SELECTION EFFICIENCY AND GENETIC AND BIOCHEMICAL BASES OF RESISTANCE TO BACTERIAL WILT IN TOMATO

By

S. RAJAN

THESIS

Submitted in partial fulfilment of the

requirement for the degree

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE

Vellanikkara — Trichur

1985

To my wife, Latha

DECLARATION

I hereby declare that this thesis entitled "Selection efficiency and genetic and biochemical bases of resistance to bacterial wilt 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,
30th September, 1985.

(S. RAJAN)

CERTIFICATE

Certified that this thesis, entitled "Selection efficiency and genetic and biochemical bases of resistance to bacterial wilt in tomato" is a record of research work done independently by Sri. S. Rajan, 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,
September, 1985.

Dr. K.V. Peter,
Chairman,
Advisory Committee
Professor and Head,
Department of Olericulture.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Sri. S. Rajan, a candidate for the degree of Doctor of Philosophy in Horticulture agree that the thesis entitled "Selection efficiency and genetic and biochemical bases of resistance to bacterial wilt in tomato" may be submitted by Sri. S. Rajan, in partial fulfilment of the requirement for the degree.

Chairman : Dr. K.V. Peter 20/12/97

Members :

1. Dr. P.K. Gopalakrishnan

2. Dr. K. Mohanakumaran (K. GOPAKUMAR)

3. Dr. Abicheeran

4. Dr. K.C. George

(VISHNU SWARUP)

ACKNOWLEDGEMENT

I express my deep sense of gratitute and indebtedness to Dr. K.V. Peter, Chairman of my Advisory Committee, Professor and Head, Department of Olericulture for his valuable guidance, unstinted support, critical suggestions all throughout the course of this investigation and inestimable help in the preparation of the thesis.

I am extremely grateful to Dr. P.K. Gopalakrishnan, Associate Dean, Dr. N. Mohanakumaran, Associate Director of Research, Dr. K.C. George, Professor of Statistics, and Dr. Abicheeran, Professor and Head, Department of Plant Pathology, members of the Advisory Committee, who have been generous of their time and knowledge in offering constructive criticisms and many valuable suggestions during the course of the investigation and the preparation of the manuscript.

I am thankful to Sri. Augustin, A., Assistant Professor for his valuable help during my laboratory analytical work.

My sincere thanks are due to Sri. V.K.G. Unnithan, Associate Professor, Department of Agricultugal Statistics for the help bestowed to me in analysing the data through computer.

It gives me pleasure to acknowledge the extreme co-operation rendered by the labourers of the College of Horticulture during the field work.

A special note of appreciation is due to Sri.V.P. Asokan for neatly typing the manuscript in time.

I sincerely thank the Kerala Agricultural University for granting me study leave for pursuing the studies.

And I remember with a sense of gratitude the Indian Council of Agricultural Research for awarding me the Senior Research Fellowship for the post-graduate programme.

S. RAJAN

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Bacterial wilt caused by the soil borne pathogen, Pseudomonas solanacearum E.F. Smith limits tomato (Lycopersicon esculentum Mill.) production in both tropical and sub-tropical areas. The disease is prevalent in every growing region of the warm temperate, sub-tropical and tropical zones of the world. It occurs commonly in North Carolina, South Carolina, Maryland, Virginia, Georgia, Columbia, Florida and Hawaii in the United States and in other parts of the world particularly the Philippines, Indonesia, Sri Lanka and India, causing considerable loss to tomato growers.

The disease is common in regions having an annual average rainfall of above 100 cm and a growing season of at least six months. The disease occurs in diverse soil types as sandy loam, red, black soils and light sandy soils. Both acidic soils of pH 5 to 5.5 and alkaline soils of pH 7.5 to 8.5 are favourable for the disease incidence.

Of the many control measures to combat the disease, use of resistant varieties was the only measure, economical and feasible. Chemical control of the disease was of little success and crop rotation was ineffective unless a long rotation with non-susceptible crops were tried. Grafting on resistant root stocks of Solanum species was impracticable for large scale cultivation.

Two serious drawbacks for the successful development of bacterial wilt resistant tomato varieties were:

1. expression of resistance was very labile, and
2. many sources of resistence had poor quality fruits.

Satisfactory levels of resistance combined with commercial fruit size and quality could not be isolated in tomato, although this was the objective of work in many parts of the world as in North Carolina, Hawaii, Puerto Rico and Philipoines. Large fruit size was the most elusive character in bacterial wilt resistance breeding programmes.

In Kerala, tomato cultivation was a total failure especially in the plains due to the incidence of bacterial wilt. As a result, area under tomato in the State is practically negligible. Availability of a variety resistant to bacterial wilt along with other desirable horticultural characteristics like medium to large fruit size and earliness would be a boon to the vegetable growers of Kerala.

An evaluation trial for resistance to bacterial wilt conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur evinced resistance in the line CL 32 d-0-1-19 GS. High variability for resistance to bacterial wilt, small fruit size, longer days to maturity and other negative horticultural and economic characters were the major defects for recommending it for commercial cultivation.

This study was mainly aimed at improving the present level of resistance to bacterial wilt, and improving the fruit size from small to medium to larger size in the line CL 32 d-0-1-19 GS. In addition, other aspects included in the study were:

1. Estimation of relative efficiency of methods of selection - mass, pureline, single seed descent and bulk - in the improvement of characters.

2. Quantification of the realised selection responses through trait-wise selection associated with resistance to bacterial wilt.

3. Inheritance of resistance to bacterial wilt and estimation of association, if any, with a few selected characters.

4. Biochemical bases of resistance and reaction of hosts to artificial inoculation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A review of literature on the pathogen, its pathogenesis, symptomatology, sources of resistance, factors affecting resistance, genetic and biochemical bases of resistance and selection methods for improving level of resistances and others economic characters are made under the following main titles:

A. Pathogen and pathogenesis

The first report on the disease came from Italy in 1882 (Walker, 1952). Smith (1896) described the disease and casual agent and reported the disease in potato, tomato and brinjal. The first report on bacterial wilt of tomato in India was by Hedayethullah and Saha (1941) from West Bengal. Later it was reported on brinjal by Das and Chattopadhyay (1955) and on banana by Chattopadhyay and Mukhopadhyay (1968) from West Bengal and on chillies from Madhya Pradesh (Remadevi, 1978).

Pseudomonas solanacearum is a complex species consisting of several races differing in host range and pathogenecity (Hayward, 1961). There occurs considerable geographical variation in the organism. Strains affecting solanaceous crops are a serious problem in S.E. Asia. The pathogen is known to attack more than 200 species of plants belonging to 33 families. Of these, the family Solanaceae contains the largest number of

hosts (Kelman, 1953). Some of the important hosts other than tomato are potato, tobacco, brinjal, chillies, banana, peanut, sesamum, castor, cassava, black gram, rubber, french bean and ornamentals like garden balsam, canna, aster, chrysanthemum, cosmos, dahlia, sunflower, marigold, petunia, black night shade, nasturtium and verbena (Duckes et al., 1965; Revilla et al. 1967; Belalcarzar et al., 1968). A few other host plants are ginger, cowpea, dolichos bean, hybrid cotton and jute (Chester, 1950; Hildebradt, 1950; Walker, 1952; Chupp and Sherf, 1960; Khristov, 1968; Zehr, 1970).

Kelman (1954) found that the wild type colonies were highly virulent and produced wilting within 14 days, whereas mutant type was either weakly pathogenic or non-pathogenic and did not induce wilting even after 21 days. Avirulent form was more active to produce brown pigments in culture, than virulent ones, which depended on the pH of the medium. The pathogen loses its virulence rapidly in culture due to transformation to avirulent forms. Most of the isolates favoured a pH range of 5.5 to 7.0 for their growth. The optimum pH requirement of Pseudomonas solanacearum was observed by others as 6.6 to 6.7 (Kelman, 1953).

Buddenhegen et al. (1962) observed race 1 of the pathogen affecting tomato, tobacco and other solanaceous crops, weeds and a few diploid bananas (Musa groups BB or AA). Race 2 is pathogenic to triploid banana (Musa groups AAA, AAB

and ABB) and Heliconia spp. or both. Race 3 infects potato and tomato and is weakly pathogenic to other solanaceous crops. They further reported that the different races have common hosts also. 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. Although the banana strain is pathogenic to tomatoes following stem inoculation, none of the strains of tomato race in Asia were found to attack Musa genotypes (Buddenhagen, 1960 and 1969). Pegg et al. (1974) reported that there are two biotypes of the pathogen; one (biotype III) which caused common tomato wilt but only non-significant and slow wilt in ginger and other one (biotype IV) which caused very rapid and severe wilt resulting, heavy losses in ginger.

Keshwal and Joshi (1976) identified six strains of Pseudomonas solanacearum isolated from different hosts in India based on colony characters, biochemical properties and pathogenicity. In an attempt to study the variation in Pseudomonas solanacearum, Rath and Addy (1977) used ten selected isolates from wilted tomato plants and the prepared culture was inoculated to tomato, chilli and potato. There was not much difference among the isolates on tomato while none of the isolates were pathogenic on potato and chilli. Though morphologically alike, the isolates exhibited variation in respect of

biochemical characters like gelatin liquefaction and action on litmus. 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 the race 2 is non-existent. The two isolates from Vellayani (Trivandrum) were found highly virulent to tomato, brinjal and chilli. The isolate from brinjal collected from Mannuthy (Trichur) was found to be a separate strain not comparable to brinjal isolates from Vellayani and Pattambi. But the brinjal and tomato isolates from Pattambi were comparable. This indicated that the same strain of the pathogen could infect and produce the disease in more than one host in different locations. It was inferred that different pathotypes of Pseudomonas solanacearum are present in Kerala soils which vary in pathogenecity and also in cultural, physiological and biochemical properties. The pathotypes could be grouped into 12 pathogroups and could be assigned to races of Buddenhagen, et al. (1962) and biotype III of Hayward (1964).

The ecology of the pathogen in naturally infested soil is poorly understood. It is inferred that the primary inoculum came from the soil but there was no conclusive evidence that the pathogen is an ubiquitous inhabitant in soils (Buddenhagen and Kelman, 1964). Under natural conditions the

organism was able to survive saprophytically in the soil for as long as six years (Chester, 1950). The pathogen entered through the root system and it was believed that a wound is necessary for entry (Walker, 1952; Kelman, 1953; Chupp and Sherf, 1960).

Wounds caused by nematodal injury, mechanical injury and root breakage from transplanting are attributed to the entry points. Hildebrandt (1950) reported entry of pathogen through natural opening of the plant. According to Libman et al. (1964) pathogen enters into the uninjured root as well. They stated that root contact with infected plants was not necessary for infection to occur. Bacteria infect at points of origin of the secondary roots. Apart from roots, other areas of the shoot portion might also be invaded. Insects were also reported to play a role in the spread of the disease (Young, 1946; Vakili and Baldwin, 1966).

Dissemination and spread of the disease were primarily from decayed and diseased plant parts (Kelman, 1953; Chupp and Sherf, 1960). Kelman and Sequeria (1965) stated that the release of a large number of bacteria in to the soil from roots of infected plants might play an important role in rapid spread and infection of adjacent plants.

B. Symptomatology

The symptoms associated with bacterial wilt are very distinct (Young, 1946; Walker, 1952; Kelman, 1953; Chupp and Sherf, 1960; Logano, 1965). The first expression of the disease is wilting of the lower leaves. Such wilting is also usually associated with a slight yellowing of older leaves. If disease development is rapid, foliage symptoms are similar to those produced by scorching due to high temperature. Chlorosis of the leaves does not occur. Dwarfing and stunting of the plant may occur. Adventitious roots appear on the stem of the disease plants. A very distinct indication of bacterial wilt is the appearance of a bacterial ooze when the vascular system is severed. This is accompanied usually by darkening of the vascular tissue. Chester (1950) reported that stem may discolour and become mushy and that no distinct fruit symptoms were observed. The root system of diseased plants develop a water soaked appearance (Kelman, 1953; Chupp and Sherf, 1960). Even dark brown to black areas develop with decay of the root system.

Following entry of the pathogen into the host plant, visible symptoms occur within 2 to 8 days (Kelman, 1953; Chupp and Sherf, 1960). The pathogen enters into the intercellular spaces of the cortex and then to pith from xylem vessels causing lysigenous cavities (Walker, 1952). Severe wilt, the primary symptom of the disease, is primarily due to

vascular plugging (Walker, 1952; Husain and Kelman, 1958). Husain and Kelman (1958) reported that the primary wilting factor is an extracellular polysaccharide or slime produced by the pathogen. This slime increases the viscocity of the vascular system and interferes with the movement of water in the vessels. They reported that weakly pathogenic strains did not produce slime. Breakdown of plant tissue due to bacterial wilt can be attributed to the production of cellulases and polygalacturonases produced by the bacterium (Husain and Kelman, 1957). They also reported that the decay of the plant tissue could be caused by Pseudomonas solanacearum in the absence of secondary bacteria. Continued tissue decay and vascular plugging resulted ultimately in the death of the infected plant. Baldacci (1977) opined that besides a polysaccharide complex, responsible for vascular plugging, a chemically unidentified fraction which alters the membrane permiability is produced by the pathogen. The bacterium also produces IAA which can initiate tylose formation and increases cell wall plasticity. Ethylene production is also associated with it.

C. Control

Chemical control was attempted with little success (Kelman, 1953; Shahrafuzzaman and Islam, 1975; Remadevi, 1978). Crop rotation was of little use. However Sohi et al. (1981) reported that rotation with Vigna sp. followed by maize and

cabbage or okra followed by Vigna sp. and maize gave effective control of Pseudomonas solanacearum in tomato. Villareal et al. (1970) reported that inoculation with different combinations of strains at 24 hours interval on susceptible, moderately susceptible and resistant varieties, gave significant reduced infection. They inferred that cross protection can reduce the subsequent severity of infection by Pseudomonas solanacearum. Graftings on Solanum diversifolium and Solanum torvum were recommended (Mahmudunnabi and Islam, 1975; Remadevi, 1978). Lum and Wong (1976) reported that through grafting the susceptible tomato scions on resistant brinjal root stocks like Sabah and Hitam Bulat, the incidence of bacterial wilt in field was reduced to 10%.

D. Sources of resistance

Much of the early disease resistance breeding work was carried out at North Carolina in U.S.A. (Schaub and Baver, 1944; Weaver, 1944). In field tests, Louisiana Pink and T 414 from Puerto Rico showed good resistance to bacterial wilt. Aberdeen (1946) found that strain derived from Louisiana Pink and T 414 were resistant also in Queensland. Two varieties Sensation and Marvel, though with poor fruit quality, showed good resistance to wilt. Resistant lines reported from North Carolina University (Annual report, 1950-51) were found to be resistant in Hawaii but fruits were too small to be of much commercial value. The trials at Sri Lanka involving several

North Carolina lines indicated resistance in Masterglobe and Rahangala to bacterial wilt (Abeygunawardena and Siriwardena, 1963). They further reported that the North Carolina lines 1960-8, 1960-2a, 1962-B2 and 1961-57-55 M and Masterglobe and Rahangala Selection II were the most resistant. The Los Banos tomato lines resistant in Philippines were susceptible in these tests indicating the existence of different pathogenic races of Pseudomonas solanacearum. The North Carolina lines were superior in wilt resistance to local cultivated varieties and outyielded the commercial varieties Masterglobe and Pearson.

A further source of resistance different from that observed in North Carolina lines was reported in Lycopersicon pimpinellifolium (PI 127805 A) (Abeygunawardena and Siriwardena, 1963). Henderson and Jenkins (1972) reported resistance in Venus, Saturn and Beltsville 3814 to bacterial wilt. Daly (1973) confirmed the resistance in Venus, Saturn and in local lines III IRAT and OTB2. But Venus and Saturn were proved to be poor yielders (Federal Biological Institute of Agriculture and Forestry, 1976). The four F_7 lines from a cross UPRI99 x Floralou showed good tolerence to Pseudomonas solanacearum (IRAT, 1970). The local line 2 ASS was observed tolerant to bacterial wilt (Serere Research Station, 1970-71). Akiba et al. (1972) reported resistance in three lines of tomato, 65 S2, 66 S 52 and 68 S4. Chetie and Kakati (1973) reported resistance to Pseudomonas solanacearum in Oxheart under natural

infection. Best Of All and Marglobe Supreme were moderately susceptible. AVRDC (1975) reported three tomato cultivars, VC-11-1, Saturn and Kewalo, resistant to bacterial wilt and the F_1 progeny of two way and three way crosses were more resistant than the parents on artificial inoculation. Mew and Ho (1976) screened 43 varieties and lines. The line VC 8-1-2-1 was resistant regardless of inoculum density and noted that susceptible varieties were not significantly effected by changes in inoculum density but resistant lines became less resistant at high inoculum densities. Bedekar (1977) tested four tomato cultivars for their reaction to different isolates of Pseudomonas solanacearum. Disease reaction varied from cultivar to cultivar to bacterial isolate mixtures. Saturn and PI 303811 showed extreme susceptibility to all highly virulent isolates. Presence of highly virulent isolates in the mixed inoculum decreased the survival percentage. Saturn and PI 303811 could withstand weakly virulent isolates and their mixtures but succumbed to highly virulent Taiwan isolates. VC 9-1 UG and VC 11-1 UG showed resistance to eight isolates and their mixtures. Venus and Saturn and the susceptible variety Manapal were inoculated with isolates of Pseudomonas solanacearum from USA and India by root wounding and stem puncture methods. It was found that Manapal was more resistant to American isolates than to Indian isolates, during four to six weeks of age (Jenkins and Nesmith, 1976). Saturn and Venus were highly susceptible to American isolates at two to four weeks of age

but became highly resistant after four to six weeks. All cultivars were highly susceptible upto ten weeks of age to Indian isolates when stem inoculated. Venus and Saturn were resistant when inoculated by root wounding with Indian isolates after six weeks. The Indian isolate was more virulent than American isolates to all cultivars at all stages in both inoculation techniques. Venus and Saturn should survive bacterial wilt if transplanted when about six weeks old.

Kann (1977) reported of a line, Cranite, which has Mi for resistance to Meloidogyne incognita besides good resistance to Pseudomonas solanacearum. Graham et al. (1977) observed resistance in VC-4. The line VC 48-1 was resistant to bacterial wilt in Taiwan (AVRDC, 1978). Rao et al. (1975) reported susceptibility of previously considered resistant lines in USA and Philippines under conditions in India, showing specificity of resistance in North Carolina source of resistance. Of the 25 lines, L 3972, L 3987 and CL 88-0-7-1 were moderately resistant in Nigeria (IITA, 1978). Sonoda et al. (1979) reported moderate resistance in tomato accessions 102, 106, 135-1, 135-2, 14 and 123-1 in Fort Pierce. Evaluation of tomato varieties against bacterial wilt conducted at Agricultural College, Vellayani, Trivandrum, indicated wilt incidence of <30% in Venus, Saturn, and CRA 66 selection A (Remadevi, 1978). The minimum % of wilted plants were recorded in Saturn (18.67%) followed by Venus (21.33%). The wilt incidence in Bonny Best,

Red Cherry, Marglobe and Lycopersicon pimpinellifolium were 56%, 62.67%, 74.62% and 48% respectively.

Sunarjono (1980) reported, the breeding lines AVRDC 33, AVRDC 15 and CL 32 d-0-1-25 were resistant to Pseudomonas solanacearum. The line Hawaii 7996 resistant to the pathogen, had very small fruits. Sonoda at al. (1980) observed that the better sources of resistance to Pseudomonas solanacearum at present are Hawaii 7997, CRA 66 and PI 126408A. AVRDC (1980) reported resistance (>90%) in CL 275-0-1-2-1, CL 949-0-8, CL 1219-0-8, CL 1351-1-6 and CL 1351-1-9.

The trial conducted at College of Horticulture, Vellanikkara, Trichur indicated resistance in CL 32 d-0-1-19 GS out of 78 lines/varieties evaluated (Celine, 1981). This line had too small fruits to be of commercial acceptance.

E. Factors affecting wilt incidence

Resistance and susceptibility to disease are conditions with defined metabolic, environmental, and genetic conditions. Even plants considered highly susceptible to a pathogen may have tissues that are resistant (Kuc and Rahe, 1970). Similarly plants may be resistant at one stage of development but highly susceptible at another. A slight change in temperature can alter disease reaction as can day length, growth regulators, various chemicals, other microorganisms and inorganic nutrition. The ability of a microorganism to cope with or repress a host

resistance mechanism would be genetically controlled and subject to external influence. Kuc (1968) opined that disease resistance is not an absolute or static condition and depends upon many factors. The expression of the biochemical potential, determined by the genetic component of the organism, is influenced by a multitude of factors including nutrition, growth regulators, temperature, moisture, day length, stage of development and nature of the tissue. Bell (1981) stated that factors which influence resistance, include intensity, duration and quality of light, moisture levels, nutrient levels and agricultural and industrial chemicals.

1. Light

Low light intensity generally decreases resistance. It may also increase the resistance depending on the specific host pathogen combination. Long photoperiods generally result in higher levels of resistance (Bell, 1981).

2. Nutrient elements

Kuc (1968) found that wilt resistance induced by growth regulators is influenced by calcium level in the plant and plants deficient in calcium remain highly susceptible. Walker (1952) reported that severity of infection of Pseudomonas solanacearum is increased by high levels of Phosphorus and decreased by high nitrogen. Bell (1981) indicated that increasing the concentration of potassium and

calcium increases most often the resistance while excess nitrogen decreases resistance. The phosphorus has variable effects.

Sequeria and Kelman (1962) reported that growth substances such as IAA, increase greatly with an increase in wilt severity.

3. Age of plant

Increased resistance in resistant lines was apparently associated with age rather than plant size (Winstead and Kelman, 1952). Coyne and Schuster (1983) reported that resistance in tomato to Pseudomonas solanacearum changes with plant age. Resistant plants become susceptible upto 21 days and become resistant again from 21 to 49 days. Jenkins and Nesmith (1976) observed that Venus and Saturn survived bacterial wilt in the field better if eight week old seedlings are transplanted. Bell (1981) reported that each plant part changes in its level of resistance with age. Resistance levels in stem and roots generally increase rapidly during the first two weeks of seedling or when new shoot grows, and slowly thereafter. Levels of resistance in leaves and fruits frequently decline with age.

4. Soil temperature

Infection may occur at soil temperature as low as 55°F (12.8°C) but symptoms of wilt do not ordinarily become

apparent at 12.8 to 15.6°C (Vaughan, 1944). The rate of development of the disease, increases with the increase in temperature from 21.1 to 43.3°C. Vaughan (1944) demonstrated that tomato plants wilted at 26.7°C but when the soil temperature is lowered to 12.8°C for five days, the plants recovered. The wilt symptoms reappeared, if the temperature was adjusted to the original temperature. Hildebrandt (1950) reported that plants did not wilt until the soil temperature remained above 21.1°C for atleast three days. He also indicated that there is relationship between pathogenecity and temperature and day length. Short days caused poor growth of pathogen whereas long days caused good growth and rapid development of the disease symptoms. The quickest disease development occurred at a temperature of 32°C with a low nitrogen concentration either in long or short days. Harrison (1961) stated that it might be possible to classify Pseudomonas solanacearum into four classes depending upon differences in their reaction to optimum temperature ranges. Chupp and Sherf (1960) reported that the temperature range for disease development was between 15 to 37.8°C with an optimum temperature of 29.4 to 35°C. Kreusz and Thurston (1975) observed that elevated temperature (32°C) in environmental control chambers significantly increased severity of bacterial wilt in two tomato lines, Philippine 1169 and Hawaii 7580, resistant to Pseudomonas solanacearum. The level of resistance in Venus to isolate K-60 was not signi-ficantly affected by temperature, but this line expressed no

resistance to isolate LB-6 at all temperatures tested. Reduced light intensity (8,075 lux.) did not reduce resistance to isolate LB-6 in line 1169 at 26.6°C but significantly decreased resistance at 29.4°C. Reduced photoperiod (9.5 and 10 hours), independent of temperature significantly decreased resistance of line 1169 to isolate LB-6. The studies of Mew and Ho (1977) on the resistance to Pseudomonas solenacearum in six cultivars as influenced by changes in soil temperature revealed that VC 48 maintained moderate resistance (20 to 40% wilted plants) at 26, 30 and 32°C. VC 8-1-2-1 and VC 11-1 were resistant (1 to 20% wilted plants) at 26°C but became moderately susceptible (40 to 60%) and susceptible (> 60%) respectively at 32°C. At 20°C there were no significant differences among resistant cultivars whereas at 32°C more than 50% of the VC 9-1 and VC 11-1 plants wilted in 5 to 6 days. VC 11-1 plants wilted in 5 to 6 days. VC 48 was still moderately resistant at the end of 19 days at all temperatures. Data thus suggested that there were two types of bacterial wilt, one dependent and another independent of soil temperatures. The high ambient air temperature had a direct effect on all resistant plants, but VC 48 was affected lesser than others. It appears that 32°C is the critical temperature for separating the two types of bacterial wilt resistance in tomatoes. They opined that in the development of bacterial wilt resistant tomato lines for tropical climate, lines should be screened at soil temperature of 30 to 32°C.

