entry is mainly through the root system (Walker, 1952; Chupp and Sherf, 1960; Kranz et al., 1977). Libman et al. (1964) reported the entry of pathogen through uninfested roots. Kelman and Sequeira (1965) found that root to root contact is not necessary for infection. The bacterium may emerge out from diseased regions and infects at the point of origin of secondary roots.

The first visible symptom following infection is observed within two to eight days (Kelman, 1953; Chupp and Sherf, 1960). The pathogen is first detected in the xylem vessels from which they progress into the intercellular spaces of cortex and pith causing lysigenous cavities (Walker, 1950). Severe wilting is caused by vascular plugging (Walker, 1952; Hussain and Kelman, 1958). Hussain and Kelman (1958) also reported that mere vascular plugging alone does not cause wilting as majority of vascular bundles are not

blocked even in wilted plants. Further, plugging was also observed even when inoculated with weakly virulent strains where no wilting was seen. All the virulent strains produced an extra cellular slime, the wilt inducing material. Based on observations, they suggested that the virulent strains after entry into the host multiply rapidly in xylem and form slime in abundance which causes a marked increase in the viscosity of vascular stream. They interfere with water movement resulting in wilting. According to Buddenhagen and Kelman (1964) virulence is a term too complex to be explained based on extra cellular slime only, since virulence in the sense of strain specificity is not related to the presence or absence of slime formation. Kelman (1954) reported that fluidal white colonies with pink centres are highly pathogenic while butyrous red colonies are weakly pathogenic or non-pathogenic. All strains rapidly change in culture from pathogenic form with mucoid often fluidal colonies to an avirulent form with small butyrous colonies (Kranz et al., 1977).

Break down of plant tissues due to bacterial wilt is attributed to the cellulase and poly galacturonase enzymes produced by the bacterium (Hussain and Kelman, 1957). Continued tissue decay and plugging finally result in the death of the plant.

D. Spread of disease

Dissemination and spread of the disease through decayed and diseased plant parts were reported (Chupp and Sherf, 1960; Kelmen and Sequeira, 1965; Kranz et al., 1977). Release of a large number of bacteria into the soil from infected plants play an important role in the rapid spread and infection of adjacent plants. Spread of the disease was favoured by various cultivation practices like transplanting, cutting and pruning and also by furrow irrigation (Walker, 1952). Keshwal et al. (1978) found that the pathogen is apparently not seed borne in tomato, brinjal or in chillies. Plants grown from seeds from infected plants or from artifically inoculated seeds were not normally diseased.

E. Factors affecting spread of disease

1. Environmental factors

The disease was favoured by high temperature (Walker, 1952). Vaughan (1944) found no disease symptom below 21°C. However, infection took place at temperature as low as 13°C. Plants grown in sand severely wilted at 27°C and recovered when temperature was brought down to 12°C. When the temperature was again brought back to 21°C the plants wilted again. According to Chupp and Sherf (1960) the temperature range for disease development

was between 15 to 38°C, with an optimum at 29 to 35°C. Kranz et al. (1977) reported that disease incidence was maximum between 21 to 35°C. Gallegly and Walker (1949) found that high soil moisture also favoured disease development. The disease could also occur in dry soils (Chupp and Sherf, 1960). Gallegly and Walker (1949) also reported increased disease incidence with increase in air temperature from 15 to 28°C. They found that disease incidence was greater at low light intensity and at short days. On the contrary, Hildebrandt (1950) obtained increased disease incidence at higher light intensity and at long days.

2. Soil and climatic factors

The disease was generally observed high in red laterite soil (Heaton and Benson, 1968). Chupp and Sherf (1960) observed no disease incidence in alkaline soils. The areas where the greatest loss occured had a pH of 5 to 5.5. Remadevi and Menon (1980) studied the seasonal incidence of bacterial wilt in the acidic tropical soils of Kerala. They reported maximum disease incidence during October and November. The disease incidence was observed minimum during February. No significant correlation was observed between the various environmental factors and disease incidence. Hildebrandt

(1950) observed the highest bacterial wilt incidence at 32°C with a low nitrogen concentration in either long or short days. The severity of infection increased with higher phosphorus levels and reduced with high nitrogen levels (Walker, 1952).

3. Plant pathogenic organisms

Lucas et al. (1955) observed higher incidence of bacterial wilt in soils infested with root-knot nematode, Meloidogyne incognita. Temiz (1968) found increased infection in the tomato variety Floradel in the presence of nematodes. Wilt development occured earlier and mortality was higher in both resistant and susceptible cultivars of tomato in soil infested with Pseudomonas solanacearum and Meloidogyne incognita, than those grown in soil infested with bacterium alone (Napiere and Quimio, 1980). Sellam et al. (1980) observed severe bacterial wilt in pot tests caused by combined inoculation of bacteria and nematode but not with either alone. The presence of bacterium in the soil had no effect on galling. Goth et al. (1983) found that bacterial wilt resistance in the tomato line LE 79 was broken down when root-knot nematode larvae were added at the rate of 100/10 cm pot at the time of inoculation with bacterial isolates. They suggested

nematode resistance should also be considered in future breeding programmes against bacterial wilt.

4. Plant age and inoculation technique

The plant age had no marked effect on susceptibility to Pseudomonas solanacearum in susceptible lines. In resistant lines, susceptibility decreased with increase in age of the plants (Winstead and Kelman, 1952). Jenkins and Nesmith (1976) also reported better survival of seedlings of resistant tomato varieties Venus and Saturn when planted at eight weeks of age. Winstead and Kelman (1952) found no significant difference in disease incidence with varying plant populations from 45 to 450 plants/flat.

F. Methods of control

Various methods have been 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 the rotation Vigna sp. followed by maize and cabbage/okra followed by Vigna sp. and maize gave effective control of the disease (Sohi et al., 1981). Jones et al. (1966) obtained reduction in wilt by covering the test plants with black plastic films and fumigating with DCB, nomex and vordex. Attempts have been made to control bacterial

wilt by dipping plants in 200 ppm streptomycin for ten minutes followed by Kocidelot 250 ppm for 60 minutes before transplanting (Pastyka et al., 1973). Enfinger and Mc Carter (1976) found that out of several chemicals tested, methyl bromide, chloripicrin and vorlex were the most effective to control bacterial wilt.

Complete control of bacterial wilt was obtained by grafting tomato scions on to resistant stock Solanum diversifolium. The two species were found highly compatible and the root stock was also resistant to root-knot nematode, Meloidogyne incognita (Reyes, 1967). Villareal et al. (1970) obtained satisfactory control of bacterial wilt by grafting 3 weeks old tomato scions on resistant tomato stocks, Selection 1169 and Hawaii-2. 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). Felix (1973) found that tomato scions tongue-grafted on Solanum torvum rootstocks were resistant to both bacterial wilt and root-knot nematodes. Bacterial wilt incidence was reduced below 10% when tomato scions were grafted on resistant brinjal stocks (Lum and Wong, 1976). Kaan (1977)

reported 5 small fruited tomato lines with good resistance to bacterial wilt as suitable stocks for grafting. Of these Cranita was also resistant to nematodes, Meloidogyne incognita. Peregrine and Ahmad (1982) grafted wilt susceptible commercial cultivars Roma and Floradel on Solanum torvum rootstocks. The grafts were planted round the year. The average survival was 66.6% and 56.5% respectively. Russell (1978) reported that the disease is very difficult to be controlled by chemical or cultural methods and accordingly there are many programmes of breeding for resistance.

G. Sources of resistance

Breeding for resistance to bacterial wilt in tomatoes started first at the North Carolina Agricultural Experiment Station, U.S.A. in 1944. Good resistance under field conditions were obtained with Louisiana Pink and a Lycopersicon esculentum line T 414 from Puerto Rico. Crosses between these two tomatoes were considered as promising sources of resistance to bacterial wilt (Weaver, 1944). The same results were also obtained by Aberdeen (1946) in Queensland. He also found that the two tomato cultivars Sensation and Marvel showed good resistance to Pseudomonas solanacearum but the fruit qualities of these varieties were poor. In the annual

report of the School of Agriculture, North Carolina State College (1950-'51) tomato lines with good resistance to bacterial wilt were reported. Only a very few of them bore fruits of marketable size. Abeyagunawardena and Siriwardena (1963) tested 49 tomato varieties and hybrids for their resistance to bacterial wilt. The North Carolina lines 1960-8, 1960-2a, 1962-B2, 1961-57-55M and the tomato varieties Masterglobe and Rahangala were the most resistant to bacterial wilt. 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. Acosta et al. (1964) reported a new source of resistance to bacterial wilt in Lycopersicon pimpinellifolium (PI 127805A). In croses involving popular varieties of U.S.A., Manalucie and Floradel with a resistant line from North Carolina, a few lines resistant to Pseudomonas solanacearum were evolved (University of Florida, 1967). Henderson and Jenkins (1972) reported two bacterial wilt resistant tomato varieties, Venus and Saturn. Both the varieties were derived from crosses among Louisiana Pink, Beltsville 3814, Pan America, Rutgers, Marglobe, STEP 174 and Manalucie at different levels.