5. Soil moisture

Gallegly and Walker (1949) reported that high moisture levels in soil affected the disease by favouring the survival of bacteria in the soil, thereby increasing capacity for infection. Thus the effect of periodic drying of the soil on bacterial viability appears to be a major factor in the incidence and magnitude of wilt. Kelman (1953) observed that high soil moisture levels usually favour development of bacterial wilt. But Chupp and Sherf (1960) reported that the infection can occur in dry soil and disease becomes serious in red laterite soils.

6. Soil pH

The disease occurs in a variety of soils such as sandy loam (Kelman, 1953), red, black dust and light sandy loam soils (Park and Fernando, 1938; Hedayatullah and Saha, 1941). The disease also occurs in both acidic soils of pH 5 to 5.5 (Miller, 1940) and alkaline soils of pH 7.5 to 8.5 (Park and Fernando, 1938). Vaughan (1944) stated that the ideal pH of 6.5 to 6.8 for tomato cultivation favours the development of bacterial wilt also. Kelman and Cowling (1965) reported a high wilt incidence at a pH 3.5.

7. Inoculum density

Winstead and Kelman (1952) studied the influence of inoculum concentration on the incidence of bacterial wilt. They found that there were no differences in disease severity

in Marglobe (susceptible) due to inoculum concentration. However there was marked decrease in disease incidence in the LI plants (resistant) as the inoculum concentration decreased. Averre and Kelman (1964) found a reduction in severity of bacterial wilt in tobacco when the ratio of the avirulent cells to those of virulent ones was increased. Jenkins et al. (1967) detected the bacterium at a concentration of 2.5×10^6 cells/ml of soil by direct isolation and at 2.5×10^4 cells/ml of soil using tomato plants as indicators. In surface soils with a high level of organic matter and microbes the bacterial population was lower than in the sub-soils. Addition of manures reduced the population in sub-soil considerably. Okabe (1965) showed that the inoculum potential of the pathogen to cause wilt in tomato was 6×10^4 cells/g of dry soil. Ramadevi (1978) reported that the population threshhold of the pathogen in the soil at the time of appearance of wilt symptoms in tomato was 1.07×10^7 and 2.5×10^7 cells/g of soil for the sterilized series and non-sterilized series respectively to which bacterial suspensions containing 10.45×10^3 and 10.45×10^4 cells/ml were initially incorporated per kg of soil. The various soil amendments like cowdung, cowdung + glyricidia leaves, neem cake, marotti cake, and sawdust + urea were not effective. Lin (1979) found that inoculation of resistant tomato line VC 8 and susceptible line C28 with avirulent and virulent isolates resulted in the increase of number of virulent bacterial cells in susceptible plants but rapidly decreased in resistant plants,

after 48 hours. Mew and Ho (1976), after studying with five inoculum levels (from 10^9 to 10^5 viable cells/ml), recorded that the susceptible varieties were not significantly affected by changes in inoculum concentration, while resistant varieties shifted from resistant to moderately resistant when inoculum density was increased. They further reported that difference in incubation periods ranging from 6 to 17 days was a good indication that resistant varieties could slow down the rate of wilting if the initial infection was established or it delayed the initial infection of the disease.

8. Season

Mew and Ho (1976) opined that no varieties were completely immune and resistance to wilt was influenced by the planting season. Remadevi (1978) observed the maximum incidence of disease (100%) in Agricultural College, Vellayani, Trivandrum during the month of October and November, 1975 and minimum (10%) during February, 1976. After February the incidence of wilt increased up to June and then declined during July-August. The incidence of wilt of tomato was found to be positively correlated with the population of Pseudomonas solanacearum in soil.

According to Remadevi (1978) there was no significant correlation between wilt incidence and the various environmental factors like grass land minimum temperature, surface

land minimum temperature, maximum and minimum atmospheric temperatures, relative humidity and rainfall. This indicated that the disease incidence was not directly influenced by the different environmental factors individually. However, she found a combined influence of the population of the pathogen and grass land minimum temperature which was positively correlated with the disease incidence. She reported that there was no possibility of internal transmission of pathogen through seeds.

9. Nematode

The presence of certain nematode species in the soil can predispose the plants to bacterial wilt infection. Lucas et al. (1954) found high incidence of bacterial wilt in soils infested with Meloidogyne incognita. Temiz (1968) reported that resistant varieties which did not get infected with Pseudomonas solanacearum in the absence of nematodes, became infected in soil that was infested with nematodes. Goth et al. (1983) observed that bacterial wilt resistance was broken down when root-knot nematode larvae were added at the rate of 100/10 cm pot at the time of inoculation with bacterial isolates.

F. Genetics of bacterial wilt resistance

Singh (1961) reported that resistance to bacterial wilt derived from Louisiana Pink is polygenic and recessive. A second source of resistance derived from Lycopersicon

pimpinellifolium (PI 127805 A) is partially dominant in seedling stage and recessive in mature plant and that the expression of resistant variety is a function of age of plant and changes with temperature (Acosta et al., 1964). They found a complex picture of inheritance in which host reaction was altered by temperature and inferred that the study seemed to follow a pattern similar to that demonstrated in the resistance of Brassica campestris to cabbage yellows. At a constant sand temperature of 24°C, all susceptible and multigenic resistant cabbage varieties were infected while those with monogenic resistance survived the infection. They further reported that a small number of dominant genes are responsible for conferring resistance; one or more genes for resistance to bacterial wilt may be located on chromosome number six. Acosta (1964) stated that resistance to Pseudomonas solanacearum in Lycopersicon pimpinellifolium is controlled by a single pair of genes. Further tests indicated a more complex mode of inheritance. North Carolina lines were intermediate in resistance. The gene sp^{+} for indeterminate growth appeared to be linked with one or more of the genes for resistance.

Acosta et al. (1964) observed no association between the gene 'U' controlling uniform fruit colour and resistance to bacterial wilt. A few resistant selections had yellow gel around the seeds of ripening fruits. They could get no lines in resistant group with fruits of commercial quality.

Suzuki et al. (1964) stated that resistance to Pseudomonas solanacearum appears to be determined quantitatively. Report of the Faculty of Agriculture, University of West Indies (1968-69) indicated that resistance to Pseudomonas solanacearum had a close linkage with genes for poor fruit characteristics. AVRDC (1975) reported that resistance to bacterial wilt is controlled by multiple recessive genes acting additively and inferred that further studies on inheritance of resistance to the disease are needed.

Ferrer (1976) observed from the segregation ratios in the F_2 of resistant 126408 plants crossed to susceptible Bonny Best or Floradel, that resistance was polygenically inherited. Reciprocal crosses showed that extra chromosomal inheritance was not involved. The genes involved were additive and no dominance was involved. Variance component analysis of P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of a cross between resistant (VC4) and susceptible (Walter) cultivars estimated a narrow sense heritability of 42% and a broad sense heritability of 53% for wilt resistance with a degree of dominance of 5% (Graham and Yap, 1976).

Inoculation studies conducted by Mew and Ho (1976) showed that three types of bacterial wilt resistance operated in tomato: the first being, plants were resistant when tested by both artificial (clipping) inoculation and natural infection. The second, resistant when evaluated with natural infection

in the screening nursery but was susceptible when artificially inoculated. The third, the intermediate type which was found to be resistant under natural infection but only moderately resistant when artifically inoculated. They inferred that the bacterial wilt resistance in the tested varieties was either specific or non-specific resistance. A diallel cross analysis of six cultivars indicated that inheritance was mainly due to additive gene action (Maw and Ho, 1976). Kann and Laterrot (1977) demonstrated that resistance to Pseudomonas solanacearum and Fusarium oxysporum f lycopersici were under multifactorial control and it was suggested that the association between them was due to pleiotropy rather than linkage. Villareal and Leis (1978) endorsed the hypothesis of additive gene action for resistance to Pseudomonas solanacearum.

G. Biochemical bases of resistance

Resistant varieties possess physical and biochemical barriers which inhibit the entry of pathogen to the host cells. Mahadevan (1973) opined that resistance against parasitic microorganisms like bacteria, fungi and viruses is not due to structural barriers like thick epidermis, leaf hairs, thick cuticle, sugar content, osmotic pressure, pH, and other features. Chemical toxicants like prohibitins, phytoalexins and other post-infectionally formed inhibiting substances appear to be important in the defence reaction. The principal antimicrobial substances biosynthesised by phanerogams are

alkaloids, glycosides, sulphur compounds, unsaturated lactones, fatty acids, phenols, quinones and their derivatives and essential oils (Thapliyal and Mene, 1967). The chemical compounds which inhibit the pathogen are classified as pre-infectional and post-infectional inhibitors (Russel, 1978). Pre-infectional inhibitors in the plant are mainly catechol, procatechuic acids, phenols, terpenes, flavanoids and tomatine (Stoessl, 1969; Langecake et al., 1972; Roddick, 1974).

Mahadevan (1970) defined prohibitins as preformed inhibitory compounds which confer some degree of protection to the host plants against microorganism. These prohibitins are particularly effective at the point of entry and are primarily active during entry and penetration of microorganism. The quantity of prohibitins in a host may largely determine the resistance of tissues to parasites; more prohibitins mean more resistance and vice versa. Parasites may differ in their sensitivity to prohibitins. Solanine and tomatine are prohibitins occurring in Lycopersicon esculentum (Irwing, 1947; Allison, 1952).

Mullar (1959) and Cruickshank (1963) stated that a host may have two kinds of defence factors, prohibitins and phytoalexins. Prohibitins are passive chemical barriers while phytoalexins are active biochemical barriers against infection (Mahadevan, 1970). Disease results if both are overpowered by the parasites.

Specific resistance is conferred by a compound or compounds extremely toxic to a small group of specialised pathogen of herbivores (Levin, 1976) and each compound is present only in a few species. Such compounds are sinigrin, gossypol, juglone, phlorizidin, α-tomatine, and solanine. And general resistance is rendered by the presence of a compound or compounds which deter, repel, or are weakly toxic to most microorganisms and/or herbivores; such compounds include chlorogenic acid, coumarin, eugenol, α-pinene, quercetin, tannin, thymol and vanillin. Kuc (1964) reported that in some instances inhibition of a microorganism may result from the cumulative effect of two or more compounds. It was further reported that non-diffusible substances like tomatine, phenols etc. have a key role in the defence mechanism (Thapliyal and Nene, 1967).

1. Tomatine

The phytochemical α-tomatine is a steroidal glycoalkaloid found in tissues of Lycopersicon genus and was shown to exhibit antibiotic activity against a wide range of organisms (Irving, 1947; Fontaine et al., 1948). This secondary plant compound is toxic to many organisms, besides fusarium, bacteria, other fungi and yeast like forms. It occurs in wilt susceptible as well as resistant tomato plants, and to a greater extent in the latter. Irving (1947) stated that the high content of tomatine in resistant tomato plants made it to

survive though they were badly affected. Tomatine gradually disappeared from susceptible plants as invasion proceeded and that tomatine was completely absent in wilted and dying plants. It was inferred that wilt resistance or wilt susceptibility in tomato plants did not necessarily depend upon the presence or absence of tomatine but rather upon the rate at which the plant was able to elaborate it as the need for this protective substance arose. If adequate rate of tomatine production is not maintained the variety will be susceptible to wilt.

Fontaine et al. (1948) isolated crystalline tomatine from tomato plants and described its properties in detail. In the genus Solanum, tomatine is largely accompanied by other steroidal glycoalkaloids whereas in the genus Lycopersicon tomatine or one of its derivatives is usually the only steroidal alkaloid present (Roddick, 1974).

Tomatine appears in all parts of the plant as they develop but varies with the plant part. Tukalo (1958) found 0.96 to 1.9% of tomatine in leaves of tomato, 0.3 to 0.6% in stems and roots and 0.93 to 2.2% in fully expanded flowers. There is considerable variation in the tomatine content of a particular plant part, as for leaves it was 0.46% (Ghgy, 1958), for stem and leaves, it was 0.08% and 0.16% respectively (Sicho, 1956). Much of the variation was attributed to tomato variety, growth stage of plant, time and seasonal conditions. Kuhn et al. (1950) found that the tomatine yield

decreased with age. Kuhn et al. (1952) observed differences in tomatine content in different species of Lycopersicon. They found that Lycopersicon esculentum had 3000 ppm of tomatine. Sinden et al. (1978) observed that tomatine content was affected by age and day length. The content increased as the plants matured. Leaf content in Lycopersicon esculentum grown in long days doubled in the 46 days interval between the young and mature development stages.

Prokoshev et al. (1952) while comparing Lycopersicon esculentum, Lycopersicon validum and Lycopersicon pimpinellifolium, found that the latter contained the highest level of tomatine. Five tomato varieties studied by Sicho (1956) had tomatine concentration 0.04 to 0.08% in their stem.

Sander (1956) reported that shoot is the main site of tomatine synthesis. Accumulation and synthesis in the shoot appear to be independent of any direct root influence. The main site of tomatine biosynthesis in the root is the actively growing region. The content of tomatine in the host plant appears to be quite variable and is influenced by the environment. The production is directly related to the rate of growth. The principal site of degradation is the fruit. Tomatine disappearence during fruit ripening is due to actual degradation of the alkaloid (Roddick, 1974). Neither the location nor the site of synthesis of tomatine within the cells are yet known (Kern, 1952). Presence of tomatine in sap exuded from

decapitated plants suggests that transport form root to shoot occurs.

Roddick (1974) reported that crude extract of tomatine inhibited *Fusarium oxysporum* f. *lycopersici* *in vitro*. He also found that impure tomatine inhibited growth of a number of bacteria and plant and animal pathogenic fungi. Partially purified tomatine possesses greater antibacterial activity than purified alkaloid. Gram-positive bacteria are more sensitive to tomatine than gram-negative. Langecake *et al.* (1972) found that tomatine was quite inhibitory to hyphal extension of *Fusarium oxysporum* f. *lycopersici* *in vitro* but following infection of the plant, the level of tomatine in stem and root increased in susceptible as well as resistant cultivars. Mohanakumaran *et al.* (1969) found that tomatine levels are high in roots of *Lycopersicon pimpinellifolium* cultivars resistant to *Pseudomonas solanacearum* than in susceptible cultivars. Alkaloid levels in roots of resistant cultivars increased following infection by this bacterium whereas those in roots of susceptible cultivars remained constant or decreased. They further reported that the tomatine content in resistant varieties increased with age of the plant. *Pseudomonas solanacearum* was completely inhibited by 350 ppm of tomatine *in vitro*. The alkaloid content was above the critical level in comparatively resistant variety Venus both in the shoot and root. The level of tomatine was lower in the susceptible variety and the content was very low in wilte

plants. Rodrick (1974) found higher levels of steroidal glycoalkaloid tomatine in the roots of Lycopersicon pimpinellifolium lines resistant to Pseudomonas solanacearum than susceptible lines.

The bacteriocidal properties of tomatine were reported by Bustinza (1947) in Phytomonas solanacearum. Fontaine et al. (1948) found that tomatine had high antifungal action and also reported that antibiotic properties of tomatine were due to tomatidine portion of its molecule. Beech and Carr (1955) in their survey of inhibitory compounds for seperation of yeasts and bacteria from a mixed culture found that tomatine was non-selective in action. Sicho and Mrhova (1961) observed that tomatine was capable of inhibiting metobolism of Escherichia coli under aerobic condition, the degree of inhibition being directly proportional to the concentration of the material. Arnesan and Durbin (1967) reported that the leaf infecting fungus Septoria lycopersici was reported to detoxify α-tomatine.

Remadevi (1978) found higher content of tomatine in the shoots and roots of Venus than in the susceptible Marglobe. Shoots and roots of wilted plants contained still lesser amount of the glycoalkaloid. In all the cases, the shoots contained more of tomatine than roots. Venus contained tomatine at a concentration of 725.17 ppm in roots and 902.42 ppm in shoots and Marglobe contained 213 ppm and

301.8 ppm respectively. Marglobe on wilting contained 101.4 ppm and 132.67 ppm of tomatine in roots and shoots respectively.

Juvick and Stevens (1982) reported that tomato cultivars with higher levels of ∝-tomatine might display increased host plant resistance to tomato pathogens and insect pests. They further reported that variation in ∝-tomatine content was controlled by the segregation of two co-dominant alleles at a single locus.

2. Phenols

Phenols play a role in most resistance but how it happens is not clear. It is responsible for disease resistance in different crops (Farkas and Kiraly, 1962; Goodman et al., 1967; Singh and Bedi, 1976; Thind et al.,1981).

Phenols, particularly chlorogenic acid, were detected in the vascular system of young potato plants (Tapliyal and Mehra, 1967). The resistant varieties contained chlorogenic acid and the concentration was higher in the roots of the resistant potato varieties than in susceptible ones. The best known example for the protective role of preformed phenolics against disease incidence is Colletotrichum circinans (Berk.) vogl. complex in onion. Resistance in onion is correlated with the red or yellow pigmentation of the bulb scales (Walker, 1923, 1926).

The pigments involved are flavons and anthocyanins, occuring with single phenolics like protocatechuic acid. Thapliyal and Nene (1967) reported that the presence of volatile and non-volatile antimicrobial substances in the fleshy pigmented onion scales is the factor for resistance in onion against Colletotrichum circinans. The removal of coloured scales renders these onion susceptible. Lawsence and Gestur (1955) found that phenolic compounds inhibited the growth of Streptomyces scabies in potato. Menon and Schechinger (1957) reported that the resistant combination of Fusarium infected tomato accumulated more phenolics than the susceptible combination. Farkas and Kiraly (1962) reported that accumulation of polyphenols upon infection is more intense in the resistant combination of potato. Thomiyama (1963) stated that aromatic compounds such as mono and dihydric phenols, phenolic glycosides, flavanoids, anthocyanins, aromatic amino acids and coumarin derivatives are increased in a host tissue invaded by a parasite. He reported that co-existence of phenolics with amino acids weakened the toxicity of the former and the ratio between concentration of phenolics and amino acids may be important.

Sakai and Takamori (1964) determined O-diphenol content in 22 potato varieties. Varieties with high diphenol levels were highly resistant to Phytophthora infestans. Kuc (1964) opined that bacteria are generally not as sensitive to these inhibitors as are the fungi. In a few instances,

inhibition of a microorganism may result from the cumulative effect of two or more compounds (Hampton, 1962; Kuc, 1964).

Stoessl (1969) observed that phenols are produced as a consequence of the increased biosynthesis of aromatics following infection. Phenols themselves are weakly fungitoxic but on oxidation reaction form quinons which may participate in resistance process by condensation with proteins and enzymes or polymerization to tannins and lignins which may act as protein precipitants or physical barriers to parasite expansion. The enzymes produced by parasites degrade polyphenols and tannins, lowering their toxicity (Mahadevan, 1970).

Bhullar et al. (1972) studied the role of phenols in relation to anthracnose, Colletotrichum capsici, in chilli. They found that resistant cultivar had higher content of phenols than susceptible ones. Narain and Mohapatra (1973) found that degree of resistance to Colletotrichum capsici in leaves was positively correlated to the phenolic content of the leaves. Cheema (1982) showed that in both the diseases, anthracnose and cercospora leaf spot of chilli, the phenolic content did not show any relation with resistance or susceptibility. Thind et al. (1981) reported that total phenols increased in resistant chilli genotypes and decreased in susceptible genotypes after infection by Xanthomonas vesicatoria.

Matta et al. (1968) observed a rise in soluble phenol content in both susceptible (Bonner Beeta and Marmande) and

resistant (Marmorum) tomato varieties after inoculation with Fusarium oxysporum. Subsequently the phenol content disappeared in the resistant variety, suggesting that it was a defensive response to infection. In a study on resistance in different Lycopersicon species to late blight it was found that phenolic content showed a greater increase in resistant varieties than susceptible varieties (Revise and Tangury, 1971). Bhatia et al. (1972) reported that early blight (Alternaria solani) resistant varieties of tomato EC 21193 and EC 120 had higher total tannin content in the leaves and stem than susceptible varieties like Marglobe. The resistant varieties also had a higher total content of phenols and flavanols in the fruit, stem, leaves and roots than susceptible varieties.

Inoculation studies on tomato with leaf curl virus showed a significant increase in phenol after three weeks of inoculation in resistant lines (B2247 and XX11354A-Silvestre) while susceptible lines showed only a marginal increase in phenol content over that of control (Som and Chaudhary, 1976). Resistant varieties contained higher amount of phenols than susceptible ones after six weeks of inoculation. Likewise phenolic compounds accumulated to a greater extent in the resistant Aikado than in the susceptible Sutton's Golden Queen after inoculation with Alternaria tenuis (Alternaria alternata) (Agarwal and Bisen, 1978).

Wilski et al. (1968) observed higher total phenol, O-dihydric phenol and flavanol, in the roots of potato seedlings resistant to Heterodera rostochiensis. Following infection by an incompatible race of Phytophthora infestans, the content of O-diphenols increased in resistant plants of potato (Ishizaka, et al. 1971).

3. Vitamin C

Voronia (1971) found a higher content of ascorbic acid in the ripe fruits of resistant tomato variety (Leningred Autumn) to Cladosporium fulvum. Rattan and Saini (1979) observed high ascorbic acid content (31-34 mg/100 g) associated with resistance to Phytophthora parasitica. In susceptible cultivars, ascorbic acid content ranged from 17 to 22 mg/100 g of fruit. Awasthi and Singh (1975) found, following infection by cucumber mosaic virus in chilli, greater reduction in ascorbic acid and capsaicin contents in fruits of susceptible variety (NP 46A) than in those of tolerant NBG local selection. The decrease was associated with increased ascorbic acid oxidation resulting from viral infection.

H. Selection Methods

Yield in tomato is a complex character based on a number of yield components, fruits/plant, plant height, locules/fruit, days to fruit set and to harvest (Nandpuri et al., 1976). The main yield components have high genotypic coefficient of variation associated with high heritability resulting in high

genetic advance. These characters are predominantly controlled by additive genes. Most of the variability existing in the plant population for various characters could be fixed in one cycle of selection (Chaudhary, 1968). Selection procedures like mass, pureline, pedigree, bulk, recurrent selection and more recently single seed descent are used to advantage in various crop plants.

1. Mass selection

Chaudhary (1968) reported that success in mass selection depends on heritability, population size, intensity of selection, linkage relationships and variability of characters. Higher the selection intensity in mass selection, the better would be the success and mass selection could be used to exploit both additive and dominance variance (Singh and Singh, 1976). Swarup (1977) remarked that mass selection was effective to improve highly heritable characters, but was not so useful in case of polygenic characters particularly those which have low heritability. To overcome the limitations of mass selection he suggested mass pedigree method. Chaubey (1979) opined that mass selection was advantageous to improve yield. The scope of improvement through mass selection became limited as the total genetic variability became limited.

2. Pureline selection

Chaudhary (1968) reported that pureline selection has special significance in the improvement of self-pollinated crops.

And, though no new genotypes would be created by this method, unimproved varieties could be sieved to isolate superior purelines.

3. Single seed descent

This method is a modification of bulk method of breeding. The method was modified by Grafius (1965) where it was designed to preserve total range of variation throughout the propagation period and to minimise the effects of natural selection in changing the genotypic array in the original population. According to Brim (1966) when additive type of epistasis was of significance in the inheritance of economic characters this method was as efficient as when genotypic variance was mostly additive. Also only less effort was necessary to obtain homozygous types for simply inherited characters which were discontinuous in expression. Boerma and Cooper (1975) reported that S.S.D allowed rapid generation advance of materials in early segregating generations. They also inferred that single seed descent required the least overall selection effort.

Tigchellaar and Casali (1972) compared two methods of plant improvement and suggested pedigree system for early generation and single seed descent method for more advanced generations. Casali and Tigchellaar (1975) compared genetic advances in tomato obtained through pedigree selection and single seed descent. They reported that single seed descent was effective when several characters with different heritability

valueswere under simulteneous selection. Pierce (1977) studied the impact of single seed descent in selecting for fruit size, earliness and total yield in tomato. The study revealed that single seed descent method of selection per se produced generally inferior and smaller fruit size and low total yield in progenies as compared with pedigree selection alone or single seed descent followed by one cycle of pedigree selection. The data further suggested that chances for recovering high performers in line would be reduced in single seed descent method of selection as compared to pedigree selection. Hill (1971) compared pureline selection, recurrent selection to an inbred tester and reciprocal recurrent selection, for a code with two alleles at one locus with complete dominance. Reciprocal recurrent selection was more effective than pureline selection. With partial dominance, reciprocal recurrent selection was equally effective to pureline selection. Muchibauer et al. (1981) compared single seed descent and bulk population method in a hypothetical crop which had seven chromosomes each with six loci and with various degrees of linkage. In the sixth inbred generation additive genetic variance was lesser in bulk population than in with single seed descent. This difference was attributed to losses in genetic variability in the bulk population during generation advance. Fecundity affected the genetic variability in the bulk population breeding method.

Butler (1962) reported that genes on chromosome two exert a pleiotropic effect on fruit size in tomato. Gene 'P' increases fruit weight and 's' 'd' and 'o' reduce it. Locule number (lc) has major influence on fruit size but the data suggest that there are genes controlling fruit size between 'sw' and 'o' and also between 's' and the centromere. Butler (1973a) studied 19 selections of tomato for fruit size in a filial population of 1200 plants selfed and reselected for six generations. Variability was reduced in most of the lines and dominance for small fruit size did not occur in all lines. He inferred that the dominance factor was associated with the gene 'Y' in chromosome one. In another cross, it was indicated that the dominance of small fruit size was associated with genes in chromosome one (Butler, 1973b).

In a diallel cross involving six cultivars of tomato, Trinklein (1975) found that dominance and epistasis were involved in the inheritance of fruit weight, early yield and fruit cracking and additive gene action involved in the inheritance of total yield. In another study involving 83 varieties of tomato, locule number was significantly correlated with fruit weight (Janoria, 1976). The studies by Butler (1976) showed that the inheritance of fruitsize depends on a few genes affecting fruit number and cell expansion. The study on yield components like plant height, days to first fruit set and to harvest and locules/fruit in tomato revealed that genotypic coefficient of variation and heritability for fruits/

plant and locules/fruit were very high and the characters correlated significantly with yield (Peter and Rai, 1976a). A divergence study among 25 varieties of tomato (Peter and Rai, 1976b) indicated that genetic divergence was mostly due to variation for locules/fruit and plant height. A selection index based on these characters was recommended for crop improvement. An investigation involving 40 tomato varieties indicated high heritability estimate for fruit size, height, days to maturity and yield/plant (Nandpuri et al., 1977). Fruit size, yield and fruits/plant had higher expected genetic advance. Positive correlation was observed between fruits/plant and yield/plant while fruit size and height were negatively correlated. The fruits/plant was the major yield component. A variability and correlation study using eight varieties of tomato showed a high genotypic and phenotypic coefficient of variation for plant height, leaves/plant, primary branches/plant and fruits/plant (Prasad and Prasad, 1977). Heritability was more than 50% in all characters and estimated genetic advance was the highest for fruits/plant. A significant negative correlation was observed between fruits/bunch and locules/fruit.

Rajanna et al. (1977) reported that genetic divergence in tomato was manifested in plant height, locules/fruit and nodes to first inflorescence. Kubicki and Michalska (1978) in a half diallel comprising 13 early varieties of tomato found incomplete dominance of smaller fruit size and partial or

complete dominance for more number of fruits among those which ripen the earliest. Mital and Singh (1978) in a 10 x 10 diallel analysis of tomato revealed that days to flower, fruits/plant, early yield and total yield were predominently conditioned by non-additive gene action and yield was polygenically controlled. Zhuchenko et al. (1979) reported that the genes for small fruit were not completely recessive.

Ponnuswamy and Muthukrishnan (1980) reported that there was consistent negative correlation between fruit weight and fruit number in tomato and simultaneous selection for the two characters is recommended. Singh and Singh (1980) reported additive gene action for days to flower, fruits/plant, fruit size, locules/fruit, fruits/bunch, primary branches/plant and plant height. Johnson and Hernandez (1980) revealed, from crosses between early maturing L401 and late maturing L 414, that early fruiting was partially dominant and heritability estimates for fruit weight and fruit number were 0.48 and 0.79 respectively, whereas crosses between high yielding VF65-433 and low yielding Beefeater had zero heritability estimate for both fruit number and fruit weight. Stefanovakrusteva (1980) observed positive correlation between yield and fruit weight and fruit number was negatively correlated with fruit weight.

Celine (1981) reported that progenies developed through mass selection were superior to those developed through bulking for days to harvest, fruits/plant and total fruit weight/plant. The progenies developed through pureline selection were superior to bulking for days to fruitset, days to first harvest, marketable fruit weight/plant and percentage of large fruited plants. The study further revealed that selection response through mass selection was positive for primary branches/plant and locules/fruit while for plant height selection response through bulk method was positive. The realised heritability was also high (0.88) for days to first fruit harvest.

MATERIALS AND METHODS

MATERIALS AND METHODS

The crops were raised in the Instructional Farm of the College of Horticulture, Kerala Agricultural University, Vellanikkara during September to December 1981, September to December 1982, February to May 1983 and September to December 1983. The experimental site is situated at an altitude of 22.25 m above mean sea level enjoying a typical warm humid tropical climate. The soil type was sandy loam with a pH of 5.1. The weather data during the period of research are given in Appendix I.

The experiments comprised of four main parts:

A. Selection efficiency associated with resistance to bacterial wilt.

B. Genetics of resistance to bacterial wilt.

C. Biochemical bases of resistance to bacterial wilt.

D. Artificial inoculation studies.

A. Selection efficiency associated with resistance to bacterial wilt.

1. Experimental materials

The bulk population of the breeding line CL 32d-0-1-19 GS was used as the base population for different methods of selection. The following characters singly and in combination were tried.

a) Fruits/plant

b) Yield/plant

c) Locules/fruit

d) Plant height

There were altogether 15 treatments as follows:

T_1 - Fruits/plant

T_2 - Yield/plant

T_3 - Locules/fruit

T_4 - Plant height

T_5 - ($T_{1.2}$) - Fruits/plant and yield/plant

T_6 - ($T_{1.3}$) - Fruits/plant and locules/fruit

T_7 - ($T_{1.4}$) - Fruits/plant and plant height

T_8 - ($T_{2.3}$) - Yield/plant and locules/fruit

T_9 - ($T_{2.4}$) - Yield/plant and plant height

T_{10} - ($T_{3.4}$) - Locules/fruit and plant height

T_{11} - ($T_{1.2.3}$) - Fruits/plant, yield/plant and locules/fruit

T_{12} - ($T_{1.3.4}$) - Fruits/plant, locules/fruit and plant height

T_{13} - ($T_{2.3.4}$) - Yield/plant, locules/fruit and plant height

T_{14} - ($T_{1.2.4}$) - Fruits/plant, yield/plant and plant height

T_{15} - ($T_{1.2.3.4}$) - Fruits/plant, yield/plant, locules/fruit and plant height

A total of 2377 plants formed the base population, grown in rows along with the variety, Pusa Ruby as susceptible check in alternate rows, to isolate resistant genotype(s) against bacterial wilt. The experimental site was a hot spot

for bacterial wilt and evaluation for resistance was done sequentially in the very same plot.

2. Methods of selection

a) Mass selection (at 5% intensity)

b) Pureline selection

c) Single seed descent (SSD)

d) Bulk

The procedure adopted for each of the methods of selection was as follows:

a) Mass selection - Observations were made on each plant for different characters and plants falling in the upper five per cent limit for each character/character combination were selected. The fruits were harvested and bulked to obtain seeds.

b) Pureline - The most promising elite plant for each character/ combination was identified and selfed to develop progenies.

c) Single seed descent - The largest sized seeds were collected from each of the well developed fruits borne on the most promising elite plant selected for pureline selection.

d) Bulk - The seeds collected randomly from the entire base population formed the bulk.

3. Layout and Experimental Design

A split-plot design with five replications was used. The four methods of selection formed the main plots and superior

progenies identified based on character/character combinations were included in the sub-plots. The experiment was laid out in a wilt-prone area. Thirty days old seedlings were transplanted at a spacing of 60 x 60 cm in rows alternated with the susceptible variety, Pusa Ruby. There were ten plants/treatment/replication.

4. Cultivation practices

A basal dose of 20 tonnes of cattle manure/ha and N, P_2O_5 and K_2O at the rate of 120:60:60 kg/ha were applied. Other cultural operations and plant protection measures were followed as per package of practices (Kerala Agricultural University, 1981).

5. Observations

Observations on the following characters were recorded.

a) Vegetative characters

   i) Plant height.

b) Productive characters

   i) Locules/fruit - Five fruits were taken at random and locules counted.

   ii) Fruits/plant

   iii) Yield/plant

   iv) Earliness - Days taken from sowing to flower, fruit set and first harvest.

   v) Fruit weight - Average fruit weight of first three harvests.

6. Evaluation for resistance to bacterial wilt

The wilt incidence was recorded at two distinct growth phases, juvenile stage and adult stage. The wilted plants were confirmed for bacterial wilt by ooze test.

The experiment was progressed for three generations.

7. Statistical analysis

The data were analysed as suggested by Panse and Sukhatme (1978). Analysis of variance was done to find out relative effectiveness of selection methods and various trait-wise selections to improve economic characters along with bacterial wilt resistance. Selection responses were estimated as per Singh and Chaudhary (1979).

The superiority of one selection method over the other was assessed by comparing the realised genetic gain (response to selection). The realised genetic gain for various characters under different methods of selection as well as traitwise selections per se for each generation was calculated as follows.

a) Realised genetic gain = Mean performance - Mean performance of bulk population (Singh and Chaudhary, 1979).

b) Realised heritability was worked out as follows:

$$\frac{R}{S} = \frac{\text{Response to selection}}{\text{Selection differential}}$$

(Falconer, 1981)

In addition to the above the following parameters for each method of selection for each generation were also estimated.

c) Genotypic coefficient of variation = $\frac{\sigma g \times 100}{\text{Arithmetic mean}}$

(Burton, 1952)

where σg = genotypic standard deviation

d) Phenotypic coefficient of variation = $\frac{\sigma p \times 100}{\text{Arithmetic mean}}$

(Burton, 1952)

where σp = Phenotypic standard deviation

e) Heritability in broad sense ($h^2(b)$) = $\frac{\sigma g^2}{\sigma p^2}$

where σ^2_g = genotypic variance

$\sigma^2_p = \sigma^2_g + \sigma^2_e$ = phenotypic variance

f) Expected genetic advance = $i.h^2_p$

where i = a constant at 5% intensity of selection = 2.06

$h^2_{(b)}$ = heritability in broad sense

σp = phenotypic standard deviation

g) Expected genetic advance as a percentage of mean =

$$\frac{\text{Genetic advance} \times 100}{\text{Arithmetic mean}}$$

B. Genetics of resistance to bacterial wilt

1. Experimental materials

The selfed progenies of resistant LE79 (CL 32 ♂ - 0-1-1-1-19 GS) (P1) and the susceptible Pusa Ruby (P2) were used to develop F_1S, F_2S, BC_1S and BC_2S.

2. Layout and experimental design

A randomised block design with five replications was used with 10 plants each in P_1, P_2 and F_1 and 40 plants each in F_2, BC_1 and BC_2/replication. The experiment was laid out in a wilt-prone area during September to December 1982.

3. Observations

Counts were taken of number of plants wilted in different generations due to bacterial wilt.

4. Association of characters with bacterial wilt resistance

To study association, if any, between bacterial wilt resistance and quantitative and qualitative characters, ten plants each from LE 79 (resistant) and Pusa Ruby (Susceptible) were grown in pots.

The following characters were observed.

Gel colour of fruits - Green/yellow.

Locules/fruit - Few loculed ($\leq$ three)

- Many loculed ($>$ three)

5. Statistical analysis

a) Inheritance of resistance to bacterial wilt

The data from segregating and non-segregating populations were collected and analysed. The confirmation of F_2 ratio was done by test cross ratios. The chi-square method suggested by Panse and Sukhatme (1978) was followed.

b) Penetrance of disease resistance

The penetrance of the genes for disease resistance was estimated as suggested by Awdeyev (1979).

c) Study of association between disease resistance/and other quantitative and qualitative characters.

The characters were analysed for association with disease reaction following the contingency chi-square test (Panse and Sukhatme, 1978) and multinomial test (Rao, 1973). Chi-square values were used to test the significance. A probability value of 0.50 and above was considered for non-significance, whereas probability below 0.50 was considered significant with regard to their association.

C. Biochemical bases of resistance to bacterial wilt

1. Experimental materials

The resistant line, LS 79 (Cl 32d-0-1-1-1-1-19 GS) and the susceptible variety Pusa Ruby were analysed for the biochemical status in 15, 30, 45, 60 and 75 days old plants.

2. Chemical constituents

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

a) ∝ - Tomatine

The method suggested by Peach and Tracey (1955) for ∝- tomatine estimation was modified. Twentyfive grams each of roots, stems and leaves were collected and minced in a waring blender with 125 ml of 95% ethanol. Five ml of glacial acetic acid was added to it and after shaking for 18 h on an automatic shaker, the mixture was filtered through whatman No.4 filter paper using a Buchner funnel. The residue was then washed twice with 50 ml portions of 64% ethanol. The ethanolic extracts were combined and concentrated to approximately 50 ml under reduced pressure in a vaccum flash evaporimeter. Five grams of annydrous sodium sulphate was added to this and the mixture was warmed on a water bath for 30 minutes when a flocculent precipitate of protein appeared. After cooling, 2 ml of 20% sulphuric acid was added to the mixture and filtered through whatman No.4 filter paper. The residue was washed with 10 ml of distilled water and the filterate plus washings were collected and made alkaline (pH 10) with strong ammonia solution. In order to remove the green colour of the solution it was filtered through glass wool and activated charcoal. The filterate was then allowed to stand overnight below 4°C. The precipitate developed was

separated by filtering through whatman No.42 filter paper and washed with 10 ml of cold ammonia solution. The precipitate was then dissolved in 5 ml of 10% acetic acid and it was used for tomatine determination.

Half ml of the samples were transferred to three clean lintfree pyrex glass test tubes and 2 ml of water was added to each of these. After cooling the solution in a water bath at 15°C, 6 ml of anthrone reagent (0.2% anthrone in concentrated sulphuric acid) was layered under the solution with a pipette, with test tubes still in cold water bath, the contents were mixed throughly with clean glass rod. The samples were heated over a boiling water bath for 10 minutes and these tubes were then returned to cold water bath and kept for 5 minutes. Percentage of transmittance was then recorded using Spectronic 20 colorimeter (B & L) at 620 m/u against a reagent blank and respective optical density values were obtained from the conversion table. Concentration of tomatine was then calculated by referring to a standard curve prepared with known levels of authentic tomatine obtained from Sigma Chemical Company, P.O.Box 14508, St.Louis, MO 63178 USA (supplied by the courtesy of Dr.R.E.Webb, Chief, Vegetable Laboratory, ARS-C-W, Beltsville, Maryland, 20705 USA).

b) Total phenols

Total phenols estimated as tannic acid. Alcoholic extracts of roots, stems and leaves from 15, 30, 45, 60 and

75 days old plants were used for estimation. The modified Folin-Denis method (Mahadevan and Sridhar, 1982) was followed for estimation.

c) Orthodihydric phenols (O.D. phenols)

The Arnow's method as described by Mahadevan and Sridhar (1982) was followed for the estimation of orthodihydric phenols in roots, stems and leaves at different stages of growth. The alcoholic extracts of the plant parts were used for the estimation.

d) Vitamin C

Vitamin C in roots, stems and leaves at different stages of growth were estimated by the visual titration method based on the reduction of 2, 6 - dichlorophenol indophenol dye method (Mahadevan and Sridhar, 1982).

To study changes in the content of α- tomatine, total phenols, O.D. phenols and Vitamin C, 60 days old plants of LE 79 and Pusa Ruby were artificially inoculated through the roots. The above constituents in roots, stems and leaves were estimated three days and seven days after inoculation.

D. Artificial inoculation studies

To study the reactions of LE 79 (CL 32d-0-1-1-1-1-19 GS), Pusa Ruby and the susceptible variety (Pusa Ruby) grafted on the resistant line (LE 79, CL 32d-0-1-1-1-1-19 GS) to

artificial inoculation, two trials were conducted. The first trial consisted of three sets of plants and second trial had one set. Each set comprised of ten plants each under LE 79, Pusa Ruby and Pusa Ruby grafted on LE 79.

Thirty days old seedlings with a stem diameter of about one cm were selected for grafting. Wedge grafting was followed. Thirty days after grafting, the grafted plants, LE 79 and Pusa Ruby were artificially inoculated with race 1 isolate (Vellanikkara) of *Pseudomonas solanacearum* through stem puncturing on the third leaf axil from the top (Kelman, 1967). Sufficient moisture was retained in the pots and in the vicinity of plants by spraying water. Weekly observation on number of plants wilted was recorded. Final observation was taken after three weeks of inoculation.

RESULTS

RESULTS

The data from the present investigations were statistically analysed and presented under the following heads:

I. Selection efficiency linked with resistance to bacterial wilt

   A. Variability of the base population

   B. Relative efficiency of four selection methods

   C. Selection efficiency and realised genetic gain through trait-wise selection

   D. Evaluation for resistance to bacterial wilt

II. Genetic bases of resistance to bacterial wilt

III. Biochemical bases of resistance to bacterial wilt

IV. Artificial inoculation studies with the Vellanikkara isolate of Pseudomonas solanacearum E.F.Smith.

I. Selection efficiency linked with resistance to bacterial wilt

A. Variability of the base population

Considerable variability was observed in the base population for fruits/plants (cv = 74.53), locules/fruit (cv = 25.30), yield/plant (cv = 278.92), plant height (cv = 27.89), days to flower (cv = 25.06), days to fruit set (cv = 18.65), days to first harvest (cv = 19.85) and fruit weight (32.30) (Table 1). Maximum variability (range) was observed for yield/plant (0.02 to 4.43 kg) followed by fruits/

Table 1. Statistical properties of the base population of CL 32d-0-1-1988

Characters	Range	Mean	Variance (σ^2)	Standard deviation (σ)	Coefficient of variation
Fruits/plant	1 - 97	19.87 ± 0.34	219.36	14.81	74.53
Locules/Fruit	2 - 7.5	3.4 ± 0.02	0.74	0.86	25.30
Yield/Plant (kg)	0.020 - 4.430	0.63 ± 0.04	3.09	1.76	278.92
Plant height (cm)	16.5 - 121.5	48.39 ± 0.31	182.23	13.49	27.89
Days to flower	52 - 99	77.15 ± 0.50	468.72	21.65	28.06
Days to fruit set	60 - 126	88.36 ± 0.38	271.66	16.48	18.65
Days to first harvest	90 - 144	115.69 ± 0.53	527.42	22.97	19.85
Fruit weight (g)	5.2 - 75.0	29.90 ± 0.22	93.30	9.66	32.30

plant (1 to 97), fruit weight (5.2 to 75 g), days to flower (52 to 99), plant height (16.5 to 121.5 cm) days to first harvest (90 to 144) and days to fruit set (60 to 126).

B. Relative efficiency of four selection methods

1. Relative efficiency measured in terms of per se performance

The general analysis of variance indicated that the selection methods were significantly different to effect changes in fruits/plant, locules/fruit, yield/plant, and fruit weight in three consecutive generations, days to first harvest in first and second generations, plant height in first and third generations, days to flower in first generation and days to fruit set in second and third generations (Table 2).

a) Fruits/plant

The mean fruit number obtained through mass, pureline and single seed descent (SSD) selections were not significantly different in the first and third generations. The three methods differed significantly from bulk selection. Mass selection was significantly different from other methods in the second generation. Pureline and SSD selection methods were similar. In the third generation maximum fruits/plant (52.53) was observed in SSD followed by mass selection (48.17) (Table 3).

b) Locules/fruit

Locules/fruit in mass, pureline, and SSD selections were significantly different from bulk in all the three

Table 2. General analysis of variance for different characters

Sources of variation	df	Mean squares					
		Fruits/plant			Locules/fruit		
		Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
Replications	4	358.19	608.62	13257.20	0.93	0.86	0.46
Selection methods	3	4834.77**	2837.35**	13764.02**	5.12**	6.77**	4.67**
Error (a)	12	463.65	274.91	1032.62	0.24	0.30	0.95
CD (P = 0.05)		7.66	5.90	11.43	0.18	0.19	0.35
Traits	14	209.19	115.86	345.33	0.54	0.43	0.56*
Methods x Traits	28	132.77	115.23	355.07	0.49	0.23	0.36
Error (b)	168	177.31	85.10	289.29	0.48	0.44	0.30
CD (P = 0.05)							
Traits		9.53	6.60	12.17	0.49	0.47	0.39
Methods x Traits		16.51	11.44	21.08	0.86	0.82	0.58
Traits under different methods		-	-	-	-	-	-

(Contd.)

Gen. - Generation
* Significant at P = 0.05
** Significant at P = 0.01

Sources of variation	df	Mean squares					
		Yield/plant			Plant height		
		Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
Replications	4	0.45	0.45	24.61	1664.10	6557.04	9284.06
Selection methods	3	5.39**	1.92**	15.02*	6026.54**	2684.27	2302.23*
Error (a)	12	0.57	0.19	1.70	1122.85	779.96	599.99
C.D. (P = 0.05)		0.268	0.156	0.46	11.93	9.94	8.72
Traits	14	0.18	5.99	0.49	109.98	310.22	271.94
Methods x Traits	28	0.14	5.08	0.54	237.96	317.72*	290.28
Error (b)	168	0.22	5.59	0.37	282.75	188.92	247.13
C.D. (P = 0.05)							
Traits		0.33	0.17	0.44	12.03	9.84	11.25
Methods x Traits		0.58	0.30	0.75	20.84	19.35	19.48
Traits under different methods		-	-	-	-	19.51	-

(Contd.)