High levels of resistance were observed both in green house and outdoors with three tomato introductions 65-S_2, 66-SS_2 and 68-S_4 from U.S.A. (Akiba et al., 1972). Daly (1973) reported that lines III IRAT and OTB_2 were also resistant to Pseudomonas solanacearum. In a screening programme conducted at the Asian Vegetable Research and Development Centre, Taiwan in 1975 involving 247 cultivars, two additional sources of resistance were observed in the accessions 1737 and 1937 (AVRDC Tomato report, 1975). Daly (1976) reported that the tomato variety IRAT L_3 was fairly resistant to Pseudomonas solanacearum with only 15% of the plants wilted even 80 days after transplanting in the field. The line Vc 8-1-2-1 was resistant regardless of inoculam density in a trial involving 43 varieties and lines (Mew and Ho, 1976). The tomato lines FP-1, FP-2 and FP-5 were observed tolerant to Pseudomonas solanacearum (University of Malaya, 1977). Sonoda and Augustine (1977) conducted field tests with 72 tomato lines. In the first test no resistant plants were observed in Hawaii-7981, CRA-66 selections or in PI 126408. Only 1% of the plants were killed in the line Hawaii 7997. The standard wilt resistant line Saturn showed 3% wilt incidence and

susceptible check Walter got completely wilted. In the second test the lines PI 365930, PI 212441 and PI 263722 showed only 2, 4 and 10% wilting respectively. The wilt incidence was 70% in the cultivar Walter and as high as 99% in the cultivar Florida MH-1. Saturn and Venus showed 57 and 60% wilting respectively. In another three field tests involving 121 cultivars and lines, only 7 to 19% wilt incidence was observed in the line PI 126408 and in the cultivars Venus and Saturn (Sonoda, 1977). In green house trials the cultivar Vc 4 was found resistant (Graham et al., 1977). Resistance was also observed in the line Vc 48-1 in Taiwan (AVRDC, 1978). Bedeker (1977) observed resistance in the tomato lines Vc 9-1UG and Vc 11-1UG to eight isolates of Pseudomonas solanacearum. Moderate resistance to bacterial wilt was observed in the tomato lines L-3972, L-3987 and CL 8d-0-7-1 (AVRDC, 1979). Sonoda et al. (1980) confirmed wilt resistance in the lines Hawaii 7977, CRA-66 and PI 126408. Out of the four cultivars tested for resistance to bacterial wilt, the cultivar Vc/Nova was the most resistant (Bissonauth, 1980). Sunarjono (1980) found that the breeding lines AVRDC 15 and AVRDC 33 were resistant to bacterial wilt. Resistance was also observed in the lines CL 32d-0-1-25

and in Hawaii 7996. Ramachandran et al. (1980) evaluated 36 tomato varieties for their resistance to bacterial wilt in the warm humid tropical soils of Kerala. Resistance was observed on in the cultivar La Bonita and CL 32d-0-1-19 GS, an AVRDC line. Hoque et al. (1981) conducted field tests with 25 varieties and found that the lines CL 8d-0 and CL 143-0-13 were highly resistant. Celine (1981) reported field tolerance to bacterial wilt in the line CL 32d-0-1-19 GS. Lin and Chen (1982) reported that TSS 1 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 to bacterial wilt. In a trial conducted at Embrapa in Brazil, the AVRDC line CL 1131-0-0-38-40 was found resistant to bacterial wilt (Instituto Nacional de pesquisas de Amazonia, 1983). Goth et al. (1983) tested selected tomato lines and cultivars to eight isolates of Pseudomonas solanacearum (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 the line CL 32d-0-1-19 GS was resistant to 3 isolates K 60, 124608-1 and Tifton 80-1 of race 1. The cultivar Venus was resistant only to the isolate 126408-1 of race 1. Peterson et al. (1983) reported

high resistance to bacterial wilt in the tomato cultivar Scorpio in South Eastern Queensland.

H. Break down of resistance in reportedly resistant varieties

Many tomato varieties previously considered resistant in the U.S.A. and the Phillipines were susceptible to isolates to Pseudomonas solanacearum in India (Rao et al., 1975). Abeyagunawardena and Siriwardena (1963) found that the Los Banos line of tomato reported resistant in Phillipines was susceptible in Sri Lanka. They suggested the presence of different races in Pseudomonas solanacearum. Krausz and Thurston (1975) observed that the cultivar Venus, resistant to the isolate K 60 was susceptible to the isolate LB 6. Jenkins and Nesmith (1976) tested the resistant tomato 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. But they became highly resistant after 4 to 6 weeks. With the Indian isolate, both the cultivars were susceptible upto ten weeks of age when stem inoculated. They found that the Indian isolate was more virulent than the American isolate. Mew and Ho (1976) found that tomato accessions 21 and 81, found resistant

under field tests shifted from resistant to moderately resistant at higher inoculam densities using artificial inoculation. Bedeker (1977) found that disease reaction varied from cultivar to cultivar and among isolate mixtures. Saturn and PI 303811 could withstand only weakly virulent isolates and their mixtures and succumbed to all highly virulent isolates and their mixtures from Taiwan. Sonoda (1977) observed that tomatoes resistant to wilt in Hawaiian soils were susceptible at Fort Pierce, Florida.

I. Genetics of resistance

The genetics of bacterial wilt resistance was found complex (Russell, 1978). There are two primary sources of resistance. The first being the North Carolina source expressed by derivatives of Louisiana Pink, was inherited as a recessive character and controlled by polygenes (Singh, 1961). Suzuki et al. (1964) reported that resistance was quantitatively inherited both in tomato and brinjal. Three tomato cultivars (Vc 11-1, Saturn and Kewalo) resistant to bacterial wilt and the corresponding F_1 progeny of two way and three way crosses were inoculated with a weak isolate and a virulent isolate of Pseudomonas solanacearum. The progeny was found more resistant

than the parents. This showed that resistance to bacterial wilt was controlled by multiple recessive genes acting additively (AVRDC, 1975). Perver (1976) crossed wilt resistant PI 126408 plants with susceptible Bonny Best and Floradel. Segregating ratios in F_2 s suggested that resistance was polygenically inherited. Reciprocal crosses showed that no extra chromosomal inheritance was involved. The genes involved in wilt resistance were additive and no dominance was observed. Graham and Yap (1976) conducted variance component analysis of parents, F_1s, F_2s, Bc_1s and Bc_2s of a cross between the resistant line Vc 4 and a susceptible cultivar Walter. Wilt resistance showed a narrow sense of heritability of 42%, broad sense of heritability of 53% with a degree of dominance of 5%. A diallel analysis using six cultivars showed that gca was more than sca. It was suggested that inheritance of resistance was due mainly to additive gene action. Mew and Ho (1977) found that polygenic inheritance was modified by changes in temperature. Villareal and Lai (1978) found that crosses between resistant cultivars were more resistant than the resistant cultivars themselves.

A second type of resistance was reported in Lycopersicon pimpinellifolium (PI 127805A) (Acosta et al.,

1964; Mohanakumaran et al., 1969 and Roddick, 1974). Acosta et al. (1964) found that resistance observed in Lycopersicon pimpinellifolium was partially dominant in the seedling stage. In mature plants resistance was controlled by recessive genes. Sreelathakumary (1983) used two distinct sources of resistance, one derived from Louisiana Pink possessing North Carolina type of gene system and the other from PI 127805A possessing Lycopersicon pimpinellifolium type of gene system and crosses were made to find out inheritance of combined wilt resistance to bacterial wilt in tomato . 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. Tikoo et al. (1983) reported the presence of two independent genetic systems for resistance to bacterial wilt. The resistance in CRA-66 sel-A from Hawaii was governed by multiple recessive genes. In contrast, the genotype 663-12-3 from Taiwan had a monogenic dominant resistant reaction.

J. Linkage of wilt resistance with fruit characters

Two serious drawbacks to the successful development of a bacterial wilt resistant tomato variety were the

labile expression of resistance and poor quality fruits in many of the sources of resistance. Many of the North Carolina lines resistant to bacterial wilt had no marketable fruit size (Russell, 1978). Acosta (1964) reported a 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 resistance to bacterial wilt. (Acosta et al., 1964). None of the resistant selections had fruits with marketable size. A few lines had a yellow gel around the seeds of ripening fruits. Investigations on resistance to Pseudomonas solanacearum indicated a close linkage between recessive genes for resistance and genes for poor fruit characteristics (University of West Indies, 1969). Celine (1981) also observed a yellow gel around the seeds of a resistant line LE 79 (CL 32d-0-1-19 GS).