Sources of variation	df	Mean squares					
		Days to flower			Days to fruit set		
		Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
Replications	4	24.51	706.65	86.19	0.44	232.47	25.09
Selection methods	3	78.73**	28.63	40.28	8.60	430.14**	48.47**
Error (a)	12	12.08	17.32	14.28	2.72	40.34	2.37
CD (P = 0.05)		1.24	1.50	1.34	0.59	2.26	0.55
Traits	14	12.97**	0.59	2.66	1.03	168.15**	2.55
Methods x Traits	28	7.82**	0.80	1.69	1.11	196.67**	3.21*
Error (b)	168	3.9	0.53	2.09	0.92	7.51	1.79
CD (P = 0.05)							
Traits		1.44	0.52	1.03	0.69	1.96	0.96
Methods x Traits		2.44	0.90	1.79	1.19	3.67	1.66
Traits under different methods		2.76	-	-	-	3.68	1.71

(Contd.)

Table 2. (Contd.)

Sources of variation	df	Mean squares					
		Days to first harvest			Fruit weight		
		Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
Replications	4	836.94	1350.1	476.93	1.85	1.00	5.38
Selection methods	3	1425.68**	3017.53**	202.62	4731.10**	2184.2**	3064.24**
Error (a)	12	138.27	92.18	69.39	0.80	1.53	0.92
CD (P = 0.05)		4.18	3.42	2.96	0.32	0.44	0.34
Traits	14	61.21	106.89**	23.29*	304.39**	511.20**	444.35**
Methods x Traits	28	61.07	103.86**	15.48	401.32**	503.90**	266.48**
Error (b)	168	56.40	41.89	11.12	0.42	0.74	10.19
CD (P = 0.05)							
Traits		5.37	4.63	2.39	0.461	0.62	2.28
Methods x Traits		9.31	8.02	4.13	0.798	1.07	3.96
Traits under different methods		-	8.23	-	0.87	1.11	4.07

generations. Mass, pureline and SSD did not differ significantly from each other except in second generation. In the second generation purelines had a fewer locule number (3.6) compared to mass and SSD (3.8 each). The highest locules/fruit attained in the third generation was 3.9 through mass and SSD and 3.8 through pureline selections.

c) Yield/plant

The maximum mean fruit yield/plant recorded for SSD (1.82 kg), pureline (1.52 kg) and mass (1.50 kg) was in the third generation. The mean yield/plant in mass, pureline and SSD selections differed significantly from bulk in the first and third generations.

d) Plant height

The maximum plant height was recorded for pureline selections in the first and third generations (74.9 and 76.6 cm respectively) followed by mass (64.3 and 75.7 cm respectively). Plants evolved through SSD had the lowest plant height (58.0, 60.9 and 74.73 cm) in all generations. Bulks did not differ from other selection methods in second generation and was similar to mass and SSD in the first generation. The mass selections were on par with purelines in the first generation and SSD in the third generation.

e) Days to flower

Under mass selection, plants were earlier to flower (60.3 days) followed by SSD (61.4 days) in the first generation.

This was significantly different from pureline and bulk. In the second generation the selection methods did not differ significantly. In the third generation, plants evolved through S D were the earliest to flower (53 days) followed by those developed through pureline (53.97) and mass (54.6). No significant difference was observed between SSD and pureline and pureline and mass.

f) Days to fruit set

The earliest to first fruit set was the progenies evolved through mass selection (70.67 days) in the first generation. In the second generation, pureline selections took 60.87 days and in the third generation SSD selections took 69.72 days. Mass, pureline and bulk selections in the first generation, mass and bulk in the second generation and mass and bulk and pure line and bulk in the third generation were on par with each other.

g) Days to first harvest

Days to first harvest were 102 days for mass and SSD selections in the first generation. It took 95 days and 97 days for all selections in the second and third generations respectively. Mass, SSD and bulk selections of the first generation, mass and pureline, pureline and bulk of the second generation, mass and pureline, and pureline, SSD and bulk of the third generation were similar.

Table 3. Mean performance of various characters under different selection methods

Characters	Gen.I				Gen.II				Gen.III			
	M	PL	S.D	B	M	PL	S.D	B	M	PL	S.D	B
Fruits/plant	26.40	23.80	21.30	8.30	18.13	5.70	11.60	4.9	48.17	41.15	52.53	21.86
CD (P = 0.05)				7.66				5.90				11.43
Locules/fruit	3.90	3.90	3.90	3.40	3.80	3.60	3.80	3.2	3.90	3.80	3.90	3.40
CD (P = 0.05)				0.18				0.19				0.35
Yield/plant (kg)	0.775	0.771	0.663	0.211	0.489	0.187	0.303	0.119	1.499	1.516	1.816	0.764
CD (P = 0.05)				0.268				0.156				0.460
Plant height (cm)	64.3	74.9	58.0	54.4	71.3	67.7	60.9	58.3	75.7	76.6	74.73	64.8
CD (P = 0.05)				11.93				9.94				8.72
Days to flower	60.3	64.4	61.4	62.00	51.5	51.5	51.4	52.7	54.6	53.97	53.01	55.80
CD (P = 0.05)				1.24				1.50				1.34
Days to fruit set	70.67	71.48	71.04	70.9	64.75	60.87	63.73	66.6	71.48	70.88	6 .72	71.10
CD (P = 0.05)				0.59				2.26				0.55
Days to first harvest	101.6	110.64	101.6	102.6	95.52	103.11	94.89	105.8	99.83	99.12	96.71	97.8
CD (P = 0.05)				4.18				3.42				2.96
Fruit weight (g)	36.3	44.4	47.3	29.8	36.6	35.7	33.5	26.5	43.9	50.8	48.3	36.5
CD (P = 0.05)				0.32				0.44				0.34

Gen. = Generation
PL = Pureline selection
B = Bulk
M = Mass selection
S.S = Single seed descent

h) Fruit weight

Mean fruit weight was the maximum for S3 selections in first generation (47.3 g) followed by pureline (44.4 g) and mass (36.3 g) which were significantly different from bulk (2[illegible].8 g). In the second generation also S3 selections recorded the maximum fruit weight (38.5 g) followed by mass (36.6 g) and pureline (35.7 g) which were also significantly different from bulk (2[illegible].5 g). But in the third generation pureline selection had the maximum mean fruit weight (50.8 g) followed by S3 (48.3 g) and mass (43.9 g) which were significantly different from bulk (30.5 g) (Plate-III). The three methods of selections - mass, pureline and S3 differed significantly from each other.

2. Relative efficiency measured in terms of positive shift in genetic parameters

The efficiency of selection methods was also assessed in terms of positive shift in the genetic parameters of progenies (Tables 4a and 4b).

a) Heritability estimates and genetic advance

i) Fruits/plant

Heritability value ($h^2_{(b)}$) for fruits/plant was more for bulk (0.13) in the third generation followed by S3 (0.12), mass and pureline (0.09 each). The maximum value for genetic advance as per cent of mean was recorded under mass selection

in the second generation (198.64). The genetic advance as per cent of mean for pureline, SSD and bulk in the third generation were 152.38, 129.90 and 325.56 respectively.

ii) Locules/fruit

The maximum heritability was recorded for SSD selections (0.20) in the third generation followed by bulk (0.09) and mass (0.06). Genetic advance as per cent of mean was also high for SSD (2.65) compared to other methods in the third generation. Mass selection in the first generation and pureline and bulk in the third generations recorded higher values (2.40, 0.26 and 1.30 respectively) than in other generations.

iii) Yield/plant

Heritability estimate was the highest for pureline selection (0.67) followed by SSD (0.16) and bulk (0.11) in the third generation. Genetic advance as per cent of mean was more in bulk (14.26) followed by SSD (8.21) and pureline (4.38) in the third generation. The mass selection had negative value in the third generation.

iv) Fruit weight

Heritability was high for bulk selection (0.26) in the third generation compared to other methods, followed by pureline in the second and third generations (0.23 and 0.07 respectively). Genetic advance as per cent of mean was the

highest in the second generation for all selection methods except bulk which had a negative value. Pureline selection recorded the maximum value (192.48) followed by SBT (24.75) and mass (15.02). In the third generation bulk had the maximum value of genetic advance as per cent of mean (97.61) followed by pureline (56.36), mass (10.61) and SSD (5.85).

v) Days to flower

Heritability values were higher in the first generation for mass (0.22), pureline (0.23) and SSD (0.22). In the second and third generations pureline and SSD had lower values and mass had negative values. In the third generation, bulk had a higher value (0.23). Genetic advance as per cent of mean was the highest in the first generation for all selections except bulk. Mass selection had negative value in the second and third generations and pureline had a low value (0.21) in the second generation and negative value in the third generation. In the case of SSD it had low values (0.11 and 0.23 respectively) in both second and third generations and bulk had negative values in the first and second generations (-0.86 and -7.29 respectively).

vi) Days to fruit set

Heritability estimates for mass, pureline and SSD were higher in the second generation compared to other generations and for bulk it had a negative value in all generations. Genetic advance as per cent of mean was also high in the second

Table 4a. Relative efficiency of selection methods in improving genetic parameters of different characters

Characters	Generations	Mass selection			Pureline selection		
		GCV	PCV	GA	GCV	PCV	GA
Fruits/plant	I	3.80	218.45	7.83	-19.49	137.47	-40.15
	II	17.49	155.56	36.02	- 2.82	39.24	- 5.79
	III	-26.05	277.99	-53.67	30.44	352.55	62.70
Locules/fruit	I	0.05	0.39	0.09	0.004	0.41	0.01
	II	-0.05	0.41	-0.11	-0.02	0.45	-0.03
	III	0.02	0.27	0.04	0.004	0.43	0.01
Yield/plant	I	0.0002	0.21	0.0004	-0.03	0.22	-0.07
	II	-0.0002	0.09	-0.001	-0.002	0.03	-0.004
	III	-0.01	0.27	-0.03	0.32	0.48	0.66
Plant height	I	-7.49	271.04	-15.42	-17.13	338.02	-35.29
	II	5.20	218.95	10.71	63.23	274.77	130.27
	III	3.90	189.02	8.03	20.96	281.85	43.18
Days to flower	I	1.16	5.17	2.38	1.05	4.68	2.17
	II	-0.004	0.69	-0.01	0.53	0.58	0.11
	III	0.11	2.26	-0.22	-0.001	2.23	-0.003
Days to fruit set	I	0.03	0.88	0.06	-0.001	1.26	-0.002
	II	31.34	44.47	64.55	35.14	36.47	72.39
	III	0.34	1.82	0.69	0.19	2.36	0.40
Days to first harvest	I	0.32	45.90	0.65	2.40	78.02	4.95
	II	0.51	55.45	11.36	32.57	58.97	67.09
	III	0.01	12.29	0.01	1.26	14.99	2.59
Fruit weight	I	28.55	28.59	58.82	84.70	84.85	174.47
	II	53.64	54.45	110.50	80.00	80.57	64.82
	III	39.33	39.65	81.02	102.66	103.25	211.48

(Cont..)

Table 4a. (Contd.)

Characters	Generations	SPD selection			Bulk selection		
		GCV	PCV	GA	GCV	PCV	GA
Fruits/plant	I	-9.56	191.51	-19.70	3.24	18.96	6.68
	II	3.50	78.00	7.28	-0.33	8.43	-0.69
	III	33.12	274.87	68.25	34.56	266.64	71.18
Locules/fruit	I	-0.03	0.45	-0.06	-0.01	0.39	-0.03
	II	-0.01	0.36	-0.02	-0.01	0.14	-0.01
	III	0.05	0.25	0.10	0.02	0.24	-0.04
Yield/plant	I	-0.01	0.18	-0.01	0.001	0.01	0.002
	II	0.001	0.04	0.003	-0.0001	0.01	-0.0002
	III	0.07	0.45	0.15	0.05	0.47	0.11
Plant height	I	-31.82	234.63	-65.54	26.56	113.99	54.71
	II	7.34	148.82	15.11	-15.82	114.60	-32.59
	III	2.12	197.15	4.37	30.69	118.22	63.22
Days to flower	I	1.17	5.25	2.42	-0.27	1.868	-0.55
	II	0.08	0.44	0.16	-1.86	11.64	-0.38
	III	0.06	1.75	0.12	1.04	4.00	2.14
Days to fruit set	I	0.09	0.75	0.18	-0.13	1.04	-0.26
	II	41.31	49.38	85.10	-2.45	23.95	-5.05
	III	0.20	1.90	0.40	-0.31	2.31	-0.63
Days to first harvest	I	-0.37	47.78	-0.76	-0.33	22.58	-0.27
	II	-0.30	49.04	-0.61	-4.48	24.43	-9.24
	III	2.98	9.98	6.15	-2.95	42.81	-6.07
Fruit weight	I	107.90	108.98	222.28	0.52	1.06	1.06
	II	169.71	170.55	349.59	0.48	2.10	0.98
	III	42.37	43.42	87.28	0.62	2.06	1.28

Table 4b. Relative efficiency of selection methods in improving genetic parameters of vegetative and economic characters

Characters	Gene-rations	Mass selection				Pureline selection			
		Range	Mean	h^2(b)	GA (%)	Range	Mean	h^2(b)	GA (%)
Fruits/plant	I	15.4 - 38.2	26.40	0.02	29.85	17.0 - 30.0	23.80	-0.14	-169.09
	II	8.0 - 29.6	18.13	0.11	198.64	1.4 - 10.4	5.70	-0.07	-101.39
	III	36.2 - 57.6	48.17	0.09	-114.44	27.6 - 56.4	41.15	0.09	152.38
Locules/fruit	I	3.2 - 4.5	3.9	0.12	2.41	3.3 - 4.7	3.9	0.01	0.23
	II	3.6 - 4.4	3.8	-0.13	-2.77	3.0 - 3.9	3.6	-0.03	-0.90
	III	3.4 - 4.2	3.9	0.06	0.92	3.2 - 4.3	3.8	0.01	0.26
Yield/plant (kg)	I	0.430-1.025	0.775	0.001	0.05	0.539-0.959	0.771	-0.15	-8.98
	II	0.301-0.688	0.489	-0.01	-0.21	0.100-0.470	0.187	-0.06	-2.27
	III	1.207-1.920	1.499	-0.05	-0.02	0.891-2.216	1.516	0.67	4.38
Plant height (cm)	I	50.3 - 73.8	64.3	-0.03	-2.40	62.00 - 87.0	74.9	-0.05	-47.14
	II	54.8 - 82.7	71.3	0.02	15.02	49.0 - 87.5	67.7	0.23	192.48
	III	66.8 - 86.4	75.7	0.02	10.61	61.9 - 92.6	76.6	0.07	56.36
Days to flower	I	58.0 - 62.6	60.3	0.22	3.95	59.2 - 64.2	64.4	0.23	3.53
	II	50.8 - 52.0	51.5	-0.01	-0.15	50.8 - 52.4	51.5	0.09	0.21
	III	53.8 - 55.8	54.6	-0.05	-0.39	52.8 - 55.4	53.97	-0.001	-0.01
Days to fruit set	I	70.0 - 71.21	70.67	0.03	0.09	70.8 - 72.0	71.48	-0.001	-0.002
	II	58.0 - 69.0	64.75	0.70	99.69	58.0 - 73.0	60.87	0.96	118.94
	III	69.0 - 72.8	71.48	0.18	0.97	69.0 - 72.0	70.88	0.08	0.56
Days to first harvest	I	98.4 -109.2	101.6	0.01	0.64	103.2 -116.8	110.64	0.03	4.47
	II	90.4 - 99.8	95.52	0.10	12.27	94.4 -112.0	103.11	0.55	65.08
	III	97.4 -102.6	99.83	0.0004	0.01	94.2 -101.8	99.12	0.08	2.61
Fruit weight (g)	I	28.8 - 49.3	36.3	0.99	162.21	29.8 - 63.1	44.4	0.99	392.71
	II	25.1 - 51.2	36.6	0.98	301.51	24.0 - 50.0	35.7	0.99	461.58
	III	33.7 - 55.6	43.9	0.99	184.53	33.2 - 72.2	50.8	0.99	417.29

(Contd.)

Table 4b. (Contd.)

Characters	Generations	SSD selection				Bulk selection			
		Range	Mean	H^2 (b)	GA (%)	Range	Mean	h^2 (b)	GA (%)
Fruits/plant	I	12.8 - 34.2	21.30	-0.05	-89.13	5.0 - 12.2	8.3	0.17	80.57
	II	6.2 - 19.2	11.60	0.05	62.77	3.2 - 7.2	4.9	-0.04	-14.15
	III	37.6 - 65.0	52.53	0.12	129.90	8.2 - 41.8	21.86	0.13	325.56
Locules/fruit	I	3.5 - 4.4	3.9	-0.06	-1.44	3.1 - 3.8	3.4	-0.04	-0.85
	II	3.4 - 4.0	3.8	-0.03	-0.62	3.0 - 3.4	3.2	-0.05	0.44
	III	3.5 - 4.4	3.9	0.20	2.65	3.0 - 3.8	3.4	0.09	1.30
Yield/plant (kg)	I	0.398-1.125	0.663	-0.03	-1.53	0.131-0.298	0.211	0.09	1.03
	II	0.175-0.455	0.303	0.03	0.87	0.082-0.204	0.119	-0.02	-0.19
	III	1.178-2.472	1.816	0.16	8.21	0.214-1.530	0.764	0.11	14.28
Plant height (cm)	I	52.6 - 62.9	58.0	-0.14	-114.17	42.6 - 62.6	54.4	0.23	100.52
	II	51.3 - 73.4	60.9	0.05	24.75	52.5 - 62.8	58.3	-0.14	-55.91
	III	63.5 - 87.0	74.73	0.01	5.85	53.8 - 78.8	64.8	0.26	97.61
Days to flower	I	58.0 - 64.0	61.4	0.22	3.93	62.0 - 63.2	62.8	-0.14	-0.88
	II	50.8 - 52.0	51.4	0.17	0.31	50.4 - 54.4	52.7	0.16	-7.29
	III	51.4 - 54.0	53.01	0.03	0.23	52.4 - 57.0	55.80	0.26	3.94
Days to fruit set	I	70.4 - 71.6	71.04	0.12	0.25	70.4 - 71.2	70.90	-0.12	-0.36
	II	58.00-71.00	63.73	0.84	133.52	64.0 - 69.0	66.60	-0.10	-7.59
	III	68.8 - 70.6	69.72	0.10	0.58	70.4 - 71.2	71.10	0.13	-0.89
Days to first harvest	I	99.0 -107.2	101.6	0.01	0.74	100.4 -106.2	102.60	-0.01	-0.26
	II	91.0 -100.6	94.89	-0.01	-0.64	102.8 -108.4	105.80	-0.18	-8.73
	III	93.0 -101.4	96.71	0.30	6.35	97.4 -100.2	97.80	-0.07	-6.04
Fruit weight (g)	I	30.0 - 65.0	47.3	0.99	470.86	26.8 - 33.0	29.8	0.48	3.57
	II	26.7 - 67.5	35.7	0.99	906.78	24.5 - 30.0	26.5	0.23	3.72
	III	37.3 - 62.4	48.3	0.98	180.75	31.5 - 41.5	36.5	0.30	3.54

generation for mass selection (99.69), pureline (118.94) and SSD selection (133.52). The bulk had negative values in all the three generations.

vii) Days to first harvest

Heritability values for mass and pureline selection were more in the second generation (0.10 and 0.55 respectively) compared to other generations. Heritability value for SSD selections was higher in third generation (0.30) compared to other generations. The bulk selections recorded negative values in all the three generations. Genetic advance as per cent of mean was also higher in the second generation for mass (12.27) and pureline (65.08). The maximum value (6.35) was shown in the third generation for SSD.

viii) Fruit weight

Higher heritability estimates were obtained for all methods of selection in all the three generations. It was inconsistent for bulk in all the three generations. Genetic advance as per cent of mean was higher in the second generation for all the selection methods. SSD method recorded the highest value of genetic advance as per cent of mean (906.78) followed by pureline (461.58), mass (301.51) and bulk (3.72). Pureline had the highest value (417.29) followed by mass (184.53), SSD (190.75) and bulk (3.54) in the third generation.

b) Realised genetic gain

The realised genetic gain under mass, pureline and SSD selections compared to bulk population were estimated for different characters (Table 5).

i) Fruits/plant

The realised genetic gain for fruits/plant was the highest for SSD selections (30.97) in the third generation and for mass in the first (18.11) and second (13.28) generations.

ii) Locules/fruit

The realised genetic gain under different selection methods were at par in all the three generations except for pureline selections. In the second and third generations pure line selection recorded lower values than other methods of selection.

iii) Yield/plant

The realised genetic gain for yield/plant was the highest for SSD selections (1.05) in the third generation and for mass in the first (0.56) and second (0.37) generations.

iv) Plant height

The progenies developed through pureline had higher values in the first and third generations. Mass selections had higher value in the second generation.

Table 5. Realised genetic gain under different selection methods in three consecutive generations

Characters	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
Fruits/plant	18.11	15.11	13.01	13.28	0.85	6.75	26.31	12.29	30.97
CD (P = 0.05)			7.66			5.90			11.43
Locules/fruit	0.5	0.5	0.5	0.6	0.4	0.6	0.5	0.4	0.5
CD (P = 0.05)			0.18			0.19			0.35
Yield/plant (kg)	0.564	0.560	0.452	0.370	0.068	0.184	0.735	0.752	1.052
CD (P = 0.05)			0.268			0.156			0.460
Plant height (cm)	9.9	20.5	3.6	13.00	11.8	2.6	10.90	11.8	9.93
CD (P = 0.05)			11.93			9.94			8.72
Days to flower	-2.5	-1.4	-1.4	-1.2	-1.2	-1.3	-1.2	-1.83	-2.79
CD (P = 0.05)			1.24			1.50			1.34
Days to fruit set	-0.23	0.58	0.14	-1.85	-5.73	-2.87	-0.38	-0.22	-1.38
CD (P = 0.05)			0.59			2.26			0.55
Days to first harvest	-1.00	3.04	-1.00	-13.28	-2.69	-10.91	2.03	1.32	-1.09
CD (P = 0.05)			4.19			3.42			2.96
Fruit weight (g)	6.5	14.6	17.5	10.1	9.2	12.0	7.4	14.3	11.8
CD (P = 0.05)			0.32			0.44			0.34

Gen. = Generation
M = Mass
PL = Pureline
SSD = Single seed descent

v) Days to flower

Earliness in flowering was observed for all the selection methods in all the generations. In the first generation mass selection had the highest gain (-2.25) and in the third generation SSD selections had the highest gain (-2.79). In the second generation there was no significant difference among the selection methods.

vi) Days to fruit set

The realised genetic gain for pureline and SSD selections were negative in the second and third generations but mass selection had positive and negative values in the third and first generations respectively.

vii) Days to first harvest

SSD selections had negative values in all the generations. Mass and pureline selections had negative and positive values in the second and third generations respectively.

viii) Fruit weight

The maximum genetic gain was observed in SSD selections in the first and second generations. Purelines had the highest value in the third generation. The values for SSD selections decreased from first to third generation.

c) Realised heritability

The realised heritability for various characters under mass, pureline and SSD are given in Table 6.

i) Fruits/plant

The maximum realised heritability was obtained under mass selection in all the three generations (0.65, 0.48 and 0.95 respectively) followed by pureline (0.32) in the first generation and SSD in the second (0.14) and third (0.63) generations.

ii) Locules/fruit

The maximum realised heritability was obtained under mass in all generations (0.65, 0.78 and 0.65) followed by SSD in the second (0.36) and third (0.30) generations. Pureline selections and SSD selections had similar values in the first generation.

iii) Yield/plant

Maximum realised heritability was observed under mass selection in all generations (0.54, 0.35 and 0.70) followed by pureline (0.20) in the first and SSD in the third (0.47) generations.

iv) Plant height

The highest value was recorded under pureline selection in the first generation and under mass in the second and third generations, whereas SSD had values lower than 0.5 in all generations.