K. Biochemical basis of resistance

Mohanakumaran et al. (1969) observed higher content of the steroidal glycoalkaloid ∝ -tomatin in resistant lines. The content of ∝ -tomatin increased after inoculation in resistant varieties. Roddick (1974) also observed higher levels of ∝ - tomatin in the roots of Lycopersicon pimpinellifolium accessions

resistant to Pseudomonas solanacearum than in susceptible cultivars.

L. Inoculation techniques

Winstead and Kelman (1952) evaluated the relative effectiveness of various procedures to inoculate susceptible and resistant tomato plants. Preliminary tests with naturally infested soils or diseased plant debris showed the superiority of pure cultures for inoculation under green house conditions. Inoculations either by puncturing the stem through a drop of bacterial suspension placed on the leaf axil or by pouring a bacterial suspension over wounded secondary roots were equally effective on susceptible tomato plants. Stem inoculations gave the highest disease incidence with resistant tomato plants. However the best differentiation between resistant and susceptible plants was made based on root inoculations. Lin et al. (1974) inoculated tomato plants by clipping off leaf tips with scissors dipped in a suspension of bacterial culture and obtained wilting to the same extend as found in plants grown in naturally infested field.

MATERIALS AND METHODS

The present studies were conducted at the Instructional farm, College of Horticulture, Kerala Agricultural University, Trichur during September to February, 1983-'84, January to May, 1984 and September to February, 1984-'85. The farm is located at an altitude of 22.25 M above mean sea level and lies at 10° 32' N latitude and 76° 16' E longitude. The farm experiences a typical warm humid tropical climate. The laterite loam soil of the experimental site is deep, well-drained and moderately acidic (pH 5.1). The soil has a high inoculam of the bacteria, Pseudomonas solanacearum E.F. Smith resulting in heavy losses to solanaceous vegetables due to wilt. The present studies consisted mainly of five parts

A. Evaluation of a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt

B. Evaluation of newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt

C. Evaluation of a set of tomato lines for wilt resistance under two environments

D. Genetics of fruit shoulder colour in inter-varietal crosses involving Pusa Ruby and LE 79

E. Efficiency of spot-planting as a method for varietal evaluation against bacterial wilt

A. Evaluation of a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt

1. Materials

a) Non-segregating populations

(i) Saturn

(ii) LE 79

(iii) Pusa Ruby

(iv) Pusa Ruby x LE 79 (F_1)

b) Segregating populations

(i) Pusa Ruby x LE 79 (F_2)

(ii) Saturn x LE 79 (F_2)

c) Susceptible check

(i) Pusa Ruby

2. Lay out and experimental design

The experiment was conducted during September to February, 1983-'84 in a uniformly fertile and wilt sick soil. There were 60 plants/non-segregating

population and 280 and 200 plants in Saturn x LE 79 F_2 and Pusa Ruby x LE 79 F_2 respectively. The susceptible check, Pusa Ruby was spot-planted with all the plants in both the segregating and non-segregating populations. The plants were critically examined for the incidence of bacterial wilt. The wilting of susceptible check indicated the presence of virulent pathogen in the soil. Bacterial-ooze test was also carried out in each of wilted plants 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)

S = susceptible ($>$ 60% plants wilted)

The following observations were also made.

a) Days to first fruit set

b) Days to first fruit harvest

c) Fruits/plant

d) Fruit yield/plant

The data were analysed to test the varience within each line.

F_1 plants were also simultaneously raised in pots to produce F_2s for the next season and F_2 in the field were selfed to produce F_3 seeds.

B. Evaluation of newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt

1. Materials

a) Parents

(i) Saturn

(ii) LE 79

(iii) Pusa Ruby

b) F_2s

(i) Saturn x LE 79 (F_2)

(ii) Pusa Ruby x LE 79 (F_2)

c) F_3s

(i) Saturn x LE 79 (F_3)

(ii) Pusa Ruby x LE 79 (F_3)

d) Susceptible check

(i) Pusa Ruby

2. Layout and experimental design

The parents, F_2s and F_3s developed during previous season were raised during September to February, 1984-'85. There were 67 plants in Saturn, 65 plants in LE 79,

70 plants in Pusa Ruby, 406 plants in Saturn x LE 79 F_2, 458 plants in Saturn x LE 79 F_3 and 430 plants each in Pusa Ruby x LE 79 F_2 and F_3. Each individual plant was spot-planted with the susceptible check, Pusa Ruby. Observations were made on bacterial wilt incidence and disease rating was carried out as in the previous experiment. The following observations were also recorded.

a) Days to first fruit set
b) Days to first fruit harvest
c) Fruits/plant
d) Fruit yield/plant
e) Average fruit weight

The data were analysed to test the variance within each line.

C. Evaluation of a set of tomato lines for wilt resistance under two environments

1. Materials

The materials included tomato lines LE 206, LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 214, LE 217, LE 79, LE 79 LFG, LE 79 DG, LE 79 LFF and IIHR Bwr 34 A. Pusa Ruby was the susceptible check. The accession numbers, name, pedigree and source of the tomato lines are given in Table 1.

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-/Tamu chico 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-8-1-2-9B/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-

(Contd.)

Table 1. (Contd.)

Accession number	Name	Pedigree	Source
LE 217	Louisiana Pink	E.C. 143572 (PI 270196)	Vegetable Laboratory, USDA BARC-W USA
LE 79	CL 32d-0-1-19 GS	Vc-9-1-2-3/Venus	AVRDC Taiwan
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-
LE 79 SPF	CL 32d-0-1-1-1-1-19 GS	Vc-9-1-2-3/Venus	-do-
IIHR Bwr 34 A	....	....	IIHR Bangalore
LE 5	Pusa Ruby	Improved Meeruti x Sioux	IARI New Delhi

During September to February, 1984-'85 the lines IIHR Bwr 34 A and LE 79 SPF were also evaluated along with the lines evaluated in the first season. The plants were grown in a randomised block design with 24 plants/line/replication. The spacing was 60 x 60 cm. The lines were genetically catalogued according to the procedure given in the Tomato Genetics Cooperative, May, 1980. The gene list of characters are given in Table 2. The plants were critically examined for wilt incidence as in the previous season. Five plants were randomly selected in each line/replication and the following observations were made.

a) Days to first fruit set
b) Days to first fruit harvest
c) Percentage of fruit set
d) Average fruit weight
e) Locules/fruit
f) Fruits/plant
g) Fruit yield/plant
h) Fruit cracking (radial/concentric/irregular)

Data were analysed as in a randomised block design. Missing-Plot technique was followed wherever necessary.

Table 2. Gene list of characters

Gene	Name	Phenotype	Locus	
			Chromosome	Site
a	anthocyaninless	Completely anthocyaninless	11L	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 elongate	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

2. Layout and experimental design

The studies were conducted during January to May, 1984 and September to February, 1984-'85. During January to May, 1984 the lines LE 206, LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 214, LE 217, LE 79, LE 79 LFG, LE 79 DG and LE 79 LFF were grown in a randomised block design with three replications. The spacing was 60 x 60 cm. These were 30 plants/line/replication. The susceptible check, Pusa Ruby was also grown, 30 plants/replication. Observations were recorded on bacterial wilt incidence by counting the plants wilted in each time and confirming bacterial wilt through the ooze-test. Five plants were randomly selected in each line/replication and the following observations were made.

a) Days to first fruit set
b) Days to first fruit harvest
c) Average fruit weight
d) Locules/fruit (Average of 5 fruits/plant)
e) T.S.S.
f) Fruits/plant
g) Fruit yield/plant

T.S.S. was measured in °brix using a hand refractometer.

D. Genetics of fruit shoulder colour in inter-varietal crosses involving Pusa Ruby and LE 79

1. Materials

a) Pusa Ruby

b) LE 79

c) Pusa Ruby x LE 79 (F_1)

d) Pusa Ruby x LE 79 (F_2)

2. Layout and experimental design

The parents, F_1 and F_2 populations were grown during September to February, 1984-'85. These were 30 plants/parent and F_1 and 170 plants in the F_2. The plants were critically examined for their fruit shoulder colour (green/white) at the fruiting stage.

E. Efficiency of spot-planting as a method for varietal evaluation against bacterial wilt

1. Materials

a) Pusa Ruby

b) LE 79

c) Venus

d) Rutgers

2. Layout and experimental design

The various methods used in evaluation against

bacterial wilt like root dipping of the seelings in the bacterial culture and planting, stem inoculation in leaf axil and alternate row planting with susceptible check were compared with spot-planting. Spot-planting consisted of combined planting of a known suscept (Pusa Ruby) with the lines under evaluation in a wilt sick field. The presence of virulent inoculam at the planting spot was confirmed through wilting of susceptible check. Data were recorded on susceptibility by counting the number of cases in which both the susceptible check and line under test wilted. Data were also recorded on resistance by counting the number of plants thrived in spots where susceptible check wilted.

RESULTS

Data collected in the present study were statistically analysed and presented under the following heads.

A. Evaluation of a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt

B. Evaluation of newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt

C. Evaluation of a set of tomato lines for wilt resistance under two environments

D. Genetics of fruit shoulder colour in inter-varietal crosses involving Pusa Ruby and LE 79

E. Efficiency of spot-planting as a method for varietal evaluation against bacterial wilt

A. Evaluation of a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt

During September to February, 1983-'84 four non-segregating populations of tomato, Saturn, Pusa Ruby, LE 79 and Pusa Ruby x LE 79 (F_1), two

segregating populations Pusa Ruby x LE 79 (F_2) and Saturn x LE 79 (F_2) were evaluated under field conditions to test their disease reaction. There was 100% disease incidence in the susceptible check Pusa Ruby confirming presence of virulent bacterial inoculam in the test field. The genotypes were classified for their disease reaction according to Mew and Ho (1976) (Table 3). Saturn x LE 79 (F_2) was resistant with a disease incidence of only 15.9%. LE 79 was moderately resistant (22.64%) while Pusa Ruby x LE 79 (F_2) and Pusa Ruby x LE 79 (F_1) were moderately susceptible (47.14% and 43.18% respectively). The data on days to fruit set, days to fruit harvest, fruits/plant and fruit yield/plant were analysed (Table 4). The genotype Pusa Ruby x LE 79 (F_2) was earlier both for fruit set and harvest (77 and 108 days respectively). LE 79 yielded the maximum (1.35kg/plant) while Pusa Ruby x LE 79 (F_2) had the highest fruits/plant (37.6). Saturn x LE 79 (F_2) had 21.25 fruits with an average yield of 1.22kg/plant.

B. Evaluation of newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt

The parents (Saturn, LE 79 and Pusa Ruby), F_2s (Saturn x LE 79 F_2, Puse Ruby x LE 79 F_2) and F_3s

Table 3. Evaluation of non-segregating and segregating lines of tomato for reaction to bacterial wilt

Lines	Number of plants	Number of plants wilted	Wilt (%) reaction
Saturn	54	25	46.29 (MS)
LE 79	53	12	22.64 (MR)
Pusa Ruby	58	58	100.00 (S)
Pusa Ruby x LE 79 (F_1)	44	19	43.18 (MS)
Pusa Ruby x LE 79 (F_2)	104	49	47.14 (MS)
Saturn x LE 79 (F_2)	176	28	15.90 (R)

R = Resistant < 20% plants wilted

MR = Moderately resistant 20 to 40% plants wilted

MS = Moderately susceptible 40 to 60% plants wilted

S = Susceptible > 60% plants wilted

Table 4. Mean performance of Saturn, LE 79, F_1 and the F_2s

Lines	Days to fruit set	Days to fruit harvest	Fruits/plant	Fruit yield/ plant(g)
Saturn	101.14 ± 2.03	137.86 ± 1.99	3.48 ± 0.65	289.52 ± 59.23
LE 79	80.65 ± 1.02	113.33 ± 1.13	29.38 ± 2.35	1347.95 ± 119.33
Pusa Ruby x LE 79 (F_1)	78.21 ± 1.59	109.82 ± 2.13	27.73 ± 2.55	1071.52 ± 131.31
Pusa Ruby x LE 79 (F_2)	76.48 ± 0.74	108.46 ± 0.79	37.61 ± 3.17	1345.00 ± 128.62
Saturn x LE 79 (F_2)	86.48 ± 0.49	121.72 ± 0.63	21.25 ± 1.23	1217.83 ± 79.64

(Saturn x LE 79 F_3, Pusa Ruby x LE 79 F_3) were grown in a wilt sick soil during September to February, 1984-'85. The lines were classified for their disease reaction as in the previous experiment (Table 5). Complete wilting (100%) was observed in the susceptible check, Pusa Ruby. The segregating Saturn x LE 79 (F_3) had the lowest wilting (10.7%), followed by Saturn x LE 79 (F_2) (18.23%) and both were found resistant. LE 79 was moderately resistant (29.54%) while Pusa Ruby x LE 79 (F_3) was moderately susceptible (44.88%). The genotypes Saturn, Pusa Ruby and Pusa Ruby x LE 79 (F_2) were susceptible to wilt. Analysis of data for days to fruit set showed that LE 79 and Pusa Ruby x LE 79 (F_2) were earlier than other genotypes in respect of days to fruit set and fruit harvest (Table 6). LE 79 took only 69 days for fruit set and 98 days for fruit harvest. Fruits/plant were also the highest in LE 79 (30.47). Fruit yield was the highest in Pusa Ruby x LE 79 (F_3) (711g/plant). Saturn had the highest average fruit weight (46.48g) followed by Saturn x LE 79 (F_3) (44.63g).

C. Evaluation of a set of tomato lines for wilt resistance under two environments

The tomato lines LE 206, LE 208, LE 209, LE 210,

Table 5. Evaluation of Saturn, LE 79, Pusa Ruby, their F_2s and F_3s for reaction to bacterial wilt

Lines	Number of plants	Number wilted	Disease reaction (%)
Saturn	67	53	79.10 (S)
LE 79	63	22	29.54 (MR)
Pusa Ruby	65	65	100.00 (S)
Saturn x LE 79 (F_2)	406	74	18.23 (R)
Pusa Ruby x LE 79 (F_2)	430	260	60.46 (S)
Saturn x LE 79 (F_3)	458	49	10.70 (R)
Pusa Ruby x LE 79 (F_3)	430	193	44.88 (MS)

R = Resistant < 20% plants wilted

MR = Moderately resistant 20 to 40% plants wilted

MS = Moderately susceptible 40 to 60% plants wilted

S = Susceptible > 60% plants wilted

Table 6. Mean performance of Saturn, LE 79, their F_2s and F_3s

Lines	Days to fruit set	Days to fruit harvest	Fruits/plant	Fruit yield/ plant(g)	Average fruit weight(g)
Saturn	104.50 ± 1.76	134.50 ± 1.61	9.16 ± 3.21	385.00 ± 55.68	46.43 ± 7.02
LE 79	69.06 ± 1.84	98.32 ± 2.01	30.47 ± 1.83	656.50 ± 70.43	22.07 ± 0.74
Saturn x LE 79 (F_2)	80.20 ± 0.89	110.61 ± 0.79	12.90 ± 0.91	489.25 ± 34.92	40.13 ± 1.96
Saturn x LE 79 (F_3)	76.41 ± 0.49	106.95 ± 0.49	12.38 ± 0.64	507.52 ± 25.29	44.63 ± 0.96
Pusa Ruby x LE 79 (F_2)	71.50 ± 1.18	102.92 ± 0.83	18.45 ± 1.57	465.75 ± 44.20	25.71 ± 0.93
Pusa Ruby x LE 79 (F_3)	75.59 ± 0.68	105.46 ± 0.85	26.30 ± 1.73	711.00 ± 49.63	26.83 ± 0.44

LE 211, LE 212, LE 213, LE 214, LE 217, LE 79, LE 79 LFG, LE 79 DG and LE 79 LFF were evaluated under field conditions along with the susceptible check Pusa Ruby during January to May, 1984 (Table 7). The lines LE 79 LFG (15.55%) and LE 217 (17.97%) were found resistant. The lines LE 79 (28.88%), LE 79 DG (28.08%) LE 208 (31.80%), LE 211 (23.80%), LE 212 (25.88%) and LE 213 (32.95%) were moderately resistant. The lines LE 210 (43.33%) and LE 79 LFF (44.72%) were moderately susceptible while the line LE 209 (73%) and the check variety Pusa Ruby (100%) were susceptible. Significant differences were observed among all the lines for days to fruit set, days to fruit harvest, fruits/plant, fruit yield/plant, locules/fruit and total soluble solids (Table 8). Days to fruit set ranged from 65 in LE 210 to 77 in LE 79 LFG. The genotypes LE 206 (68 days), LE 209 (67 days) and LE 208 (68 days) were also earlier. Days to fruit harvest ranged from 99 to 114 days. Fruit harvesting was earlier in LE 210 (100 days), LE 209 (100 days), LE 211 (100 days) and LE 212 (100 days) also . The line LE 79 LFG was the most late (114 days). Fruits/plant was the lowest in LE 79 LEF (19.8). It was the highest in LE 213 (59.33). The line LE 79 DG gave the maximum yield (948.17g/plant) closely followed by LE 79 LFG