Table 6. Realised heritability for various vegetative and economic characters under different selection methods

Characters	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
Fruits/plant	0.65	0.32	0.27	0.48	0.02	0.14	0.95	0.40	0.63
Locules/plant	0.65	0.30	0.30	0.78	0.24	0.36	0.65	0.24	0.30
Yield/plant	0.54	0.25	0.20	0.35	0.03	0.08	0.70	0.33	0.47
Plant height	0.61	0.68	0.12	0.30	0.31	0.09	0.67	0.39	0.33
Days to flower	0.58	0.14	0.14	0.28	0.12	0.13	0.28	0.18	0.27
Days to fruit set	0.03	-0.04	-0.01	0.22	0.40	0.20	-0.05	0.02	0.10
Days to first harvest	0.17	-0.69	0.09	2.30	0.23	0.94	-0.35	-0.11	0.09
Fruit weight	1.14	1.18	1.41	1.8	0.74	0.87	1.30	1.15	1.94

v) Days to flower

The realised heritability for days to flower was low under all selection methods in all the three generations except mass selection (0.58) in the first generation.

vi) Days to fruit set

Only a very low realised heritability was recorded under the four methods in all the generations.

vii) Days to first harvest

Of all the three generations, only in the second generation, the realised heritability values were high and positive. In the third generation, mass and pureline had low and negative values. Positive but very low values were obtained for SSD selections.

viii) Fruit weight

SSD selections had high values in the second and third generations (0.97 and 0.94 respectively). Except for pureline selections in the second generation (0.74), all other selections had values greater than one.

C. Selection efficiency and realised genetic gain through traitwise selection

1. Relative efficiency measured in terms of per se performance

The general analysis of variance indicating the effects of traitwise selection on the morphological and economic

characters are presented in Table 2. There was significant difference per se for locules/fruit in the third generation, days to flower in the first generation, days to fruit set in the second generation, days to first harvest in the second and third generations and average fruit weight in all the three generations developed through traitwise selections. The overall mean performance of progenies evolved through traitwise selections are given in Table 7.

a) Locules/fruit

Selections based on the trait combination $T_{1.2.4}$ recorded the highest number of locules/fruit (4.2).

b) Days to flower

Selections based on the trait combination $T_{1.2.3.4}$ resulted in plants with the shortest number of days to flower (59 days), closely followed by T_1. No significant difference was observed among T_1, T_2, T_3, $T_{1.2}$, $T_{1.3}$, $T_{1.4}$, $T_{2.3}$, $T_{2.4}$, $T_{1.2.3}$, $T_{1.3.4}$ and $T_{2.3.4}$.

c) Days to fruit set

Selections based on the trait combination $T_{1.3.4}$, $T_{2.3.4}$ and $T_{1.2.3.4}$ took the shortest number of days (58 days each) in the second generation followed by $T_{2.3}$ (61.67 days).

d) Days to first harvest

The earliest to harvest was recorded in the trait

Table 7. Mean performance of progenies developed through traitwise selection

	Fruits/plant			Locules/fruit			Yield/plant			Plant height		
	G.I	G.II	G.III	G.I	G.II	G.III	G.I	G.II	G.III	G.I	G.II	G.III
T_1	28.27	9.73	45.73	3.6	3.7	3.9	0.831	0.263	1.584	65.80	67.20	75.80
T_2	24.60	12.60	55.60	3.9	3.9	4.0	0.738	0.371	1.907	63.93	70.10	75.23
T_3	19.87	8.60	52.87	3.8	3.5	3.8	0.680	0.251	1.857	66.53	68.10	80.97
T_4	22.73	10.67	39.13	3.9	4.0	3.8	0.757	0.309	1.337	68.97	65.20	71.23
$T_{1.2}$	26.87	9.93	46.06	3.9	3.5	3.8	0.812	0.270	1.559	63.93	73.70	66.57
$T_{1.3}$	23.27	17.60	47.20	4.0	3.7	3.5	0.703	0.419	1.456	64.90	59.83	72.70
$T_{1.4}$	30.00	9.80	48.13	3.6	3.7	3.8	0.858	0.293	1.543	68.37	69.73	78.07
$T_{2.3}$	29.00	16.20	43.87	3.8	4.0	4.0	0.939	0.446	1.755	67.33	64.23	76.63
$T_{2.4}$	21.87	11.73	51.00	4.0	3.6	4.0	0.721	0.298	1.765	62.37	69.13	82.57
$T_{3.4}$	27.60	10.47	44.87	3.9	3.8	3.7	0.816	0.307	1.449	67.93	62.53	71.00
$T_{1.2.3}$	22.47	14.00	53.06	3.9	3.6	3.7	0.765	0.362	1.610	63.67	61.87	80.93
$T_{1.3.4}$	21.33	11.93	40.60	3.8	3.8	3.7	0.613	0.307	1.310	71.07	73.73	75.70
$T_{2.3.4}$	17.33	15.20	51.73	4.2	3.8	4.1	0.510	0.402	1.620	60.93	67.30	73.57
$T_{1.2.4}$	21.27	8.53	46.67	3.6	3.6	4.2	0.606	0.241	1.813	66.70	58.83	74.87
$T_{1.2.3.4}$	20.87	10.27	42.67	4.0	3.8	4.0	0.699	0.355	1.589	64.30	68.63	76.70
CD (P = 0.05)	9.53	6.60	12.17	0.49	0.47	0.39	0.333	0.169	0.430	12.03	9.84	11.25

(Contd.)

G - Generation

Table 7. (Contd.)

	Days to flower			Days to fruit set			Days to 1st harvest			Fruit weight		
	G.I	G.II	G.III	G.I	G.II	G.III	G.I	G.II	G.III	G.I	G.II	G.III
T_1	60.33	51.53	53.07	70.53	66.00	70.07	102.53	96.33	96.27	37.7	34.3	43.3
T_2	60.60	51.47	54.00	71.07	66.00	70.20	105.07	96.13	96.27	43.1	42.9	49.0
T_3	61.73	51.47	53.47	71.47	63.00	70.60	102.73	98.27	98.93	49.0	35.4	50.2
T_4	62.53	51.33	53.67	71.20	63.00	71.00	108.27	94.53	97.87	46.7	32.1	43.1
$T_{1.2}$	60.73	51.80	54.07	70.93	62.33	71.13	103.13	95.33	100.40	39.4	27.8	42.7
$T_{1.3}$	61.27	51.00	53.53	70.87	66.67	70.47	105.07	92.80	98.40	42.5	30.2	42.8
$T_{1.4}$	60.40	51.67	54.13	71.33	62.40	71.13	106.00	96.93	100.47	40.6	35.4	43.7
$T_{2.3}$	60.93	57.27	53.47	70.93	61.67	70.87	103.40	92.93	98.40	52.2	50.0	58.5
$T_{2.4}$	61.53	51.33	53.67	70.93	65.33	70.53	105.87	93.07	97.67	48.5	33.6	46.7
$T_{3.4}$	61.20	51.20	53.93	71.20	62.33	71.00	101.00	98.20	100.00	38.0	40.9	45.3
$T_{1.2.3}$	62.07	51.33	53.93	71.20	64.33	71.13	105.47	98.80	98.27	39.9	40.2	44.0
$T_{1.3.4}$	61.27	51.53	54.27	70.80	58.00	70.93	104.73	99.20	99.13	40.4	33.4	42.3
$T_{2.3.4}$	60.47	51.53	53.80	71.07	58.00	70.00	105.67	99.87	98.60	39.2	36.7	48.8
$T_{1.2.4}$	61.93	51.60	54.73	71.47	66.67	71.07	107.67	99.13	98.60	38.8	37.4	56.5
$T_{1.2.3.4}$	58.67	51.33	54.40	70.80	58.00	70.27	102.20	101.07	99.00	43.4	44.4	55.2
CD (P=0.05)	1.44	0.52	1.03	0.69	1.96	0.96	5.37	4.63	2.39	0.461	0.62	2.28

G. = Generation

combination $T_{1.3}$ and $T_{2.3}$ (93 days each) which were on par with T_1, T_2, T_4, $T_{1.2}$, $T_{1.4}$ and $T_{2.4}$ in the second generation. In the third generation T_1 and T_2 selections resulted in the earliest plant to harvest (96 days) followed by $T_{2.4}$ (98 days) and these were on par with selections based on T_3, T_4, $T_{1.3}$, $T_{2.3}$, $T_{1.2.3}$, $T_{2.3.4}$ and $T_{1.2.4}$.

e) Fruit weight

Selections based on $T_{2.3}$ had the maximum fruit weight in all generations (52.2, 50.0 and 58.5 g respectively). The traitwise selection T_3 (49.0 g) and $T_{2.4}$ (48.5 g) in the first generation and $T_{1.2.3.4}$ (44.4 g) and T_2 (42.9 g) in the second generation and $T_{1.2.4}$ (56.5 g) and $T_{1.2.3.4}$ (55.2 g) in the third generation were superior in performance. No difference was observed among $T_{2.3}$, $T_{1.2.4}$ and $T_{1.2.3.4}$ in the third generation.

2. Interaction effect

An interaction effect between methods of selection and traitwise selection was evident for plant height in the second generation, days to flower in the first generation, days to fruit set in the second and third generations, days to first harvest in the second generation and fruit weight in all the generations (Table 8).

a) Plant height

In the second generation maximum plant height was observed for pureline selection based on $T_{1.3.4}$ (87.5 cm)

followed by mass selection based on $T_{1.2}$ (82.7 cm) and S.D selection based on T_1 (73.4 cm). The dwarfest plants were observed for $T_{1.2.4}$ under S.D selection (51.3 cm) followed by that under mass selection (54.8 cm). Plants were relatively dwarfer under S.D selections.

b) Days to flower

In the first generation, mass selection based on T_1 and T_2 were the earliest to flower 58 and 58.4 days respectively followed by $T_{1.2.3.4}$ (59.8 days) and were on par with each other. Pureline selections based on $T_{1.2.3.4}$ were the earliest to flower (59.2 days) followed by $T_{1.3}$ and $T_{2.3.4}$ (60 and 60.2 days respectively) and these were on par with each other. S.D based on $T_{1.2}$ (58 days), $T_{2.3}$ (60.2 days) and $T_{1.2.3.4}$ (60.4 days) were significantly different from others.

The selections based on traits T_1 and T_2 had the shortest number of days (58.0 and 58.4 respectively) to flower under mass compared to that under pureline and S.D. The trait combination $T_{2.3.4}$ did not differ significantly between mass and pureline and pureline and S.D.

c) Fruit set

In the second generation mass and pureline selections based on T_3, T_4, $T_{3.4}$, $T_{1.3.4}$, $T_{2.3.4}$ and $T_{1.2.3.4}$ recorded the shortest number of days (58 days each) for fruit set. S.D selections based on $T_{2.3}$, $T_{1.3.4}$, $T_{2.3.4}$, $T_{1.2.4}$ and $T_{1.2.3.4}$ also had the same duration for fruit set. In the third

generation under mass, selections based on T_3 and $T_{1.2.3.4}$ were the earliest to fruit set (70 days each) followed by $T_{1.3}$, $T_{2.3.4}$ and $T_{1.2.4}$ (71 days each), which were on par with each other. Selections based on T_1 took 6[illegible] days, followed by T_2, T_3 and $T_{1.3}$ (70 days each), $T_{2.3}$, $T_{3.4}$, $T_{2.3.4}$ and $T_{1.2.3.4}$ (71 days each) under pureline. T_1, T_2, T_3, $T_{1.3}$, $T_{2.3}$, $T_{3.4}$, $T_{2.3.4}$ and $T_{1.2.3.4}$ were on par with each other. Under SSD, selections based on $T_{2.3.4}$ were the earliest to set fruit (6[illegible] days) followed by T_1, T_2 and $T_{2.4}$ and these were on par with each other.

The selections based on $T_{2.4}$ and $T_{2.3}$ under SSD were the earliest (6[illegible] and 70 days respectively) which were significantly different from those under mass and pureline selection methods.

d) Days to first harvest

In the second generation mass selections based on $T_{1.2}$ and $T_{2.4}$ were the earliest to first harvest (86 days each) followed by those based on $T_{2.3}$ and $T_{1.3}$ (8[illegible] days each). Pureline selections based on T_4 and $T_{1.3}$ (9[illegible] days each) followed by T_1 (9[illegible] days) and T_2 (97 days) and SSD selections based on $T_{2.3}$ were the earliest to harvest (8[illegible] days) followed by those based on $T_{2.4}$ (9[illegible] days) and $T_{1.2.3}$ (92 days) and these were not significantly different. Selections based on $T_{1.2}$, $T_{2.3}$, $T_{2.4}$ and $T_{1.2.3}$ took fewer days to harvest under mass and SSD methods.

Table 8. Mean performance of progenies developed through traitwise selection under three selection methods

	Fruits/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	SoD	M	PL	SoD	M	PL	SoD
T_1	33.8	25.2	25.8	14.4	6.8	8.0	43.2	56.4	37.6
T_2	31.8	18.2	23.8	13.2	5.4	19.2	52.2	55.4	50.2
T_3	23.8	22.4	12.8	10.8	8.6	6.4	46.6	49.0	63.0
T_4	29.4	23.0	15.8	14.2	3.0	14.8	36.2	32.6	48.6
$T_{1.2}$	30.0	26.0	24.6	8.0	5.4	16.4	48.2	36.0	54.0
$T_{1.3}$	17.0	28.0	24.8	29.6	5.6	17.6	52.2	27.6	61.8
$T_{1.4}$	38.2	24.4	27.4	17.6	5.2	6.6	49.4	36.0	59.0
$T_{2.3}$	31.6	21.2	34.2	28.2	10.4	10.0	41.6	34.4	55.6
$T_{2.4}$	15.4	25.6	24.6	22.8	3.0	9.4	57.6	33.6	61.8
$T_{3.4}$	30.8	30.0	22.0	19.4	5.8	6.2	46.4	45.0	43.2
$T_{1.2.3}$	28.6	25.6	13.2	24.0	1.4	16.6	50.4	43.8	65.0
$T_{1.3.4}$	24.2	25.2	14.6	17.2	7.8	10.8	44.4	36.0	41.4
$T_{2.3.4}$	15.8	17.0	19.2	26.2	8.4	11.0	53.2	54.4	47.6
$T_{1.2.4}$	24.4	21.0	18.4	10.4	4.0	11.2	43.6	38.0	48.4
$T_{1.2.3.4}$	20.8	23.4	18.4	16.0	5.0	9.8	57.2	29.0	41.8
CD (P = 0.05)									
Methods x Traits			16.51			11.44			21.08
Traits under different methods			-			-			-

(Contd.)

Table 8. (Contd.)

	Locules/fruit								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	3.2	3.7	3.7	3.8	3.4	3.8	4.2	3.6	4.0
T_2	4.0	3.9	3.9	3.8	3.8	3.9	4.0	3.9	4.0
T_3	3.8	3.7	4.0	3.6	3.4	3.4	3.8	3.7	3.9
T_4	3.9	3.9	3.8	4.4	3.7	3.9	4.0	3.8	3.8
$T_{1.2}$	4.0	3.9	3.8	3.8	3.0	3.6	3.4	3.9	4.0
$T_{1.3}$	4.0	4.1	3.0	3.6	3.7	3.8	3.4	3.6	3.5
$T_{1.4}$	3.8	3.3	3.6	3.9	3.7	3.7	4.2	3.8	3.4
$T_{2.3}$	4.2	3.6	3.7	4.0	3.9	4.2	3.9	3.9	4.3
$T_{2.4}$	4.0	3.8	4.4	3.7	3.5	3.5	4.0	4.3	3.7
$T_{3.4}$	4.5	3.9	3.6	3.9	3.4	4.0	4.2	3.2	3.8
$T_{1.2.3}$	3.8	3.9	3.9	3.6	3.0	4.0	4.1	3.4	3.5
$T_{1.3.4}$	4.1	4.0	3.5	3.8	3.9	3.6	3.8	3.6	3.7
$T_{2.3.4}$	4.3	4.0	4.4	3.8	3.6	3.9	4.0	3.8	4.4
$T_{1.2.4}$	3.5	4.0	3.8	3.8	3.7	3.4	4.1	4.2	4.3
$T_{1.2.3.4}$	3.4	4.7	3.9	3.8	3.7	4.0	4.0	4.2	3.8
CD (P = 0.05)									
Methods x Traits			0.86			0.82			0.68
Traits under different methods			-			-			-

(Contd.)

Table 8. (Contd.)

	Yield/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	0.914	0.959	0.611	0.435	0.174	0.175	1.597	1.738	1.416
T_2	0.883	0.595	0.736	0.491	0.181	0.441	1.920	1.758	2.042
T_3	0.876	0.663	0.501	0.312	0.242	0.200	1.776	1.850	1.944
T_4	0.981	0.718	0.571	0.457	0.100	0.369	1.368	1.156	1.488
$T_{1.2}$	0.944	0.768	0.724	0.247	0.164	0.399	1.360	1.372	1.946
$T_{1.3}$	0.478	0.852	0.778	0.634	0.168	0.455	1.252	0.891	2.226
$T_{1.4}$	1.025	0.705	0.844	0.488	0.184	0.207	1.288	1.340	2.002
$T_{2.3}$	0.864	0.827	1.125	0.688	0.318	0.332	1.438	1.376	2.450
$T_{2.4}$	0.463	0.935	0.764	0.584	0.980	0.212	1.570	1.254	2.472
$T_{3.4}$	0.890	0.887	0.671	0.540	0.192	0.188	1.388	1.336	1.622
$T_{1.2.3}$	0.959	0.937	0.398	0.650	0.470	0.389	1.572	1.462	1.796
$T_{1.3.4}$	0.630	0.763	0.453	0.384	0.274	0.262	1.207	1.546	1.178
$T_{2.3.4}$	0.430	0.539	0.562	0.604	0.245	0.357	1.410	2.048	1.404
$T_{1.2.4}$	0.641	0.621	0.555	0.301	0.154	0.268	1.576	2.216	1.648
$T_{1.2.3.4}$	0.653	0.795	0.650	0.512	0.257	0.297	1.760	1.396	1.608
CD (P = 0.05)									
Methods x Traits			0.576			0.293			0.750
Traits under different methods			-			-			-

(Contd.)

Table 8. (Contd.)

	Plant height								
	Gen.I			Gen.II			Gen.III		
	M	PL	S D	M	PL	S D	M	PL	SSD
T_1	72.9	67.9	52.6	79.2	49.0	73.4	78.5	71.9	77.0
T_2	68.3	70.1	53.4	75.5	68.5	66.3	68.7	68.2	82.8
T_3	58.8	83.2	56.6	70.2	71.0	63.1	86.4	88.4	68.1
T_4	69.6	71.7	57.6	66.1	64.3	65.2	67.9	68.6	77.2
$T_{1.2}$	78.8	62.0	56.0	82.7	77.6	60.8	68.7	73.4	73.8
$T_{1.3}$	59.6	72.2	62.9	71.4	53.0	55.1	82.0	61.9	74.2
$T_{1.4}$	71.5	72.6	61.0	73.5	73.5	57.1	78.4	77.2	78.6
$T_{2.3}$	65.2	68.5	68.3	71.8	61.1	58.8	79.0	70.6	80.3
$T_{2.4}$	56.1	74.8	56.2	67.4	71.9	66.1	78.9	81.6	87.0
$T_{3.4}$	68.1	78.4	57.3	68.7	65.8	53.1	75.3	74.2	63.5
$T_{1.2.3}$	63.3	67.4	60.3	74.3	54.2	57.1	83.0	82.8	77.0
$T_{1.3.4}$	68.2	87.0	58.0	71.6	87.5	62.1	81.0	72.3	73.8
$T_{2.3.4}$	50.3	72.1	60.4	74.0	69.3	58.6	68.4	82.6	69.7
$T_{1.2.4}$	61.3	83.5	55.3	54.8	70.4	51.3	66.8	92.6	65.2
$T_{1.2.3.4}$	56.0	83.5	53.4	63.0	78.1	64.8	72.6	84.9	72.6
CD (P = 0.05)									
Methods x traits			20.84			19.35			19.48
Traits under different methods			-			19.51			-

(Contd.)

Table 8. (Contd.)

	Days to flower								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SST
T_1	58.0	62.2	60.8	51.0	51.6	52.0	54.4	53.4	51.4
T_2	58.4	61.8	61.6	51.2	51.2	52.0	55.0	54.0	53.0
T_3	60.0	64.2	61.0	51.0	51.6	51.6	53.8	52.8	53.8
T_4	60.6	63.0	64.0	51.8	50.8	51.4	53.8	54.0	53.2
$T_{1.2}$	61.6	60.4	60.2	51.6	52.4	51.4	54.4	55.4	52.2
$T_{1.3}$	61.4	60.0	52.4	50.8	51.2	51.0	54.2	53.4	53.0
$T_{1.4}$	59.0	61.2	61.0	51.8	51.6	51.6	54.8	54.4	53.2
$T_{2.3}$	61.8	60.6	60.4	51.4	51.4	51.0	54.0	54.0	52.2
$T_{2.4}$	60.8	62.4	61.4	52.0	51.2	50.8	54.2	53.6	53.2
$T_{3.4}$	59.8	60.8	63.0	51.0	51.4	51.8	54.8	54.0	53.0
$T_{1.2.3}$	62.6	60.8	62.8	51.4	51.4	51.2	54.8	53.6	53.4
$T_{1.3.4}$	60.6	62.2	61.0	51.6	51.4	51.6	54.8	54.0	54.0
$T_{2.3.4}$	59.0	60.2	62.2	52.0	51.8	50.8	55.2	53.6	52.6
$T_{1.2.4}$	61.6	62.6	61.6	51.4	52.0	51.4	55.6	55.2	53.4
$T_{1.2.3.4}$	58.8	59.2	58.0	51.6	51.4	51.0	55.8	54.2	53.2
CD (P = 0.05)									
Methods x Traits			2.44			0.90			1.79
Traits under different methods			2.76			-			-

(Contd.)

Table 8. (Contd.)

	Days to fruit set								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	70.0	71.2	70.4	71.0	58.0	6[illegible].0	72.4	6[illegible].0	68.8
T_2	70.4	71.6	71.6	67.0	71.0	6[illegible].0	71.4	70.2	69.0
T_3	71.2	72.0	71.2	58.0	58.0	6[illegible].0	72.4	70.2	6[illegible].2
T_4	70.4	71.6	71.6	58.0	58.0	69.0	70.4	72.0	70.6
$T_{1.2}$	70.4	71.2	71.2	71.0	58.0	58.0	72.8	71.4	69.2
$T_{1.3}$	70.8	70.2	71.6	69.0	73.0	58.0	70.6	70.2	70.6
$T_{1.4}$	71.2	71.6	71.2	71.2	58.0	58.0	71.4	71.4	70.6
$T_{2.3}$	70.8	71.6	70.4	69.0	58.0	59.0	72.0	70.6	70.0
$T_{2.4}$	70.0	71.6	71.2	67.0	58.0	71.0	71.4	71.4	68.8
$T_{3.4}$	70.8	72.0	70.8	58.0	58.0	71.0	72.0	70.6	70.4
$T_{1.2.3}$	71.2	71.2	71.2	6[illegible].0	58.0	66.0	72.2	71.2	70.0
$T_{1.3.4}$	70.4	71.6	70.4	58.0	58.[illegible]	58.0	71.4	71.4	70.0
$T_{2.3.4}$	70.8	72.0	70.4	58.0	58.[illegible]	58.0	70.6	70.8	68.6
$T_{1.2.4}$	71.2	72.0	71.2	6[illegible].0	73.0	58.0	70.8	72.0	70.4
$T_{1.2.3.4}$	70.4	70.[illegible]	71.2	58.0	59.[illegible]	58.0	70.4	70.8	6[illegible].6
CD (P = 0.05)									
Methods x Traits			1.19			3.67			1.66
Traits under different methods			-			3.68			1.71

(Contd.)