Table 7. Evaluation of tomato lines for their reaction to bacterial wilt during January to May, 1984

Lines	Number of plants	Number wilted	Disease reaction (%)
LE 206	64	15	23.40 (MR)
LE 208	88	28	31.80 (MR)
LE 209	89	65	73.00 (S)
LE 210	60	26	43.33 (MS)
LE 211	84	20	23.80 (MR)
LE 212	85	22	25.88 (MR)
LE 213	88	29	32.95 (MR)
LE 214	90	22	24.40 (MR)
LE 217	89	16	17.97 (R)
LE 79	90	26	28.88 (MR)
LE 79 LFG	90	14	15.55 (R)
LE 79 DG	89	25	28.08 (MR)
LE 79 LFF	88	42	44.72 (MS)
Pusa Ruby	90	90	100.00 (S)

R = Resistant < 20% plants wilted

MR = Moderately resistant 20 to 40% plants wilted

MS = Moderately susceptible 40 to 60% plants wilted

S = Susceptible >60% plants wilted

Table 8. Mean performance of tomato lines during January to May, 1984

Lines	Days to fruit set	Days to harvest	Fruits/ plant	Fruit yield(g)	Locules/ fruit	Average fruit weight (g)	Total soluble solids (°brix)
LE 206	67.60	103.07	25.07	922.87	3.86	37.04	6.11
LE 208	67.81	100.87	37.33	893.33	2.57	23.92	4.53
LE 209	66.80	99.65	22.50	474.17	2.82	21.27	5.63
LE 210	64.60	99.60	35.33	685.33	2.05	19.20	5.04
LE 211	70.60	99.67	28.48	452.00	3.13	16.55	5.45
LE 212	68.33	99.80	41.27	595.33	2.72	14.58	5.58
LE 213	79.07	98.73	59.33	778.67	3.13	13.49	5.25
LE 214	69.07	105.53	25.20	756.60	3.53	30.31	4.94
LE 217	70.07	104.33	27.53	826.67	3.48	30.02	5.29
LE 79	72.93	104.77	21.95	712.20	3.61	33.07	5.03
LE 79 LFG	77.40	113.67	24.07	938.20	4.04	40.10	4.13
LE 79 DG	76.67	113.13	25.25	948.17	4.17	38.13	5.16
LE 79 LFF	76.50	11.52	19.80	679.83	4.17	35.03	4.65
CD (P=0.05)	3.34	5.31	11.39	272.60	3.34	8.24	0.86
Sem. ±	1.14	1.82	3.91	93.57	0.12	2.83	2.29

(938.2g/plant) and LE 206 (922.87g/plant). The line LE 211 yielded the lowest (452g/plant). The lines LE 79 LFF and LE 79 DG had the maximum number of locules/fruit (4.17). LE 210 had the minimum number of locules/fruit (2.05) in a set of four lines which had lesser than 3 locules/fruit. The other three lines are LE 208 (2.57), LE 212 (2.72) and LE 209 (2.82). The fruit weight ranged from 13.49g in LE 213 to 40.1g in LE 79 LFG. The lines LE 79 DG and LE 206 had fruit weights 38.13g and 37.04g respectively. The line LE 206 had the highest total soluble solids (6.11°brix). The total soluble solids ranged from 4 to 6°brix among the other lines.

During September to February, 1984-'85 the lines LE 206, LE 208, LE 209, LE 210, LE 211, LE 212, LE 213, LE 214, LE 217, LE 79, LE 79 LFG, LE 79 DG, LE 79 LFF, LE 79 SPF and IIHR Bwr 34 A were evaluated under field conditions for their disease reaction. Pusa Ruby was used as the suceptible check. The lines were genetically catalogued for important morphological characters in the juvenile and adult plant stages (Table 9). The line LE 210 was completely free of anthocyanin. It was potato-leaved and had ovate, nipple-tipped fruits with a peristant style. The lines

Table 9. Genetic cataloguing of 15 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.,	pstpst.,	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	a^+-.,	c^+-.,	dp^+-.,	f^+-.,	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^+-.,
LE 79 LFF	a^+-.,	c^+-.,	dp^+-.,	ff.,	n^+-.,	o^+-.,	pst^+-.,	sp^+-.,	u^+-.,
LE 79 SPF	a^+-.,	c^+-.,	dp^+-.,	f^+-.,	n^+-.,	oo.,	pst^+-.,	sp^+-.,	u^+-.,
IIHR Bwr 34 A	a^+-.,	c^+-.,	dp^+-.,	f^+-.,	n^+-.,	o^+-.,	pst^+-.,	sp^+-.,	uu.,

LE 206, LE 208, LE 209, LE 210 and IIHR Bwr 34 A had uniform fruit ripening habit and had no green shoulders. The lines LE 208, LE 210 and LE 79 SPF had ovate fruits. The line LE 79 LFF had fasciated fruits. All the lines were semideterminate in their growth habit. Analysis of wilt incidence indicated the Lines LE 214, LE 217, LE 79 LFG, LE 79 DG, LE 79 SPF and LE 79 to be resistant (Table 10). The lines LE 217 (11.11%), LE 214 (11.62%) and LE 79 LFG (11.85%) showed minimum susceptibility to bacterial wilt. The lines, IIHR Bwr 34 A (40.68%), LE 79 LFF (42.3%), LE 206 (42.85%) LE 211 (43.13%) LE 208 (49.99%), LE 212 (52.26%), LE 210 (54.89%) and LE 213 (58.62%) were found moderately susceptible. The check line Pusa Ruby showed (100%) susceptibility. The line LE 209 was also found susceptible (76.59%). Since there was 100% wilt incidence in one replication of LE 209, missing-plot technique was followed for the analysis of data. Analysis of mean performance of lines showed significant differences among the lines for days to fruit set, days to fruit harvest, fruits/plant, fruit yield/plant, locules/fruit and average fruit weight (Table 11). Days to fruit set ranged from 87 in LE 212 to 102 in LE 79 LFG. The days to fruit harvest varied from 124 to 138. The lines LE 208

Table 10. Evaluation of tomato lines for their reaction to bacterial wilt during September to February, 1984-'85

Lines	Number of plants	Wilt incidence				Total wilt (%)
		Juvenile stage		Adult stage		
		Number wilted	wilt(%)	Number wilted	wilt(%)	
LE 206	49	9	18.36	12	24.48	42.85 (MS)
LE 208	54	9	16.66	18	33.33	49.99 (MS)
LE 209	47	30	63.83	6	12.76	76.59 (S)
LE 210	51	7	13.72	21	41.17	54.89 (MS)
LE 211	51	12	23.52	10	19.61	43.13 (MS)
LE 212	44	13	29.54	10	22.72	52.26 (MS)
LE 213	58	18	31.03	16	27.58	58.62 (MS)
LE 214	43	0	0.00	5	11.62	11.62 (R)
LE 217	63	0	0.00	7	11.11	11.11 (R)
LE 79	59	1	1.69	10	16.95	18.64 (R)
LE 79 LFG	59	1	1.69	6	10.16	11.85 (R)
LE 79 DG	55	1	1.80	6	10.90	12.70 (R)
LE 79 LFF	52	7	13.46	15	28.84	42.30 (MS)
LE 79 SPF	50	2	4.00	6	12.00	14.00 (R)
IIHR Bwr 34 A	54	3	5.50	19	35.18	40.68 (MS)
Pusa Ruby	61	61	100.00	0	0.00	100.00 (S)

R = Resistant < 20% plants wilted

MR = Moderately resistant 20 to 40% plants wilted

MS = Moderately susceptible 40 to 60% plants wilted

S = Susceptible > 60% plants wilted

Table 11. Mean performance of tomato lines during September to February, 1984-'85

Lines	Days to fruit set	Days to fruit harvest	Fruits/ plant	Fruit yield/ plant (g)	Locules/ fruit	Average fruit weight (g)
LE 206	90.97	126.92	39.13	1242.66	3.93	31.88
LE 208	90.80	123.67	52.60	1198.00	2.46	22.55
LE 209	89.91	124.72	23.24	475.55	3.09	19.66
LE 210	95.68	129.93	35.33	620.33	2.00	17.40
LE 211	94.33	130.67	76.80	1229.86	3.10	15.76
LE 212	87.00	124.05	45.30	671.75	2.87	15.02
LE 213	95.35	128.17	65.16	845.33	2.95	14.21
LE 214	96.13	133.33	70.13	2102.66	3.46	29.96
LE 217	96.63	130.95	49.56	1547.66	3.69	31.12
LE 79	94.33	129.73	65.26	1814.66	3.53	27.75
LE 79 LFG	101.93	137.53	55.06	2054.00	4.38	37.01
LE 79 DG	96.86	132.20	48.26	1370.00	4.14	28.27
LE 79 LFF	99.23	133.33	63.86	1745.66	4.08	27.41
LE 79 SPF	96.13	128.40	65.13	1703.33	3.38	26.15
IIHR Bwr 34 A	93.20	129.43	25.86	993.33	5.53	39.31
CD for comparing lines with no missing value (P=0.05)	3.99	5.28	28.75	650.85	0.30	3.88
CD for comparing lines with missing value (P=0.05)	4.45	5.89	32.08	726.22	0.34	4.33
Sem ±	1.37	1.81	9.89	23.84	0.10	1.33