Table 8. (Contd.)

	Days to first harvest								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	100.6	107.2	99.8	96.8	95.6	96.6	100.4	94.2	94.2
T_2	101.0	113.4	100.8	92.0	96.8	99.6	100.0	95.8	93.0
T_3	99.8	103.2	106.2	95.8	93.6	96.4	101.6	98.	98.2
T_4	101.2	116.4	107.2	93.0	94.4	96.6	97.2	99.2	97.2
$T_{1.2}$	98.8	111.6	99.0	86.0	106.6	93.4	100.8	101.8	99.6
$T_{1.3}$	106.0	106.0	103.6	89.0	94.4	95.0	97.2	101.0	97.0
$T_{1.4}$	104.0	112.4	101.6	90.4	106.8	93.6	100.6	99.4	101.4
$T_{2.3}$	98.4	114.6	97.2	86.6	101.2	89.0	100.0	100.0	95.2
$T_{2.4}$	98.4	116.8	102.4	86.0	102.2	91.0	97.4	100.8	94.8
$T_{3.4}$	99.0	107.4	97.4	94.8	105.0	94.8	102.6	98.6	98.8
$T_{1.2.3}$	109.2	106.4	100.8	92.6	112.0	91.8	100.4	98.2	96.2
$T_{1.3.4}$	102.4	112.2	99.6	93.8	111.0	92.8	99.8	100.0	97.6
$T_{2.3.4}$	101.8	112.8	102.4	94.4	104.6	100.6	100.0	100.4	95.4
$T_{1.2.4}$	104.4	112.8	105.8	95.4	105.4	96.6	98.8	100.4	96.6
$T_{1.2.3.4}$	100.0	106.4	100.2	95.6	112.0	95.6	101.6	99.0	96.4
CD (P = 0.05)									
Methods x Traits			9.31			8.02			4.13
Traits under different methods			-			8.23			-

(Contd.)

Table 8. (Contd.)

	Fruit weight								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	34.7	48.6	30.0	50.0	24.0	28.8	40.5	33.2	48.3
T_2	28.9	45.5	55.0	51.2	30.0	47.5	48.6	50.5	47.9
T_3	49.3	35.7	62.0	32.8	46.0	27.5	50.3	54.8	45.6
T_4	40.7	52.5	47.5	37.3	36.3	22.7	40.0	40.5	40.3
$T_{1.2}$	40.8	29.8	47.5	31.4	25.0	27.0	33.7	48.3	46.3
$T_{1.3}$	33.3	47.5	46.7	32.8	25.0	32.7	41.8	43.2	43.3
$T_{1.4}$	33.9	35.3	52.5	33.5	28.8	44.0	35.7	45.5	49.2
$T_{2.3}$	33.7	58.0	65.0	42.3	40.0	67.5	55.6	58.0	62.4
$T_{2.4}$	33.3	63.1	49.2	40.4	31.4	28.6	45.3	46.6	57.8
$T_{3.4}$	38.8	34.1	41.1	32.7	50.0	40.0	39.6	43.6	52.8
$T_{1.2.3}$	42.2	45.7	32.1	36.7	30.0	54.0	47.3	42.6	42.0
$T_{1.3.4}$	28.8	35.6	56.7	25.1	45.0	30.0	39.0	50.7	37.3
$T_{2.3.4}$	36.2	45.8	36.2	27.2	33.0	51.0	38.8	54.2	53.3
$T_{1.2.4}$	34.2	44.1	38.0	39.3	45.0	28.7	51.0	61.7	48.7
$T_{1.2.3.4}$	35.2	45.0	50.0	36.9	46.3	59.0	43.7	72.2	49.6
CD (P = 0.05)									
Methods x Traits			0.80			1.07			3.96
Traits under different methods			0.87			1.11			4.07

e) Fruit weight

The SSD selections based on T_3 and $T_{2.3}$ had significantly higher fruit weight, followed by those under mass and pureline in the first generation. In the second generation, SSD selections based on $T_{2.3}$ recorded the highest fruit weight (67.5 g) followed by $T_{1.2.3}$, $T_{2.3.4}$ and $T_{1.2.3.4}$. Pureline selections based on $T_{3.4}$ had the maximum fruit weight (50 g) followed by $T_{1.2.3.4}$ and T_3. Mass selections based on T_2 had the maximum fruit weight (51.2 g) followed by T_1 and $T_{2.3}$. In the third generation, pureline selection based on $T_{1.2.3.4}$ recorded the highest fruit weight (72.2 g) followed by $T_{1.2.4}$ (6[illegible].7 g) and $T_{2.3}$ (58.0 g) (Plate-IV). Under SSD method, selections based on $T_{2.3}$ recorded the highest fruit weight (62.4 g) followed by $T_{2.4}$ (57.8 g) and $T_{2.3.4}$ (53.3 g). Under mass selection method, selections based on $T_{2.3}$ had a fruit weight of 55.6 g followed by $T_{1.2.4}$ (51.0 g) and T_3 (50.3 g). Selections based on $T_{2.3}$ had significantly higher fruit weight under SSD in all the three generations (65.0, 67.5 and 62.4 g respectively) compared to those under either mass or pureline in each generation.

3. Realised genetic gain for various traitwise selections

The realised genetic gain for various traitwise selections under mass, pureline and SSD methods and per se response to selections are presented in Table 9 and 10 respectively.

a) Fruits/plant

In the first generation, the maximum realised genetic gain was obtained for mass selections based on $T_{1.4}$ (29.91) followed by those based on T_1 and $T_{2.3}$. Pureline selections based on $T_{3.4}$ recorded the maximum gain (21.71) followed by $T_{2.3}$ and $T_{1.2}$. Under S D, selections based on $T_{2.3}$ had the maximum gain (25.9) followed by $T_{1.4}$ and T_1. In the second generation, mass selections based on $T_{1.3}$ (24.75) had the maximum value followed by $T_{2.3.4}$ and $T_{1.2.3}$. Under pureline selection the trait combination $T_{2.3}$ (5.55) was followed by T_3 and $T_{2.3.4}$. S D selections based on T_2 recorded the maximum genetic gain (14.35) followed by $T_{1.3}$ and $T_{1.2.3}$. In the third generation mass selections based on $T_{2.4}$ had the maximum gain (35.74) followed by $T_{1.2.3.4}$ and $T_{2.3.4}$. Under pureline method, selections based on T_1 (34.54) was followed by T_2 and $T_{2.3.4}$ and under S D selection $T_{1.2.3}$ (43.34) was followed by T_3 and $T_{1.3}$ and $T_{2.4}$. The per se response to selection was the highest for the trait combination $T_{2.3}$ in the first and second generations (20.71 and 11.35 respectively).

b) Locules/fruit

In the first generation, under mass method, maximum genetic gain was obtained for the trait combination $T_{2.3.4}$ (0.9), followed by $T_{2.3}$ and $T_{1.3.4}$. Selections based on $T_{1.2.3.4}$ under pureline method had the maximum value (0.6) followed by $T_{1.3}$ and $T_{1.3.4}$. $T_{2.3.4}$ and $T_{1.2.4}$. Selection based on

$T_{2.4}$ and $T_{2.3.4}$ recorded the highest genetic gain (1.0 each) followed by T_3 under S&D. In the second generation selections based on T_4 (1.2) was followed by $T_{2.3}$, $T_{1.4}$ and $T_{3.4}$ under mass method of selection. The trait combinations $T_{2.3}$ and $T_{1.3.4}$ (0.7 each) was followed by T_2 under pureline method. Under S&D method the trait combination $T_{2.3}$ (1.3) was followed by $T_{3.4}$, $T_{1.2.3}$ and $T_{1.2.3.4}$. In the third generation, selections based on T_1, $T_{1.4}$ and $T_{3.4}$ had the maximum genetic gain (0.8 each), followed by $T_{1.2.3}$ and $T_{1.2.4}$ under mass method of selection. Under pureline method, selections based on $T_{2.4}$ (0.9) was followed by $T_{1.2.4}$ and $T_{1.2.3.4}$. S&D selections based on $T_{2.3.4}$ recorded the maximum gain (1.0), followed by $T_{2.3}$ and $T_{1.2.4}$. Selections based on trait combination $T_{2.3.4}$, per se had high response in the first and third generation (0.8 and 0.7 respectively). Also $T_{2.4}$ in the first and third generation (0.6 each) and T_2 in the second and third generation (0.7 and 0.6 respectively) had higher per se genetic gain.

c) Yield/plant

The maximum realised genetic gain was recorded for the trait combination $T_{2.3}$ (0.914) under mass selection in the first generation. The trait combination $T_{2.4}$ under pureline selection in the second generation (0.861) and under S&D selection (1.708) in the third generation elicited maximum response to selection. The per se response to selection was high for the trait combination $T_{2.3}$ in the first (0.728) and second (0.327) generations.

e) Plant height

Maximum genetic gain was recorded for the trait combination $T_{1.3.4}$ under pureline selection in the first and second generations (32.6 and 29.2 respectively). In the third generation also pureline selection based on $T_{1.2.4}$ recorded the maximum value (27.8). The per se response to selection was the highest for $T_{1.3.4}$ (16.64) in the first generation, $T_{1.2}$ in the second generation (15.40) and $T_{2.4}$ in the third generation (17.77).

e) Days to flower

The maximum genetic gain for days to flower was obtained for selections based on T_1 under mass and $T_{1.2.3.4}$ under SSD selection methods (-4.8 each) in the first generation. In the second generation the trait combination $T_{1.3}$ under mass and $T_{2.4}$ and $T_{2.3.4}$ under SSD selections had the maximum value (-1.9 each). SSD selections based on $T_{1.2}$ and $T_{2.3}$ recorded the maximum value (-3.6 each) in the third generation. The per se genetic gain was maximum for T_1 in the first and third generations (-2.47 and -2.73 respectively) followed by $T_{2.3}$ in the second and third generations (-1.43 and -2.33 respectively).

f) Days to fruit set

Selections based on T_1 under mass in the first generation had the maximum realised genetic gain (-0.9). In the

second generation out of 15 trait combinations, 12 traitwise selections under pureline and seven traitwise selections under SSD recorded the maximum value (-8.6 each). SSD selections based on $T_{2.3.4}$ recorded the maximum gain (-2.5) in the third generation. Higher per se response was obtained for T_1 (-0.37 and -0.03 in the first and second generation respectively), $T_{1.2.3.4}$ (-0.10 and -8.60 in the first and second generation respectively) and for $T_{2.3.4}$ (-8.60 and -1.10 in the second and third generation respectiv ly).

g) Days to harvest

Maximum gain was obtained in selections based on $T_{2.3}$ (-5.4) under SSD in the first generation. In the second generation $T_{2.4}$ (-19.8) was followed by $T_{2.3}$ (-16.8) under SSD and $T_{2.3}$ (-17.2) under mass selection. In the third generation $T_{2.4}$ under mass (-0.4) and under SSD (-3.0) had higher genetic gain. The response to selection for all traitwise selections were positive using pureline method in the first generation. The per se selection response was maximum for days to first harvest for selections based on T_1 in the first (-0.07) and third (-1.67) generations. Selections based on trait combination $T_{2.4}$ had the highest response (-12.73) in the second generation.

h) Fruit weight

The maximum genetic gain was realised from selections based on $T_{2.3}$ under SSD method in the first and second

Table 9. Realized genetic gain in progenies developed through traitwise selection under three selection methods

	Fruits/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	25.51	16.91	17.51	9.55	1.95	3.15	21.34	34.54	15.74
T_2	23.51	9.91	15.51	8.35	0.55	14.35	30.34	33.86	37.34
T_3	15.51	14.11	4.51	5.95	3.75	1.55	24.74	27.14	41.34
T_4	21.11	14.71	7.51	3.35	-1.85	9.95	14.34	10.74	26.74
$T_{1.2}$	21.71	17.71	16.31	3.15	0.55	11.55	25.34	14.14	32.34
$T_{1.3}$	8.71	13.71	16.51	24.75	0.75	12.75	30.34	5.74	39.94
$T_{1.4}$	29.91	16.11	19.11	12.75	0.35	1.75	27.54	14.14	37.14
$T_{2.3}$	23.91	12.91	25.91	23.35	5.55	5.15	19.74	12.54	33.74
$T_{2.4}$	7.11	17.31	16.31	17.95	-1.85	4.55	35.74	11.74	39.94
$T_{3.4}$	22.51	21.71	13.71	14.55	0.95	1.35	24.54	23.14	21.34
$T_{1.2.3}$	20.31	17.31	4.91	19.15	-3.45	11.75	2[illegible].54	21.94	43.34
$T_{1.3.4}$	15.91	16.91	6.31	12.35	2.95	5.95	2[illegible].54	14.14	10.54
$T_{2.3.4}$	7.51	7.71	10.91	21.35	3.55	6.15	31.34	32.54	25.74
$T_{1.2.4}$	16.11	12.71	10.11	5.55	-0.85	6.35	21.74	26.14	26.54
$T_{1.2.3.4}$	12.51	15.11	10.11	11.15	0.15	4.95	35.34	7.14	15.94
CD (P = 0.05) Methods x Traits			16.51			11.44			21.08

(Contd.)

Table 9. (Contd.)

	Locules/fruit								
	Gen.I			Gen.II			Gen.III		
	M	PL	SEP	M	PL	SEP	M	PL	SEP
T_1	-0.2	0.3	0.3	0.6	0.2	0.6	0.8	0.2	0.6
T_2	0.6	0.5	0.5	0.6	0.6	0.7	0.6	0.5	0.6
T_3	0.4	0.3	0.6	0.4	0.2	0.2	0.4	0.3	0.5
T_4	0.5	0.5	0.4	1.2	0.5	0.7	0.6	0.4	0.4
$T_{1.2}$	0.6	0.5	0.6	0.6	-0.2	0.4	0	0.5	0.6
$T_{1.3}$	0.6	0.7	0.6	0.4	0.5	0.6	0	0.2	0.1
$T_{1.4}$	0.4	-0.1	0.2	0.7	0.9	0.5	0.8	0.8	0
$T_{2.3}$	0.8	0.2	0.3	0.8	0.7	1.0	0.5	0.5	0.9
$T_{2.4}$	0.6	0.4	1.0	0.5	0.3	0.4	0.6	0.9	0.3
$T_{3.4}$	1.1	0.5	0.2	0.7	0.2	0.8	0.8	-0.2	0.4
$T_{1.2.3}$	0.4	0.5	0.5	0.4	-0.2	0.8	0.7	0	0.1
$T_{1.3.4}$	0.7	0.6	0.1	0.6	0.7	0.4	0.4	0.2	0.3
$T_{2.3.4}$	0.9	0.6	1.0	0.6	0.4	0.7	0.6	0.4	1.0
$T_{1.2.4}$	0.1	0.6	0.4	0.6	0.5	0.2	0.7	0.8	0.9
$T_{1.2.3.4}$	0	1.3	0.5	0.6	0.5	0.8	0.6	0.8	0.4
CD (P = 0.05)									
Methods x Traits			0.86			0.82			0.68

(Contd.)

Table 9. (Contd.)

	Yield/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	SST	M	PL	SST	M	PL	SST
T_1	0.703	0.748	0.400	0.316	0.055	0.056	0.833	0.974	0.652
T_2	0.672	0.384	0.525	0.372	0.062	0.322	1.156	0.994	1.278
T_3	0.665	0.452	0.290	0.143	0.123	0.081	1.012	1.086	1.180
T_4	0.770	0.507	0.360	0.338	-0.019	0.250	0.602	0.392	0.724
$T_{1.2}$	0.733	0.557	0.513	0.128	0.045	0.280	0.596	0.608	1.182
$T_{1.3}$	0.267	0.641	0.567	0.515	0.049	0.336	0.488	0.127	1.462
$T_{1.4}$	0.814	0.494	0.633	0.369	0.065	0.088	0.524	0.576	1.238
$T_{2.3}$	0.653	0.616	0.914	0.569	0.195	0.213	0.674	0.612	1.696
$T_{2.4}$	0.252	0.724	0.553	0.665	0.861	0.093	0.806	0.490	1.708
$T_{3.4}$	0.679	0.676	0.460	0.421	0.073	0.069	0.624	0.572	0.858
$T_{1.2.3}$	0.748	0.726	0.187	0.531	0.351	0.270	0.808	0.698	1.032
$T_{1.3.4}$	0.419	0.552	0.242	0.265	0.155	0.143	0.443	0.782	0.414
$T_{2.3.4}$	0.219	0.328	0.351	0.435	0.126	0.238	0.746	1.284	0.640
$T_{1.2.4}$	0.430	0.410	0.344	0.182	0.035	0.149	0.812	1.452	0.884
$T_{1.2.3.4}$	0.442	0.484	0.439	0.393	0.138	0.178	0.596	0.632	0.844
CD (P = 0.05) Methods x Traits			0.576			0.293			0.750

(Contd.)

Table 9 (Contd.)

	Plant height								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	18.5	13.5	-1.8	20.9	-9.3	15.1	13.7	7.1	12.2
T_2	13.9	15.7	-1.0	17.2	10.2	8.0	3.[illegible]	3.4	18.0
T_3	5.4	28.8	2.2	11.9	12.7	4.8	21.6	23.6	3.3
T_4	15.2	25.3	3.2	7.8	6.0	6.9	3.1	3.8	12.4
$T_{1.2}$	19.4	7.6	1.6	24.4	19.3	2.5	3.9	8.6	9.0
$T_{1.3}$	5.2	17.8	8.5	13.1	-5.3	-3.2	17.2	-2.9	9.4
$T_{1.4}$	17.1	18.2	6.6	20.3	15.2	-1.2	13.6	12.4	13.8
$T_{2.3}$	10.8	14.1	13.9	13.5	2.8	1.5	14.2	5.8	15.5
$T_{2.4}$	1.7	20.4	1.8	9.1	13.6	7.8	14.1	18.0	2.2
$T_{3.4}$	13.7	24.0	2.9	10.4	7.5	-5.2	10.5	9.4	-1.3
$T_{1.2.3}$	8.9	13.0	5.9	16.0	-4.1	-1.2	18.2	18.0	12.2
$T_{1.3.4}$	13.8	32.6	3.6	13.3	29.2	3.9	16.2	7.5	9.0
$T_{2.3.4}$	4.1	17.7	6.0	15.7	11.0	0.3	3.6	17.8	4.9
$T_{1.2.4}$	6.9	29.1	0.9	-3.5	12.1	-7.0	2.0	27.8	0.4
$T_{1.2.3.4}$	1.6	29.1	-1.0	4.7	19.8	6.5	7.8	20.1	7.8
CD (P = 0.05) Methods x Traits			20.84			19.35			18.48

(Contd.)

Table 9. (Contd.)

	Days to flower								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	-4.8	-0.6	-2.0	-1.7	-1.1	-0.7	-1.4	-2.4	-3.4
T_2	-4.4	-1.0	-1.2	-1.5	-1.5	-0.7	-0.8	-1.8	-2.8
T_3	-2.8	+1.4	-1.8	-1.7	-1.1	-1.1	-2.0	-3.0	-2.0
T_4	-2.2	-1.8	+2.8	-1.1	-1.9	-1.3	-2.0	-1.8	-2.6
$T_{1.2}$	-1.2	-2.4	-2.6	-1.1	-0.3	-1.3	-1.4	-0.4	-3.6
$T_{1.3}$	-1.4	-2.8	-0.4	-1.9	-1.5	-1.7	-1.6	-2.4	-2.8
$T_{1.4}$	-3.8	-1.6	-1.8	-0.9	-1.1	-1.1	-1.0	-1.4	-2.6
$T_{2.3}$	-1.0	-2.2	-2.4	-1.3	-1.3	-1.7	-1.8	-1.8	-3.6
$T_{2.4}$	-2.0	-0.4	-1.4	-1.5	-1.5	-1.9	-1.6	-2.2	-2.6
$T_{3.4}$	-3.0	-2.0	+0.2	-1.7	-1.3	-1.1	-1.0	-1.8	-2.8
$T_{1.2.3}$	-0.2	-2.0	0	-1.3	-1.3	-1.5	-1.0	-2.2	-2.4
$T_{1.3.4}$	-2.2	-0.6	-1.8	-1.1	-1.3	-1.1	-1.0	-1.8	-1.8
$T_{2.3.4}$	-3.8	-2.6	-0.6	-0.7	-1.1	-1.9	-0.6	-2.2	-3.2
$T_{1.2.4}$	-1.2	-0.2	-1.2	-1.3	-0.7	-1.3	-0.2	-0.6	-2.4
$T_{1.2.3.4}$	-4.0	-3.6	-4.8	-1.0	-1.4	-1.7	0	-1.6	-2.6
CD (P = 0.05)									
Methods x Traits			2.44			0.90			1.79

(Contd.)

Table 9. (Contd.)

	Days to fruit set								
	Gen.I			Gen.II			Gen.III		
	M	PL	SGD	M	PL	SGD	M	PL	SGD
T_1	-0.9	+0.3	-0.5	+4.4	-8.6	+2.4	+1.3	-2.1	-2.3
T_2	-0.5	+0.7	+0.7	+0.4	+4.4	+2.4	+0.3	-0.9	-2.1
T_3	+0.3	+1.1	+0.3	-8.6	-8.6	+2.4	+1.3	-0.9	-1.9
T_4	-0.5	+0.7	+0.7	-8.6	-8.6	+2.4	-0.7	+0.9	-0.5
$T_{1.2}$	-0.5	+0.3	+0.3	+4.4	-8.6	-3.6	+1.7	+0.3	-1.9
$T_{1.3}$	-0.1	-0.7	+0.7	+2.4	+6.4	-8.6	-0.5	+0.1	+0.5
$T_{1.4}$	+0.3	+0.7	+0.3	+4.6	-8.6	-8.6	+0.3	-0.3	-0.5
$T_{2.3}$	-0.1	+0.7	-0.5	-2.4	-8.6	-7.6	+0.9	-0.5	-1.1
$T_{2.4}$	-0.9	+0.7	+0.3	+0.4	-8.6	-4.4	+0.3	+0.3	-2.3
$T_{3.4}$	-0.1	+1.1	-0.1	-8.6	-8.6	+4.4	+0.9	-0.5	-0.7
$T_{1.2.3}$	+0.3	+0.3	+0.3	+2.4	-8.6	-0.6	+1.1	+0.1	-1.1
$T_{1.3.4}$	-0.5	+0.7	-0.5	-8.6	-8.6	-8.6	+0.3	+0.3	-1.1
$T_{2.3.4}$	-0.1	+1.1	-0.5	-8.6	-8.6	-8.6	-1.5	-0.3	-2.5
$T_{1.2.4}$	+0.3	+1.1	+0.3	2.4	+6.4	-8.6	-0.3	+0.9	-0.7
$T_{1.2.3.4}$	-0.5	-0.1	+0.3	-8.6	-8.6	-8.6	-0.7	-0.3	-1.5
CD (0.05) Methods x Traits			1.19			3.67			1.66

(Contd.)

Table 9. (Contd.)