(124 days), LE 209 (125 days) and LE 212 (124 days) were earlier. Fruit number was maximum in LE 211 (76.8) followed by LE 214 (70.13). LE 209 had the lowest fruits/plant (23.24). The fruit yield was also the lowest in LE 209 (495.77g/plant). The fruit yield was the highest in LE 214 (2.102kg/plant). The line LE 79 LFG yielded 2.05kg fruits/plant. The linesLE 217, LE LFF, LE SPF and LE 79 had fruit yields ranging from 1.5kg to 2.0kg/plant. The number of locules was the highest in IIHR Bwr 34 A (5.53). The line LE 210 had only 2 locules/fruit. The lines LE 79 LFF, LE 79 LFG and LE 79 DG had more than 4 locules/fruit. The average fruit weight was maximum in IIHR Bwr 34 A (39.31g). The line LE 79 LFG had an average fruit weight of 37.01g. LE 213 had the lowest fruit weight (14.21g).

The 15 lines were also observed for their percentage fruit set and fruit cracking. The fruit set ranged from 38.3% in LE 206 to 63.31% in LE 211 (Table 12). All the other lines showed fruit set between 50 to 62%. Cracking was found higher in the lines LE 214, LE 217, LE 79, LE 79 SPF and LE 79 LFG (Table 13). Concentric cracking was observed maximum in LE 217. Out of 691 fruits observed, 82 showed

Table 13. Percentage of fruit set in tomato lines

Lines	Number of flowers observed	Number of flowers which set fruits	Fruit set (%)
LE 206	207	69	38.30
LE 208	239	136	56.90
LE 209	85	43	50.58
LE 210	193	107	55.44
LE 211	229	145	63.31
LE 212	253	147	58.10
LE 213	185	115	62.16
LE 214	239	149	62.34
LE 217	198	112	56.56
LE 79	222	134	60.36
LE 79 LFG	167	99	54.28
LE 79 DG	205	108	52.60
LE 79 LFF	224	128	57.14
LE 79 SPF	260	153	58.64
IIHR Dwr 34 A	199	102	51.25

concentric cracking (11.86%). The lines LE 79 and LE 79 SPF showed 10.72% and 10.34% cracking respectively. Irregular cracking was the highest in LE 79 SPF (13.63%) with 148 fruits cracked out of a total of 1112 fruits observed. The lines LE 79 and LE 210 showed cracking to the extend of 8.78% and 8.50% respectively. Radial cracking was very low in all lines, the maximum observed was in LE 206 (1.16%). The line LE 213 showed the least total cracking (1.01%). The lines LE 208, LE 212, and LE 211 also showed lesser cracking.

D. Genetics of fruit shoulder colour in inter-varietal crosses involving Pusa Ruby and LE 79

The parents, F_1 and F_2 populations were critically observed for the colour of fruit shoulder. A total of 30 plants each in parents and F_1 and 170 plants in the F_2 were observed (Table 14). The parent Pusa Ruby had fruits all with white shoulders. In LE 79 all the fruits were green shouldered. All the fruits in the F_1 were also green shouldered. In the F_2 out of 170 plants 46 were white shouldered and 124 were green shouldered which fitted well to a 3:1 ratio ($X^2 = 0.378$ $0.7 > P > 0.5$).

Table 14. Genetics of fruit shoulder colour in tomato

Generation	Number of plants			Expected phenotypic ratio	x^2	Probability
	white shouldered	green shouldered	Total			
Parents:						
Pusa Ruby	30	--	30			
LE 79	--	30	30			
F_1:						
Pusa Ruby x LE 79	--	30	30			
F_2:						
Pusa Ruby x LE 79	46	124	170	3:1	0.378	0.5 - 0.7

E. Efficiency of spot-planting as a method for varietal evaluation against bacterial wilt

The various methods used to evaluate against bacterial wilt resistance like dipping roots in the bacterial culture and planting, stem inoculation with bacterial culture, alternate row planting with susceptible check and spot planting were carried out simultaneously to evaluate their effectiveness. Root dipping and stem inoculation were found effective only at 35°C (Table 15). In case of alternate row planting wilting observed was lower than spot planting with the same variety (Table 16).

Table 15. Evaluation for wilt incidence by root-dipping and stem inoculation

Lines	Root-dipping				Stem inoculation	
	24°C		35°C		35°C	
	Date of inoculation	Date of wilting	Date of inoculation	Date of wilting	Date of inoculation	Date of wilting
Pusa Ruby	14/10	17/11 (34)	24/9	28/9 (4)	24/9	28/9 (4)
LE 79	14/10	-	24/9	-	24/9	-
Venus	14/10	-	24/9	24/9 (5)	24/9	29/9 (5)
Rutgers	14/10	12/11 (29)	24/9	29/9 (5)	24/9	29/9 (5)

Data in paranthesis indicate days taken to wilt after inoculation

Table 16. Evaluation for wilt incidence by alternate row planting and spot-planting

Lines	Alternate row planting			Spot-planting		
	Number of plants	Number of plants wilted	Wilt (%)	Number of plants	Number of plants wilted	Wilt (%)
LE 79	59	11	18.64	63	22	29.54
Pusa Ruby	61	61	100.00	65	65	100.00

DISCUSSION

Bacterial wilt caused by Pseudomonas solanacearum E.F. Smith is reported in 106 crop species (Young, 1946). The economic plant species of the family, Solanaceae are the major susceptible ones (Kelman, 1953). Among the Solanaceous vegetables, tomatoes and brinjal are reported more susceptible than chillies. Hayward (1964) described the pathogen as complex, consisting of different races differing in host range and pathogenicity. Okabe and Goto (1961) recognised three types of strains in the pathogen. Buddenhagen et al. (1962) classifed 4000 isolates into 3 races based on their pathogenicity. Out of the 3 races, races 1 and 3 were pathogenic on tomato. The occurence of the disease was affected by a set of environmental factors. Vaughan (1944) found no disease symptom below 21°C. The plants wilted when temperature was raised to 27°C. Chupp and Sherf (1960) reported 29 to 35°C as optimum for disease development. Heaton and Benson (1968) reported generally high incidence of the disease in red laterite soils. The pH range of 5 to 5.5 favoured the disease development. Fluctuations in disease incidence as a function of season of cultivation was reported by Remadevi and Menon (1980).

Control of the disease through management practices has not been effective. Identification and isolation of sources of resistance are the obvious genetic control measures. Weaver (1944) reported the crosses between Louisiana Pink x T 414 from Puerto Rico to be a promising source of resistance. Acosta et al. (1964) reported another source of resistance in Lycopersicon pimpinellifolium (PI 127805A). Goth et al. (1983) tested a few of the lines, reported resistant to bacterial wilt. They reported CL 32d-0-1-19 GS resistant to 3 isolates of Pseudomonas solanacearum and susceptible to 5 other isolates. The above information lead us to the need for continuous evaluation of tomato lines to isolate new sources of wilt resistance.

Winstead and Kelman (1952) employed stem inoculation technique to evaluate lines for resistance. The root dipping method was reported less effective. The alternate row planting with a susceptible check is the conventional planting method in the evaluation for disease resistance. This method does not exclude the chances for escape. The escape of susceptible lines can cause havoc in crops like tomato where the

seed multiplicative rate is high.. There is a need to develop an appropriate field screening technique.

The present studies were undertaken to identify and to isolate additional sources of resistance to bacterial wilt. The problem of fruit cracking was also considered in the wilt resistance breeding studies.

Among the four non-segregating tomato lines evaluated, LE 79 was rated moderately resistant in the Mew and Ho (1976) scale. Pusa Ruby wilted completely indicating the high virulence of pathogen in the test soil. The F_1 cross involving Pusa Ruby and LE 79 was moderately susceptible. This confirmed the earlier reports of dominant nature of disease susceptibility. Among the two segregating generations evaluated, the F_2 families of Saturn and LE 79 showed a resistant reaction. Goth *et al.* (1983) reported Venus resistant to 126408-1 and LE 79 resistant to K 60, 126408-1, Tifton 80-1 and tolerant to TFP 13. Henderson and Jenkins (1972) reported Saturn and Venus resistant to Faison and Oxford isolates of *Pseudomonas solanacearum*. Progenies with Saturn and LE 79 pedigree obviously showed a

resistant reaction. There is definite scope of getting progenies from the Saturn x LE 79 crosses which combine the two sources of resistance.