	Days to first harvest								
	Gen.I			Gen.II			Gen.III		
	M	PL	SED	M	PL	SED	M	PL	SED
T_1	-2.0	+4.6	-2.8	-9.0	-10.2	-9.2	+2.6	-3.6	-3.6
T_2	-1.6	+10.8	-1.8	-13.8	-9.0	-6.2	+2.2	-2.0	-4.8
T_3	-3.8	+0.6	+3.6	-6.0	-7.2	-9.4	+2.8	+0.2	+4.0
T_4	-1.4	+13.8	+4.6	-12.8	-11.4	-9.2	-0.6	+1.4	-0.6
$T_{1.2}$	-3.8	+9.1	-3.6	-10.8	+0.8	-12.4	+3.0	+4.0	-0.8
$T_{1.3}$	+3.4	+3.4	+1.0	-16.8	-11.2	-10.8	-0.6	+3.2	-0.8
$T_{1.4}$	+1.4	+9.8	-1.0	-15.4	+1.0	-12.2	+2.8	+1.6	+3.6
$T_{2.3}$	-4.2	+12.0	-5.4	-17.2	-4.6	-16.8	+2.2	+2.2	-2.6
$T_{2.4}$	-4.2	+14.2	-0.2	-19.8	-3.6	-14.8	-0.4	+3.0	-3.0
$T_{3.4}$	-3.6	+4.8	-5.2	-11.0	-0.8	-11.0	+4.8	+0.8	+1.0
$T_{1.2.3}$	+6.6	+3.8	-1.8	-13.2	+6.2	-14.0	+2.6	+0.4	-1.6
$T_{1.3.4}$	-0.2	+9.6	-3.0	-12.0	+5.2	-13.0	+2.0	+2.2	-0.2
$T_{2.3.4}$	-0.8	+10.2	-0.2	-11.4	-1.2	-5.2	+2.2	+2.6	-2.4
$T_{1.2.4}$	+1.8	+10.2	+3.2	-10.4	-0.4	-9.2	+1.3	+2.6	-1.2
$T_{1.2.3.4}$	-2.6	+1.8	-0.4	-10.2	+6.2	-10.2	+4.1	+1.2	-1.4
CD (P = 0.05) Methods x Traits			9.31			8.02			4.13

(Contd.)

Table 9. (Contd.)

	Fruit weight								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	4.9	18.8	0.2	23.5	-2.5	2.3	12.0	-3.3	11.8
T_2	-0.9	15.7	25.2	24.7	3.5	21.0	12.1	14.0	11.4
T_3	19.5	5.9	32.2	6.3	19.5	1.0	13.8	18.3	9.1
T_4	10.9	22.7	17.7	10.8	9.8	-3.8	3.5	12.0	3.8
$T_{1.2}$	11.0	0	17.7	4.9	-1.5	0.5	-2.8	11.8	9.8
$T_{1.3}$	3.5	17.7	16.9	6.3	-1.5	6.2	5.3	6.7	6.8
$T_{1.4}$	4.0	5.5	22.7	7.0	2.3	17.5	-0.8	9.0	12.7
$T_{2.3}$	3.9	28.2	35.2	15.8	13.5	41.0	19.1	21.5	25.9
$T_{2.4}$	3.5	33.3	19.4	13.9	4.9	2.1	8.8	20.1	21.3
$T_{3.4}$	9.0	4. 3	11.3	6.2	23.5	13.5	3.1	7.1	16.0
$T_{1.2.3}$	12.4	15.9	2.3	10.2	3.5	27.5	10.8	6.1	6.5
$T_{1.3.4}$	-1.0	5.8	26.9	-1.4	18.5	3.5	2.5	14.2	0.8
$T_{2.3.4}$	6.4	16.0	6.4	0.7	6.5	23.5	2.3	17.7	16.8
$T_{1.2.4}$	4.4	14.3	8.2	12.8	18.5	0.2	14.5	33.2	12.2
$T_{1.2.3.4}$	5.3	15.2	20.2	10.4	19.8	23.5	7.2	35.7	13.1
CD (P = 0.05) Methods x Traits			0.80			1.07			3.96

Table 10. Selection response per se in progenies developed through traitwise selection in three consecutive generations

	Fruits/plant			Locules/fruit			Yield/plant			Plant height		
	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
T_1	19.98	4.84	23.87	0.2	0.5	0.5	0.620	0.144	0.820	11.37	8.9	11.00
T_2	16.31	7.75	33.74	0.5	0.7	0.6	0.527	0.252	1.143	9.50	11.8	10.43
T_3	11.58	3.75	31.01	0.4	0.3	0.4	0.469	0.132	1.093	1. 21	9.8	16.17
T_4	14.44	5.82	17.27	0.5	0.8	0.4	0.546	0.190	0.573	14.54	6.9	6.43
$T_{1.2}$	18.58	5.08	24.20	0.5	0.3	0.4	0.601	0.151	0.795	9.50	15.40	1.77
$T_{1.3}$	14.98	12.75	25.34	0.6	0.5	0.1	0.492	0.300	0.692	10.47	1.53	7.90
$T_{1.4}$	21.71	4.95	26.27	0.2	0.5	0.4	0.647	0.174	0.779	13.94	11.43	13.27
$T_{2.3}$	20.71	11.35	22.01	0.4	0.6	0.6	0.728	0.327	0.991	12.90	5.93	11.83
$T_{2.4}$	13.58	6.88	29.14	0.6	0.4	0.6	0.510	0.179	1.001	7.94	10.83	17.77
$T_{3.4}$	19.31	5.62	23.01	0.5	0.6	0.3	0.605	0.188	0.685	13.50	4.23	6.20
$T_{1.2.3}$	14.18	9.15	31.20	0.5	0.4	0.3	0.554	0.243	0.846	9.24	3.57	16.13
$T_{1.3.4}$	13.04	7.08	13.74	0.5	0.6	0.3	0.402	0.188	0.546	16.64	13.43	10.00
$T_{2,3.4}$	9.04	10.35	29.87	0.8	0.6	0.7	0.298	0.283	0.856	6.50	9.00	8.77
$T_{1.2.4}$	12.98	3.68	24.81	0.2	0.4	0.8	0.395	0.122	1.049	12.27	0.53	10.07
$T_{1.2.3.4}$	12.58	5.42	20.31	0.6	0.6	0.6	0.488	0.236	0.625	10.87	10.33	11.90
CD (P=0.05)	9.53	6.60	12.17	0.49	0.47	0.39	0.333	0.169	0.44	12.03	9.84	11.25

(Contd.)

Table 10. (Contd.)

	Days to flower			Days to fruit set			Days to 1st harvest			Fruit weight		
	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
T_1	-2.47	-1.37	-2.73	-0.37	-0.60	-1.03	-0.07	-0.47	-1.67	7.97	7.8	6.8
T_2	-2.20	-1.23	-1.80	+0.17	+2.40	-0.90	+2.47	-9.67	-1.53	13.33	16.4	12.5
T_3	-1.07	-1.23	-2.33	+0.57	-3.60	-0.50	+0.13	-7.53	+1.13	19.20	8.9	13.7
T_4	-0.27	-1.37	-2.13	+0.30	-3.60	-0.10	+5.67	-9.27	+0.07	16.90	5.6	6.6
$T_{1.2}$	-2.07	-0.90	-1.73	+0.03	-4.27	+0.03	+0.53	-10.47	+2.60	9.60	1.3	6.2
$T_{1.3}$	-1.53	-1.70	-2.27	-0.03	+0.07	-0.63	+2.47	-13.00	+0.60	12. 70	3.7	6.3
$T_{1.4}$	-2.40	-1.03	-1.67	+0.43	-4.20	+0.03	+3.40	-8.87	+2.67	20.80	8.9	7.2
$T_{2.3}$	-1.87	-1.43	-2.33	+0.03	-4.93	-0.23	+0.80	-12.87	+0.60	22.40	23.5	22.0
$T_{2.4}$	-1.27	-1.37	-2.13	+0.03	-1.27	-0.57	+3.27	-12.73	-0.13	18.70	7.1	10.2
$T_{3.4}$	-1.60	-1.50	-1.87	+0.30	-4.27	-0.10	-1.60	-7.60	+7.20	8.20	14.4	8.8
$T_{1.2.3}$	-7.30	-1.37	-1.87	+0.30	-2.27	+0.03	+2.87	-7.00	+5.47	10.10	13.7	8.5
$T_{1.3.4}$	-1.53	-1.17	-1.53	-0.10	-8.60	-0.17	+2.13	-6.60	+6.33	20.60	6.9	5.8
$T_{2.3.4}$	-2.33	-1.17	-2.00	+0.17	-8.60	-1.10	+3.07	-5.93	+5.80	9.40	10.2	12.3
$T_{1.2.4}$	-0.87	-1.10	-1.07	+1.43	+0.07	-0.03	+5.07	-6.67	+5.80	9.00	10.9	20.0
$T_{1.2.3.4}$	-4.13	-1.37	-1.40	-0.10	-8.60	-0.83	-0.40	-4.73	+6.20	13.60	17.9	8.7
CD (P=0.05)	1.44	0.52	1.03	0.69	1.96	0.96	5.37	4.63	2.39	0.461	0.62	2.28

generations (35.2 and 41.0 respectively). In the third generation, pureline selections based on $T_{1.2.3.4}$ and $T_{1.2.4}$ (36.7 and 33.2 respectively) were followed by SSD selections based on $T_{2.3}$ (25.9). The per se response was also the highest for selections based on $T_{2.3}$ in all the three generations (22.40, 23.5 and 22.0 respectively).

4. Realised heritability for different traitwise selections

The realised heritability for various traitwise selections under mass, pureline and SSD methods and per se realised heritability for different traitwise selections are presented in Tables 11 and 12 respectively.

a) Fruits/plant

A high realised heritability was recorded for selections based on $T_{2.3}$ under SSD (0.96) and under mass (0.54) in the first generation. In the second generation this combination had high heritability under mass selection (0.93) and in the third generation also it had high heritability under mass (0.79) and under SSD (0.70).

The realised heritability per se for traitwise selections was the highest for $T_{3.4}$ in the first and third generations (0.78 and 0.93 respectively) followed by T_4 (0.56 and 0.69 respectively) and $T_{2.3}$ (0.50 and 0.54 respectively).

b) Locules/fruit

In the first generation the traitwise selection T_2 under pureline and SSD methods (0.83 each), $T_{2.3}$ under mass (0.67), $T_{2.4}$ under pureline (0.67) and $T_{2.3.4}$ under mass (0.90) had high heritability. In the second generation also T_2 under pureline (1.0), $T_{2.3}$ under mass (0.67), $T_{2.4}$ under pureline (0.50) and $T_{1.2.3.4}$ under mass (0.86) had high realised heritability. In the third generation T_2 under SSD (1.0) and under pureline methods (0.83), $T_{2.4}$ under SSD (0.50), $T_{2.3.4}$ under mass (0.60) and $T_{1.2.3.4}$ under mass (0.86) recorded high realised heritability. The per se realised heritability was maximum for the trait combination $T_{1.2}$ in all the three generations (1.0, 0.60 and 0.80 respectively).

c) Yield/plant

A high realised heritability was obtained for $T_{2.3}$ under mass selection in the first and second generations (0.61 and 0.53 respectively). Selections based on $T_{3.4}$ also had high realised heritability under mass as well as under SSD (0.90 and 0.70) in the first generation and under mass in the second and third generations (0.50 and 0.83 respectively). In the third generation T_4 had high realised heritability under mass, pureline and SSD selection methods (0.80, 0.61 and 0.60 respectively). The per se realised heritability was high for T_4 in the first and second generations (0.50 and 0.52 respectively) and $T_{3.4}$ in the first and third generations (0.88 and 0.9 respectively).

d) Plant height

The realised heritability was high for selections based on T_2 under mass method in the first generation and under SSD in the third generation (0.90 and 0.61 respectively). The trait combination $T_{2.3}$ under mass and SSD in the first generation (0.73 and 0.50 respectively) and that under mass in the second generation (0.92) and that under mass and SSD (0.97 and 0.56 respectively) in the third generation had high realised heritability. The trait combination $T_{2.3}$, per se had high realised heritability in the first and third generations (0.55 and 0.51 respectively).

e) Days to flower

A high realised heritability was observed for days to flower for the trait combination $T_{3.4}$ under mass in the second and third generations (0.92 and 0.54 respectively). Selections based on $T_{2.3.4}$ under mass (0.82) in the first generation, under SSD (0.32) in the third generation and $T_{1.2.3.4}$ under mass (0.95) and SSD (0.47) in the first generation had higher heritability. The trait combination $T_{1.2.3}$ per se had high realised heritability in the first (0.80) and third (0.71) generations.

f) Days to fruit set

In the first generation all traitwise selections under different selection methods had negative values or values lower than 0.5. In the second generation, T_4 recorded

heritability values of 0.61 and 0.56 under mass and pureline methods respectively. In the third generation also, all traitwise selections had values lower than 0.5 or negative values. Realised heritability per se for all traitwise selections were either negative or values lesser than 0.5 in the first and third generations. In the second generation the trait combination $T_{1.3.4}$ recorded the maximum value (0.71) followed by $T_{2.3.4}$ and $T_{1.2.3.4}$ (0.70 each) and $T_{1.4}$ (0.57).

g) Days to first harvest

Selections based on T_2 under mass in the first generation, under pureline in the second generation and under S.D in the third generation recorded realised heritability values of 0.47, 0.54 and 0.29 respectively. The trait combinations $T_{1.2}$ under mass and pureline (0.57 and 0.55 respectively) in the first generation and $T_{2.3}$ under mass and S.D (0.58 and 0.46 respectively) in the first generation, under mass (0.42) in the second generation and under S.D (0.22) in the third generation had higher heritability values compared to other traitwise selections. Certain traitwise selections had negative or values greater than 1.0 in all the generations. The per se realised heritability values for traitwise selections in the first and third generations were negative or values lower than 0.5. In the second generation T_4, $T_{2.4}$, T_2 and $T_{1.2}$ recorded heritability values of 0.96, 0.93, 0.79 and 0.78 respectively.

Table 11. Realised heritability of various characters effected by traitwise selections under three selection methods

	Fruits/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	0.66	0.22	0.23	0.25	0.03	0.04	0.55	0.45	0.20
T_2	0.66	0.18	0.28	0.23	0.01	0.26	0.85	0.60	0.67
T_3	3.21	3.42	1.09	1.23	0.91	0.38	5.12	6.57	10.00
T_4	1.07	0.50	0.26	0.47	0.06	0.34	0.73	0.37	0.92
$T_{1.2}$	0.58	0.32	0.29	0.08	0.01	0.21	0.70	0.25	0.58
$T_{1.3}$	0.34	0.41	0.34	0.38	0.02	0.26	1.20	0.12	0.83
$T_{1.4}$	0.92	0.26	0.31	0.39	0.01	0.03	0.85	0.23	0.61
$T_{2.3}$	0.96	0.27	0.54	0.93	0.12	0.11	0.79	0.26	0.70
$T_{2.4}$	0.20	0.31	0.29	0.51	-0.03	0.08	1.01	0.21	0.71
$T_{3.4}$	1.26	0.77	0.49	0.85	0.03	0.05	1.38	1.22	0.76
$T_{1.2.3}$	0.78	0.36	0.10	0.74	-0.07	0.24	1.10	0.46	0.90
$T_{1.3.4}$	0.58	0.35	0.13	0.45	0.06	0.12	0.82	0.29	0.41
$T_{2.3.4}$	0.28	0.16	0.23	0.80	0.07	0.13	1.18	0.68	0.53
$T_{1.2.4}$	0.48	0.16	0.13	0.17	-0.01	0.08	0.65	0.34	0.34
$T_{1.2.3.4}$	0.40	0.31	0.21	0.38	0.003	0.10	1.13	0.15	0.41

(Contd.)

Table 11. (Contd.)

	Locules/fruit								
	Gen.I			Gen.II			Gen.III		
	M	PL	SSD	M	PL	SSD	M	PL	SSD
T_1	1.0	0.30	0.30	2.0	2.0	6.0	4.0	2.0	6.0
T_2	1.5	0.83	0.83	1.50	1.0	1.17	1.50	0.83	1.0
T_3	0.21	0.08	0.16	0.21	0.05	0.05	0.21	0.08	0.13
T_4	1.25	1.25	1.0	3.0	1.25	1.75	1.50	1.0	1.0
$T_{1.2}$	2.0	0.83	1.0	2.0	0.33	0.67	0	0.83	1.0
$T_{1.3}$	0.55	0.27	0.23	0.36	0.19	0.23	0	0.08	0.04
$T_{1.4}$	1.33	0.50	-1.0	2.33	-2.5	-2.5	2.67	2.0	0
$T_{2.3}$	0.67	0.08	0.12	0.67	0.26	0.38	0.42	0.19	0.35
$T_{2.4}$	1.50	0.67	1.67	1.25	0.50	0.67	1.50	1.50	0.50
$T_{3.4}$	1.10	0.15	0.06	0.70	0.06	0.24	0.80	-0.06	0.12
$T_{1.2.3}$	0.36	0.19	0.19	0.36	-0.08	0.31	0.64	0	0.38
$T_{1.3.4}$	0.7	0.23	0.04	0.80	0.27	0.15	0.40	0.08	0.12
$T_{2.3.4}$	0.9	0.23	0.36	0.60	0.15	0.27	0.60	0.15	0.38
$T_{1.2.4}$	0.2	0.60	0.40	1.20	5.00	2.00	1.40	0.80	0.90
$T_{1.2.3.4}$	0	0.50	0.19	0.86	0.19	0.31	0.86	0.31	0.15

(Contd.)

Table 11. (Contd.)

	Yield/plant								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	0.61	0.32	0.17	0.27	0.02	0.02	0.72	0.43	.28
T_2	0.49	0.10	0.14	0.27	0.02	0.08	0.85	0.26	0.34
T_3	2.65	1.15	0.74	0.77	0.31	0.21	4.03	2.76	3.00
T_4	1.03	0.40	0.28	0.45	-0.01	0.20	0.80	0.31	0.60
$T_{1.2}$	0.55	0.15	0.14	0.10	0.01	0.07	0.45	0.16	0.31
$T_{1.3}$	0.29	0.28	0.25	0.56	0.02	0.15	0.54	0.06	0.63
$T_{1.4}$	0.70	0.33	0.42	0.32	0.04	0.06	0.45	0.34	0.82
$T_{2.3}$	0.61	0.27	0.40	0.53	0.0	0.09	0.63	0.27	0.73
$T_{2.4}$	0.19	0.19	0.15	0.50	0.23	0.12	0.60	0.13	.45
$T_{3.4}$	0.90	1.03	0.70	0.56	0.11	0.1	0.83	0.87	1.30
$T_{1.2.3}$	0.73	0.31	0.08	0.52	.15	0.12	0.78	0.3	0.45
$T_{1.3.4}$	0.36	0.24	0.1	0.24	.07	0.06	0.40	0.34	0.18
$T_{2.3.4}$	0.20	0.14	.15	.44	.05	0.1	0.68	0.56	.28
$T_{1.2.4}$	0.34	0.17	0.15	0.14	0.01	0.06	0.64	0.61	0.37
$T_{1.2.3.4}$	0.39	0.25	0.1	0.34	0.06	0.06	0.87	0.27	.37

(Contd.)

Table 11. (Contd.)

	Plant height								
	Gen.I			Gen.II			Gen.III		
	M	PL	SCD	M	PL	SSI	M	PL	SCD
T_1	1.40	0.50	-0.07	1.57	-0.34	0.56	1.03	0.26	0.45
T_2	0.90	0.53	-0.03	1.12	0.34	0.27	0.25	0.11	0.61
T_3	2.16	3.79	0.29	4.76	1.67	0.63	8.64	3.10	0.43
T_4	0.57	0.35	0.04	0.29	0.08	0.09	0.12	0.05	0.17
$T_{1.2}$	1.27	0.26	0.05	1.59	0.65	0.08	0.25	0.29	0.30
$T_{1.3}$	0.46	0.64	0.31	1.16	-0.19	-0.12	1.50	-0.11	0.34
$T_{1.4}$	0.86	0.48	0.17	1.03	0.40	-0.03	0.69	0.33	0.36
$T_{2.3}$	0.73	0.51	0.50	0.92	0.10	0.05	0.97	0.21	0.56
$T_{2.4}$	0.09	0.69	0.06	0.46	0.46	0.26	0.71	0.61	0.07
$T_{3.4}$	0.67	0.67	0.14	0.51	0.36	-0.25	0.51	0.46	0.06
$T_{1.2.3}$	0.68	0.47	0.21	1.22	-0.15	-0.04	1.39	0.65	0.44
$T_{1.3.4}$	0.93	1.18	0.13	0.89	1.06	0.14	1.09	0.27	0.33
$T_{2.3.4}$	-0.25	0.64	0.22	0.95	0.40	0.01	0.22	0.64	0.18
$T_{1.2.4}$	0.34	1.07	0.03	-0.17	0.45	-0.26	0.10	1.03	0.01
$T_{1.2.3.4}$	0.08	1.05	-0.03	0.25	0.72	0.24	0.41	0.73	0.28

(Contd.)

Table 11. (Conto.)

	Days to flower								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	0.73	0.05	0.15	0.26	0.08	0.05	0.21	0.18	0.26
T_2	0.90	0.07	0.08	0.31	0.10	0.05	0.16	0.12	0.18
T_3	1.72	-0.09	0.12	1.04	0.07	0.07	1.23	0.20	0.13
T_4	1.85	0.15	-0.23	0.92	0.16	0.11	1.68	0.15	0.21
$T_{1.2}$	0.23	0.16	0.17	0.22	0.02	0.09	0.27	0.03	0.24
$T_{1.3}$	0.25	0.28	0.04	0.34	0.15	0.17	0.29	0.24	0.28
$T_{1.4}$	0.76	0.39	0.43	0.18	0.08	0.27	0.20	0.10	0.18
$T_{2.3}$	0.22	0.22	0.24	0.29	0.13	0.17	0.40	0.18	0.35
$T_{2.4}$	0.37	0.03	0.09	0.13	0.10	0.13	0.30	0.15	0.17
$T_{3.4}$	1.60	-0.16	-0.02	0.92	-0.12	-0.10	0.54	-0.17	-0.26
$T_{1.2.3}$	0.04	0.2	0	0.27	0.13	0.15	0.21	0.22	0.24
$T_{1.3.4}$	0.63	0.06	0.13	0.31	0.13	0.11	0.29	0.18	0.18
$T_{2.3.4}$	0.92	0.26	0.06	0.17	0.11	0.13	0.14	0.27	0.32
$T_{1.2.4}$	0.21	0.02	0.05	0.22	0.05	0.10	0.03	0.05	0.18
$T_{1.2.3.4}$	0.95	0.35	0.47	0.24	0.14	0.17	0	0.16	0.26

(Cont'd.)

Table 11. (Contd.)

	Days to fruit set								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	0.09	-0.02	0.03	-0.42	0.50	-0.14	-0.12	0.12	0.13
T_2	0.06	-0.04	-0.04	-0.04	-0.23	-0.12	-0.03	0.05	0.11
T_3	-0.05	-0.66	-0.02	1.60	0.44	-0.12	-0.24	0.05	0.10
T_4	0.10	0.05	0.05	0.61	-0.56	0.16	- 0.13	-0.06	0.03
$T_{1.2}$	0.06	-0.02	-0.02	-0.48	0.44	0.44	-0.19	-0.02	0.10
$T_{1.3}$	0.01	0.05	0.05	0.25	0.45	0.60	0.05	- .01	-0.03
$T_{1.4}$	-0.03	-0.10	-0.04	-0.47	1.17	1.17	-0.03	0.04	0.07
$T_{2.3}$	-0.01	-0.05	0.03	0.27	0.60	0.53	-0.10	0.03	0.08
$T_{2.4}$	0.09	- .04	-0.02	-0.04	0.44	0.23	-0.03	-0.02	0.12
$T_{3.4}$	0.02	0.17	-0.02	1.56	-1.30	0.66	-0.16	- .08	-0.11
$T_{1.2.3}$	-0.03	-0.02	-0.02	0.27	0.60	0.04	-0.12	-0.01	0.08
$T_{1.3.4}$	-0.07	0.05	0.03	1.14	0.60	0.60	-0.04	-0.02	-0.08
$T_{2.3.4}$	0.01	-0. 8	0.03	1.03	0.60	0.60	0.16	0.02	0.02
$T_{1.2.4}$	-0.03	-0.06	-0.02	-0.23	-0.37	-0.50	0.03	-0.05	0.04
$T_{1.2.3.4}$	0.06	0.01	-0.02	1.03	.60	.60	0.08	0.02	0.10

(Contd.)