The above observation was further substantiated in the highly resistant reaction of the F_3 progenies of Saturn x LE 79 cross. Further the high resistance of F_2 progenies of Saturn x LE 79 was confirmed through repeated trials during September to February, 1984-'85. A considerable increase in the average fruit weight was also observed in the F_3 progenies of Saturn x LE 79 cross (Fig.1). This information is important in the context of breeding large fruited varieties associated with bacterial wilt resistance. The F_3 progenies of Saturn x LE 79 cross were late by 8 days to LE 79 and this calls for emphasis on earliness along with higher average fruit weight and wilt resistance. The reportedly resistant 15 lines of tomato were also evaluated in the bacteria-sick soil. The lines LE 217 and LE 79 LFG exhibited resistant reaction in two consecutive trials (Figs. 2 and 3). The line LE 79 LFG had higher average fruit weight (40.1g) and took 114 days for first fruit harvest. This

line appears to be promising in the continuous breeding programmes. The 15 lines now evaluated were reported resistant in one location or another. Nine of the lines were rated moderately susceptible to susceptible indicating a different virulent isolate in the experimental site. The identification of resistant lines from such areas would definitely enhance the success of breeding efforts. The lines LE 217 and LE 79 LFG had a fruit set percentage of 56.56 and 59.28 respectively, during November, 1984 when average minimum temperature was 23°C (Appendix - I). This embellish the usefulness of these two lines in the tropical warm areas with wilt-sick soil.

Fruit cracking was observed serious in the lines under study. An attempt was made to identify lines with low fruit cracking. Concentric cracking was found more in number followed by irregular cracking and radial cracking. The lines LE 212 and LE 213 had the lowest percentage of total cracking among the 15 lines evaluated. Among the medium fruited varieties, IIHR Bwr 34 A had a total of only 9.79% (Fig. 4). Radial cracking was found quite negligible in all the lines. This implies Mendelian genetic control for

radial cracking. Young (1960) worked out the genetics of different types of cracking. He explained radial cracking to be genetically controlled and governed by recessive genes. He could not explain concentric cracking through common genetic models. The present study also indicated concentric cracking to be more governed by environment rather than genetic factors.

Efficiency of screening techniques for field evaluation of resistance was studied. Root dipping method, though easy and quick, is effective only at higher temperatures. Stem inoculation on the leaf axil is very effective, but required laboratory facilities and active help of professional plant pathologists. Alternate row planting with susceptible check though a conventional method is handicapped with high probability of escape (Fig. 5). Combined planting of the line under evaluation and a known suscept in the same spot - "spot-planting" - is obviously more effective. Wilting of the suscept and non-wilting of the line under evaluation preclude the chance of escape (Figs. 6 and 7). A non-wilted line under evaluation along with a non-wilted suscept is considered escape (Table 17).

The lines LE 217 and LE 79 LFG were found promising and high yielding, medium fruited and as

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Table 17. Advantages/disadvantages of four methods of evaluation

Methods	Advantages	Disadvantages
a) Laboratory methods		
1. Root-dipping	Simple, quick	Effective only at high temperatures
2. Stem inoculation	More effective	Laborious requiring professional assistance
b) Field methods		
1. Alternate row planting	Simple, easiness in execution	Probability of escape is more
2. Spot-planting	Probability of escape is nil	-

additional sources of resistance to bacterial wilt. The observation of monogenic inheritance with recessive gene action for white shouldered fruit is only a confirmatory finding.

Fig. 1. Improvement in fruit size and bacterial wilt resistance in a Saturn x LE 79 F_3 selection x (0.12)

Fig. 1

Fig. 2. Bacterial wilt resistant line
LE 217 x (0.15)

Fig. 3. Bacterial wilt resistant line
LE 79 LFG x (0.20)

Fig. 2

Fig. 3

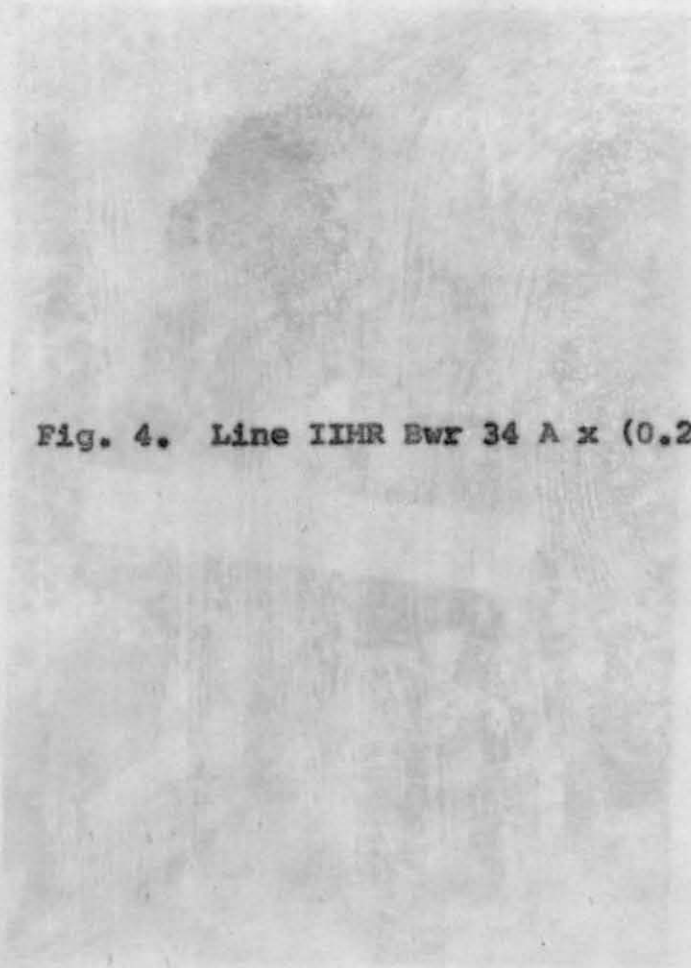
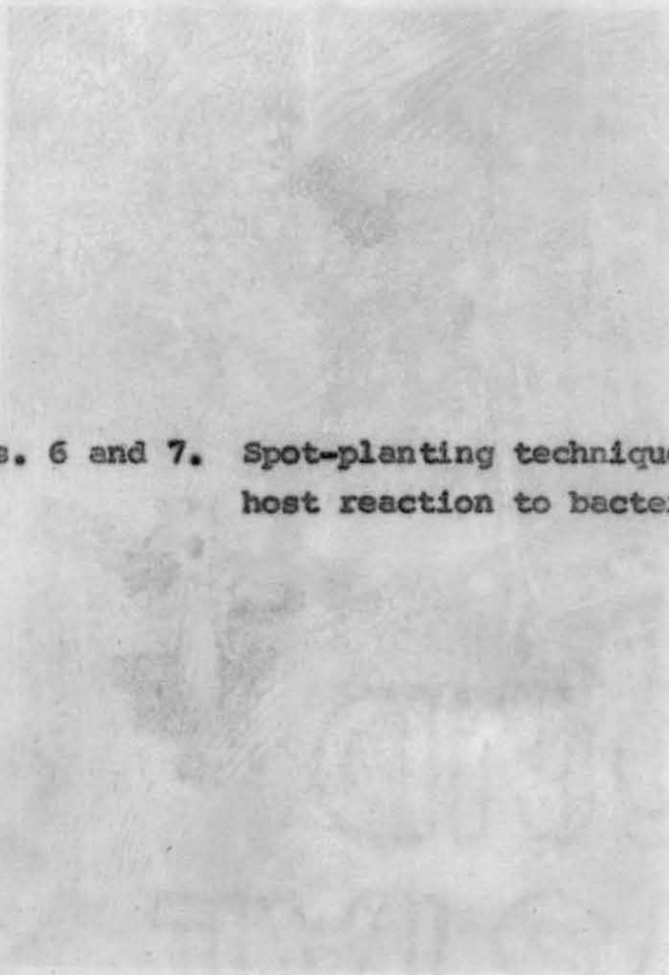


Fig. 4. Line IIHR Bwr 34 A x (0.20)

Fig. 5. Alternate row planting with susceptible check to test host reaction to bacterial wilt

Fig. 4

Fig. 5



Figs. 6 and 7. Spot-planting technique to confirm host reaction to bacterial wilt

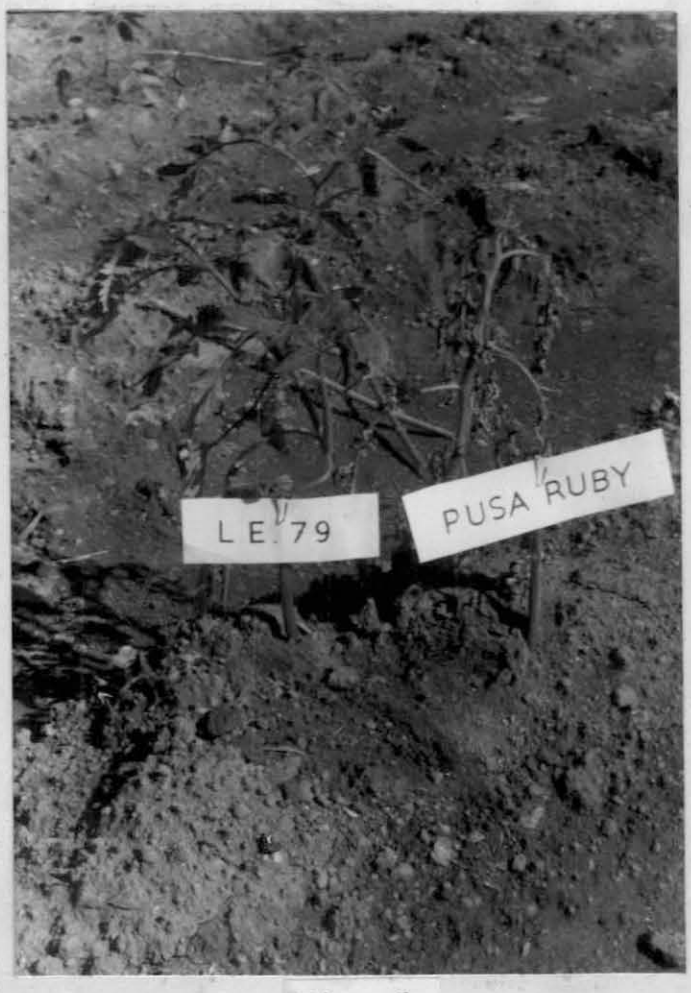


Fig. 6

Fig. 7

Summary

SUMMARY

1. The present studies, "Evaluation of a set of non-segregating and segregating populationsof tomato for field resistance to bacterial wilt" were conducted during September to February, 1983-'84, January to May, 1984 and September to February, 1984-'85, at the Instructional farm of College of Horticulture, Vellanikkara, Trichur. The experiment consisted of five parts.

A. Evaluation of a set of non-segregating and segregating populations of tomato for resistance to bacterial wilt.

B. Evaluation of newly bred F_2 and F_3 hybrids of tomato for resistance to bacterial wilt.

C. Evaluation of a set of tomato lines for wilt resistance under two environments.

D. Genetics of fruit shoulder colour in inter-varietal crosses involving Pusa Ruby and LE 79.

E. Efficiency of spot-planting as a method for varietal evaluation against bacterial witt.

2. The experimental materials comprised of four non-segregating populations, four segregating population and 15 other reportedly resistant lines of tomato.

3. Saturn x LE 79 F_2 was found resistant to bacterial wilt out of the four non-segregating and two segregating populations evaluated. LE 79 was moderately resistant and yielded 1.35 kg/plant on an average. Moderate susceptibility to wilt was observed in Pusa Ruby x LE 79 F_1 and Saturn. Pusa Ruby x LE 79 F_2 was the earliest both for fruit set and harvest (77 and 108 days respectively) but was moderately susceptible to wilt. The variety Pusa Ruby showed 100% susceptibility.

4. Resistance was confirmed in Saturn x LE 79 F_2s and F_3s in further trials, during September to February, 1984-'85. Saturn x LE 79 F_3s also showed higher average fruit weight (44.63g). LE 79 was moderately resistant to wilt and was earlier for fruit set and fruit harvest by a week than the resistant Saturn x LE 79 crosses. The variety Saturn was susceptible to wilt. Pusa Ruby x LE 79 F_2s were moderately susceptible to susceptible.

5. The 15 lines of tomato were evaluated during two seasons to identify sources of resistance. Resistance was observed only in LE 79 LFG and LE 217 during both the trials. All the other lines showed moderate resistance to susceptibility. A higher average fruit weight (40.1g) and yield (2.054kg) were observed in LE 79 LFG. Concentric cracking and irregular cracking were higher than radial cracking in all the lines evaluated. Among the medium fruited lines, IIHR Bwr 34 A had the lowest total cracking. A high fruit set was also observed in all the lines at average night temperatures of 23°C.

6. The fruit shoulder colour is inherited monogenically with a recessive gene action for white shoulder. This was clearly proved from Pusa Ruby x LE 79 crosses.

7. A comparison of evaluation techniques for bacterial wilt resistance showed that the probability of escape is nil in spot-planting. Spot-planting is simple and easy to execute, while there is high probability of escape in the method, alternate row planting with a known suscept. Stem inoculation in the leaf axil is laborious and requires professional assistance.

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Appendix

Appendix - 1. Meteorological data during the period of experimentation

Year	Month	Temperature (°C)			RH (%)	Rainfall	
		Average maximum	Average minimum	Highest maximum		Total (mm)	Rainy days
1983	September	29.5	23.4	31.0	84.0	494.6	24
1983	October	31.2	23.1	33.0	77.0	149.0	6
1983	November	31.8	22.3	33.5	71.0	60.2	3
1983	December	31.2	23.9	33.0	63.0	24.4	3
1984	January	32.4	23.3	34.5	58.0	0.0	0
1984	February	34.3	24.2	36.6	56.0	27.0	3
1984	March	35.2	24.3	39.8	67.0	18.9	2
1984	April	34.5	24.9	39.5	72.6	109.2	9
1984	May	34.5	25.8	37.0	71.0	40.6	6
1984	June	29.0	22.7	33.0	87.0	853.1	28
1984	July	28.6	22.9	30.8	87.0	730.4	24
1984	August	29.3	22.2	30.5	83.5	260.2	21
1984	September	30.4	23.2	32.6	68.2	158.6	7
1984	October	29.9	22.1	33.0	67.5	323.7	12
1984	November	32.1	23.1	33.8	54.4	7.8	1
1984	December	31.9	20.8	35.0	46.0	16.4	1

Source: Meteorological observatory, Vellanikkara

EVALUATION OF A SET OF NON-SEGREGATING AND SEGREGATING POPULATIONS OF TOMATO FOR FIELD RESISTANCE TO BACTERIAL WILT

By
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ABSTRACT OF A THESIS

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ABSTRACT

Bacterial wilt caused by Pseudomonas solanacearum E.F. Smith is the single limiting factor for tomato cultivation in the warm humid tropical soils of Kerala. The susceptibility of reportedly resistant varieties elsewhere necessitates the need for continuous evaluation of tomato lines for wilt resistance. An experiment was planned and carried out during 1983-'85 at the College of Horticulture, Vellanikkara to identify new sources of resistance to bacterial wilt.

The susceptible check Pusa Ruby showed 100% susceptibility in all the trials. The F_2 hybrids of Saturn and LE 79 were found resistant, out of the four non-segregating (Saturn, LE 79, Pusa Ruby and Pusa Ruby x LE 79 F_1) and two segregating populations (Pusa Ruby x LE 79 F_2, Saturn x LE 79 F_2) evaluated. In a repeated trial F_3s were also 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 wilt, 10.7) and Saturn x LE 79 F_2 (percentage wilt, 19.23). Pusa Ruby x LE 79 F_2s and F_3s were susceptible to moderately susceptible. Among the non-segregating populations, LE 79 showed moderate resistance, while Saturn was moderately

susceptible to susceptible in both the trials. Information on days to fruit set, days to harvest, fruit yield/plant and average fruit weight were also gathered. A higher average fruit weight (44.63g) was observed in the resistant Saturn x LE 79 F_3s.

Evaluation of 15 reportedly resistant lines of tomato confirmed resistance in LE 79 LFG and LE 217. The line LE 79 LFG was also medium fruited (40.1g) and high yielding. Concentric cracking and irregular cracking were observed higher than radial cracking in all the lines evaluated. Fruit set ranging from 50 to 63% was observed in all the lines at higher night temperatures (23°C average).

Genetics of fruit shoulder colour revealed that white colour was recessive to green and governed by a single gene.

Evaluation techniques like root dipping in bacterial culture and planting, stem inoculation in leaf axil and alternate row planting were compared with spot-planting for efficiency. Spot-planting was found easier and effective. The chances for escape are negligible in this method of evaluation.