Table 11. (Contd.)

	Days to first harvest								
	Gen.I			Gen.II			Gen.III		
	M	PL	[illegible]	M	PL	[illegible]	M	[illegible]	[illegible]
T_1	0.24	-0.31	0.19	1.10	0.69	0.63	-0.32	0.25	0.25
T_2	0.47	-0.65	0.11	4.04	0.54	0.37	-0.64	0.12	0.29
T_3	1.34	-0.04	-0.22	2.12	0.43	0.56	-0.99	-0.01	-0.02
T_4	0.39	-1.09	-0.36	3.60	0.90	0.72	0.17	-0.11	0.05
$T_{1.2}$	0.57	0.55	0.22	2.55	-0.05	0.74	-0.45	-0.24	0.05
$T_{1.3}$	-0.49	-0.29	-0.09	2.41	0.96	0.92	0.09	-0.27	0.07
$T_{1.4}$	-0.16	-2.09	0.21	1.79	-0.21	2.60	-0.33	-0.34	0.77
$T_{2.3}$	0.58	-1.03	0.46	0.42	0.39	1.44	-0.30	-0.19	0.22
$T_{2.4}$	0.54	-0.85	0.01	2.53	0.22	0.89	0.05	-0.18	0.18
$T_{3.4}$	1.94	0.52	-0.56	5.91	-0.09	-1.18	-2.58	0.09	0.11
$T_{1.2.3}$	-1.04	-0.33	0.15	2.08	-0.53	1.20	-0.41	-0.03	0.14
$T_{1.3.4}$	-0.04	-0.82	0.26	2.43	-0.44	1.1	-0.41	-0.19	0.02
$T_{2.3.4}$	0.14	-0.87	0.02	1.98	0.10	0.44	-0.38	-0.22	0.21
$T_{1.2.4}$	-0.23	-0.69	0.22	1.35	0.03	0.63	-0.17	-0.18	0.08
$T_{1.2.3.4}$	0.45	-0.15	0.03	1.78	-0.53	0.87	-0.72	-0.10	0.12

(Contd.)

Table 11. (Cont.)

	Fruit weight								
	Gen.I			Gen.II			Gen.III		
	M	PL	S.D	M	PL	S.D	M	PL	S.D
T_1	5.44	14.46	0.15	26.11	-1.92	1.77	13.33	2.54	9.08
T_2	0.15	0.55	0.88	3.68	0.12	0.73	1.95	0.44	0.40
T_3	3.20	0.45	2.46	1.03	1.49	0.08	2.26	1.40	0.69
T_4	2.06	2.49	1.95	2.04	1.08	-0.42	0.66	1.32	0.42
$T_{1.2}$	2.39	0	0.62	1.07	-0.05	0.02	-0.61	0.41	0.34
$T_{1.3}$	0.78	1.30	1.42	1.40	-0.81	0.46	1.18	0.49	0.50
$T_{1.4}$	0.85	1.77	7.32	1.49	0.74	5.65	0.17	2.90	4.10
$T_{2.3}$	0.46	2.07	2.59	1.88	0.99	3.01	2.27	0.63	1.90
$T_{2.4}$	0.59	1.16	0.68	2.36	0.17	0.07	1.49	1.70	0.74
$T_{3.4}$	1.27	-1.59	4.04	0.87	-8.70	4.82	0.44	-2.63	5.71
$T_{1.2.3}$	1.91	1.17	0.17	1.57	0.26	2.02	1.66	0.45	0.48
$T_{1.3.4}$	-0.15	0.43	1.98	-0.21	1.36	0.26	0.37	1.04	0.06
$T_{2.3.4}$	0.84	1.18	0.47	0.09	0.48	1.73	0.30	1.30	1.24
$T_{1.2.4}$	0.71	11.1	6.31	2.06	14.23	0.15	2.34	25.54	9.38
$T_{1.2.3.4}$	1.04	1.12	1.43	2.04	1.46	1.73	1.41	2.63	0.96

Table 12. Per se realised heritability of various characters effected by traitwise selections considering all the selection methods together

	Fruits/plant			Locules/fruit			Yield/plant			Plant height		
	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
1	0.31	0.09	0.37	1.54	3.85	3.85	0.32	0.07	0.42	0.51	0.40	0.49
2	0.33	0.16	0.68	0.94	0.13	0.13	0.38	0.08	0.38	0.38	0.47	0.42
3	2.66	0.86	7.11	0.13	0.09	0.13	1.36	0.38	3.16	0.21	1.66	2.74
4	0.56	0.22	0.66	1.25	2.00	1.00	0.50	0.17	0.52	0.25	0.12	0.11
1.2	0.37	0.10	0.48	1.00	0.60	0.80	0.20	0.05	0.27	0.38	0.62	0.07
1.3	0.37	0.31	0.63	0.29	0.29	0.05	0.27	0.16	0.38	0.47	0.07	0.36
1.4	0.42	0.10	0.51	6.67	16.67	1.33	0.45	0.12	0.56	0.44	0.36	0.41
2.3	0.50	0.29	0.54	0.19	0.28	0.28	0.38	0.17	0.52	0.55	0.25	0.51
2.4	0.28	0.14	0.59	1.13	0.75	1.13	0.17	0.06	0.34	0.30	0.41	0.67
3.4	0.78	0.23	0.93	0.19	0.23	0.12	0.88	0.27	0.99	0.66	0.21	0.30
1.2.3	0.35	0.22	0.77	0.24	0.19	0.14	0.29	0.15	0.45	0.41	0.16	0.71
1.3.4	0.22	0.17	0.45	0.24	0.29	0.14	0.21	0.10	0.29	0.71	0.57	0.47
2.3.4	0.22	0.25	0.73	0.38	0.20	0.33	0.16	0.15	0.45	0.27	0.38	0.37
1.2.4	0.21	0.06	0.40	0.45	1.08	2.16	0.23	0.07	0.61	0.49	0.02	0.40
1.2.3.4	0.30	0.13	0.49	0.30	0.30	0.30	0.25	0.12	0.43	0.44	0.42	0.48

(Contd.)

	Days to flower			Days to fruit set			Days to first harvest			Fruit weight		
	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III	Gen.I	Gen.II	Gen.III
T_1	0.23	0.13	0.25	0.02	0.04	0.07	0.01	0.76	0.13	9.96	9.75	8.50
T_2	0.19	0.12	0.15	-0.01	-0.15	0.06	-0.20	0.79	0.12	0.63	0.78	0.59
T_3	0.68	0.12	0.22	-0.04	0.24	0.03	-0.01	0.62	-0.09	1.78	0.83	1.27
T_4	0.68	3.43	5.33	-0.03	0.30	0.01	-0.59	0.96	-0.01	2.16	0.07	0.08
$T_{1.2}$	0.18	0.08	0.15	-0.002	0.27	-0.002	-0.04	0.78	-0.19	0.47	0.06	0.30
$T_{1.3}$	0.18	0.20	0.26	0.002	-0.01	0.05	-0.25	1.30	-0.06	1.20	0.04	0.60
$T_{1.4}$	0.54	0.23	0.38	-0.05	0.51	-0.004	-0.57	1.48	-0.45	41.6	17.8	14.40
$T_{2.3}$	0.23	0.17	0.29	-0.002	0.40	0.02	-0.08	1.26	-0.06	1.89	1.98	1.85
$T_{2.4}$	0.11	0.12	0.18	-0.002	0.08	0.04	-0.24	0.93	0.01	0.89	0.34	0.49
$T_{3.4}$	-0.24	0.23	0.28	0.12	-1.66	-0.04	-0.29	-1.36	1.29	3.42	6.0	3.67
$T_{1.2.3}$	0.87	0.16	0.22	-0.02	0.18	-0.002	-0.29	0.71	-0.55	0.90	1.22	0.76
$T_{1.3.4}$	0.19	0.15	0.19	0.01	0.71	0.01	-0.23	0.70	-0.67	1.82	0.61	0.51
$T_{2.3.4}$	0.29	0.14	0.25	-0.01	0.70	0.09	-0.32	0.61	-0.60	0.81	0.88	1.06
$T_{1.2.4}$	0.08	0.10	0.10	-0.10	-0.01	0.002	-0.41	0.54	-0.47	3.07	3.72	6.83
$T_{1.2.3.4}$	0.50	0.17	0.17	0.01	0.70	-0.07	0.04	-0.49	-0.64	1.26	1.66	0.81

h) Fruit weight

The traitwise selection T_2 under [illegible] in the first and second generations (0.88 and 0.73 respectively) and that under pureline in the first generation (0.55) had higher realised heritability. Similarly $T_{2.3}$ under pureline in the second and third generations (0.99 and 0.63 respectively) and $T_{2.4}$ under pureline and [illegible] in the third generation (0.70 and 0.74 respectively) had higher realised heritability.

A high per se realised heritability was observed for T_2 in the first, second and third generations (0.63, 0.78 and 0.59 respectively) and $T_{2.3.4}$ in the first and second generations (0.81 and 0.84 respectively).

i. Evaluation for resistance to bacterial wilt

The data on the incidence of bacterial wilt in the base population and in the advanced generations under different selection methods are presented in Table 13.

A wilt incidence of 22.13% was recorded in the base population. The wilt incidence reduced significantly in the third generation. This was achieved through [illegible] which recorded a disease incidence of only 9.86%. The wilt incidences in pureline and mass selections were 12.13% and 10.93% respectively. The data also indicated that more plants wilted in the adult plant stage than in juvenile stage. The wilt incidence for various trait combinations under different selection methods

Table 13. Evaluation for resistance to bacterial wilt in progenies developed through three methods of selection

Methods of selection	Generations	Total number of plants	Plants wilted			
			Juvenile stage	Adult plant stage	Total	Wilt (%)
Mass Selection	I	750	27	66	93	12.40
	II	750	15	100	115	15.33
	III	750	20	62	82	10.93
Pure line selection	I	750	38	79	117	15.60
	II	750	3	103	106	14.13
	III	750	31	60	91	12.13
Single seed descent	I	750	46	93	139	18.53
	II	750	16	110	126	16.80
	III	750	14	60	74	9.86
Bulk	I	100	6	20	26	26.00
	II	100	12	14	26	26.00
	III	100	2	14	16	16.00
Base population		2377	171	286	457	22.13

Table 14. Evaluation for wilt resistance in progenies developed through traitwise selections under three selection methods

Traits	Generations	Total No.of plants	Plants wilted											
			Mass				Pure line				Single seed descent			
			Juvenile stage	Adult stage	Total	%	Juvenile stage	Adult stage	Total	%	Juvenile stage	Adult stage	Total	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T_1	I	50	1	5	6	12	2	5	7	14	5	5	10	20
	II	50	1	5	6	12	-	6	6	12	1	5	6	12
	III	50	-	1	1	2	4	3	7	14	1	1	2	4
T_2	I	50	1	2	3	6	-	6	6	12	5	15	20	40
	II	50	2	5	7	14	-	4	4	8	-	9	9	18
	III	50	-	4	4	8	-	5	5	10	1	1	2	4
T_3	I	50	3	2	5	10	12	30	42	84	3	9	12	24
	II	50	2	6	8	16	-	6	6	12	1	6	7	14
	III	50	1	5	6	12	1	3	4	8	1	1	2	4
T_4	I	50	3	6	9	18	3	3	6	12	4	11	15	30
	II	50	1	4	5	10	-	7	7	14	2	5	7	14
	III	50	3	3	6	12	2	1	3	6	-	4	4	8
$T_{1.2}$	I	50	1	6	7	14	2	2	4	8	1	3	4	8
	II	50	3	7	10	20	-	11	11	22	3	8	11	22
	III	50	-	4	4	8	2	3	5	10	0	0	0	0

(Contd.)

Table 14. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	I	50	2	2	4	8	0	0	0	0	3	5	8	16
$T_{1.3}$	II	50	-	6	6	12	1	2	3	6	-	10	10	20
	III	50	-	7	7	14	1	8	9	18	-	2	2	4
	I	50	3	2	5	10	2	2	4	8	2	5	7	14
$T_{1.4}$	II	50	2	5	7	14	-	3	3	6	1	7	8	16
	III	50	1	4	5	10	6	4	10	20	1	9	10	20
	I	50	2	4	6	12	4	6	10	20	4	5	9	18
$T_{2.3}$	II	50	-	8	8	16	1	7	8	16	-	12	12	24
	III	50	1	4	5	10	4	3	7	14	1	3	4	8
	I	50	2	7	9	18	1	5	6	12	2	4	6	12
$T_{2.4}$	II	50	-	12	12	24	-	9	9	18	-	3	3	6
	III	50	1	6	7	14	-	9	9	18	1	3	4	8
	I	50	1	4	5	10	1	2	3	6	4	7	11	22
$T_{3.4}$	II	50	-	5	5	10	-	9	9	18	-	15	15	30
	III	50	1	4	5	10	-	8	8	16	-	11	11	22
	I	50	3	7	10	20	2	1	3	6	3	9	12	24
$T_{1.2.3}$	II	50	-	5	5	10	-	7	7	14	1	8	9	18
	III	50	2	5	7	14	-	-	0	0	3	2	5	10

(Contd.)

Table 14. (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$T_{1.3.4}$	I	50	1	6	7	14	2	3	5	10	3	4	7	14
	II	50	-	7	7	14	-	7	7	14	1	4	5	10
	III	50	3	1	4	8	-	1	1	2	2	9	11	22
$T_{2.3.4}$	I	50	1	4	5	10	2	6	8	16	3	3	6	12
	II	50	-	8	8	16	-	8	8	16	2	5	7	14
	III	50	-	4	4	8	-	5	5	10	2	6	8	16
$T_{1.2.4}$	I	50	2	6	8	16	3	4	7	14	2	4	6	12
	II	50	4	6	10	20	1	10	11	22	3	6	9	18
	III	50	2	8	10	20	3	5	8	16	1	1	2	4
$T_{1.2.3.4}$	I	50	1	3	4	8	2	4	6	12	2	4	6	12
	II	50	-	11	11	22	-	7	7	14	1	7	8	16
	III	50	5	2	7	14	8	2	10	20	-	7	7	14
Bulk	G. I	100	6	20	26	26								
	G. II	100	12	14	26	26								
	G.III	100	2	14	16	16								

Table 15. Performance of L-79 (C.V. 32d-0-1-1-1-1-19 GS) under multilocational trials

District	Total No.of plants	Plants wilted	Per cent survival
Trivandrum	137	29	78.8
Quilon	36	4	95.0
Kottayam	15	0	100.0
Idukki	50	0	100.0
Pathanamthitta	100	4	96.0
Alleppey	11	3	72.7
Ernakulam	48	14	70.8
Trichur	1013	102	89.1
Palghat	50	2	96.0
Malapuram	66	2	97.0
Calicut	10	3	70.0
Cannanore	156	2	98.7
Wynad	30	0	100.0 (av. 89.5%)
*Karnataka (IIHR Bangalore)	-	-	100.0
Bihar (Ranchi)	-	-	100.0

*Artificially inoculated

for different generations are given in Table 14. The traitwise selections T_1, T_2, $T_{1.2}$, $T_{1.4}$, $T_{2.3}$, $T_{3.4}$, $T_{1.2.4}$ and $T_{2.3.4}$ under mass selection recorded a low wilt incidence (2-10%) in the third generation. Similarly the traitwise selection T_3, T_4, $T_{1.2.3}$, $T_{1.2.4}$ and $T_{2.3.4}$ under pureline (0-10%) and T_1, T_2, T_3, T_4, $T_{1.2}$, $T_{1.3}$, $T_{2.3}$, $T_{2.4}$, $T_{1.2.3}$ and $T_{1.3.4}$ under RBD (0-10%) had low wilt incidence in the third generation.

The performance of LE79 (CL 32 d-0-1-1-1-1-19 SS) was further tested through a multilocational trial (Table 15). The mean incidence of wilt was only 10.5%.

II. Genetic bases of resistance to bacterial wilt

A. Inheritance of resistance

Number of plants transplanted, plants survived and wilted in both segregating and non-segregating generations of LE79 x Pusa Ruby crosses are presented in Table 16.

The result indicates that the resistance to bacterial wilt in LE79 is inherited monogenically and is controlled by a single incompletely dominant gene. The gene system operating in this line of Lycopersicon esculentum has a penetrance of 72%. There was a survival of 12% of plants in F_1.

B. Association of characters

1. Gel colour of fruit

Of the 20 plants observed - 10 each under resistant

Table 16. Inheritance of resistance to bacterial wilt.

Generations	Number of plants			Expected ratio assuming partial penetrance	χ^2*	P
	Total	Resistant	Susceptible			
P1 (LS 79)	50	36	14	-	-	-
P2 (Pusa Ruby)	50	0	50	-	-	-
F_1	50	6	44	-	-	-
F_2	200	41 (48)	159 (152)	0.96:3.04	1.34	0.3 - 0.2
BC_1 (F1 x LS79)	200	71 (84)	129 (116)	0.84:1.16	3.47	0.1 - 0.05
BC_2 (F1 x Pusa Ruby)	200	18 (12)	182 (188)	0.06:0.94	3.19	0.1 - 0.05

* χ^2 = 3.84
(P = 0.05)

Figures in parentheses are expected number assuming partial penetrance of resistance

Table 17a. Contingency table for testing association between fruit gel colour and resistance to bacterial wilt

Disease reaction	Fruit gel colour		Total
	Green gel	Yellow gel	
Resistant	0	10	10
Susceptible	0	10	10
Total	0	20	20

Table 17b. Contingency table for testing association between locules/fruit and resistance to bacterial wilt

Disease reaction	Locules/fruit		Total
	≤ 3	> 3	
Resistant	4	6	10
Susceptible	1	9	10
Total	5	15	20

Multinomial probability test

$$P_1 = \frac{5!\,1!\,5!\,1!\,0!\,1!}{20!} \times \frac{1}{1!\,9!\,4!\,6!}$$

$$P_0 = \frac{5!\,1!\,5!\,1!\,0!\,1!}{20!} \times \frac{1}{0!\,1!\,0!\,5!\,5!\,1!}$$

(P_0 = assuming ≤3 locules/fruit under susceptibility as zero)

$$P_1 = 849341424.2 \times \frac{1}{6270566400}$$

$$= 0.135449$$

$$P_0 = 849341424.2 \times \frac{1}{52254\,720000}$$

$$= 0.0162539$$

$$P_0 \div P_1 = 0.15$$

(LE79 (CL 32 6-0-1-1-1-1-19 GS)) and susceptible (Pusa Ruby) - all the plants had fruits with yellow gel colour (Table 17a).

2. Locules/fruit

Ten plants each under resistant (LE79 (CL 32 6-0-1-1-1-1-19 GS)) and susceptible (Pusa Ruby) genotypes were observed for locules/fruit. Those falling under the two groups, viz., locule number ≤ 3 and > 3 in the two varieties were analysed for its association with resistance to bacterial wilt by using multinomial probability test (Table 17b). A probability of 0.15 was found for the association of fewer locules (≤ 3) per fruit and resistance to bacterial wilt.

III. Biochemical bases of resistance

A. Estimation for total content of α- tomatine, total phenols, O.H. phenols and Vitamin C

1. α - Tomatine content

The α - tomatine contents in roots, stem and leaves of LE79 (CL 32 6-0-1-1-1-1-19 GS)) and Pusa Ruby at five different stages are presented in Table 18. The total α- tomatine in LE79 was more than that in Pusa Ruby at all stages. The maximum content was observed in 15 days old seedlings in both LE79 and Pusa Ruby but decreased in 30 days old and then gradually increased. The content in roots of LE79 was more than that in Pusa Ruby at all stages. The root content was maximum in 15 days old seedlings and after a slump, it again reached the maximum in 45 days old plants.

Table 18. ∝ - Tometine content (ppm) at different growth stages

	15th day		30th day		45th day		60th day		75th day	
	LE 79	PR	LE 79	PR	LE 79	PR	LE 79	PR	LE 79	PR
Root	3810.4	3176.6	1357.9	694.9	2815.2	1771.2	1891.9	1235.3	2091.4	1487.9
Shoot	3456.3	1389.2	1379.6	804.8	2521.3	1652.5	1871.2	1553.1	2215.9	1955.1
Total	3574.4	1985.0	1372.4	768.1	2520.6	1692.1	1879.1	1313.8	2174.4	1799.4

LE 79 = CL 326-0-1-1-1-1-1-1 GS
PR = Pusa Ruby

Table 19. Total phenol content (Tannic acid (ppm) at different growth stages

	15th day		30th day		45th day		60th day		75th day	
	LE 79	PR	LE 79	PR	LE 79	PR	LE 79	PR	LE 79	PR
Root	270.0	206.0	283.0	304.0	376.0	579.0	350.0	258.0	345.0	419.0
Shoot	773.0	746.5	793.5	691.5	961.0	1171.3	1188.0	637.5	1363.0	1021.0
Total	605.3	536.3	625.3	564.0	766.6	907.2	922.0	511.0	1025.0	820.3

2. Total phenols

The total phenols in the plant was more in LE79 at all stages except in 45 days old plants (Table 19). The content in root was lower in LE79 than that in Pusa Ruby at all stages except in 60 days old plants.

3. O.D. phenols

The total plant content of O.D. phenols was more in LE79 than in Pusa Ruby at all stages. The root content was same in 15 and 30 days old seedlings of both varieties. It was higher in Pusa Ruby in 45 and 60 days old plants and lesser in 75 days old plants as compared to LE79. The shoot contained more O.D. phenols than roots in both the varieties (Table 20).

4. Vitamin C content

The total Vitamin C content in LE79 was lesser than Pusa Ruby in 15 and 30 days old seedlings. The content was more in LE79 than in Pusa Ruby in 45, 60 and 75 days old plants. The Vitamin C content in roots of LE79 was more than that in roots of Pusa Ruby at all stages (Table 21).

B. Relative proportion among chemical constituents in resistant and susceptible lines

The relative proportion of α - tomatine, total phenols O.D. phenols, and Vitamin C in roots and shoots of LE79 (CL 32d-0-1-1-1-1-1-0) and Pusa Ruby at five different growth stages were studied (Table 22).

Table 20. O.P. phenol content (Catechol content (ppm) at different growth stages

	15th day		30th day		45th day		60th day		75th day	
	Ls 79	PR	Ls 79	PR	Ls 79	PR	Ls 7[illegible]	PR	Ls 79	PR
Root	32.0	32.0	35.0	35.0	37.0	55.0	22.0	29.0	38.0	32.0
Shoot	228.5	201.3	245.5	224.8	261.5	235.0	227.5	173.5	316.5	299.4
Total	163.0	144.9	175.0	162.0	186.6	174.	159.0	125.0	223.0	210.3

Table 21. Vitamin C content (ppm) at different growth stages

	15th day		30th day		45th day		60th day		75th day	
	Ls 79	PR	Ls 79	PR	Ls 7[illegible]	PR	Ls 7[illegible]	PR	Ls 7[illegible]	PR
Root	63.1	47.3	69.6	58.[illegible]	59.2	4[illegible].1	84.3	60.2	78.6	44.9
Shoot	250.0	289.4	393.8	454.0	321.2	295.[illegible]	230.8	169.7	30[illegible].0	174.1
Total	187.7	209.7	2[illegible]5.7	325.6	233.5	246.5	168.6	148.5	232.2	131.0

1.α - Tomatine : total phenols

The ratio ofα- tomatine to total phenols in roots of LE79 was more than that in Pusa Ruby at all stages studied. In the shoot also the trend was same except in 60 and 75 days old plants where proportion was high in Pusa Ruby.

2.α - Tomatine : O.D.phenols

The ratio ofα- tomatine/O.D. phenols in roots of LE79 was more than that in Pusa Ruby at all stages. In shoot, except in 60 days old plants, the trend was same as that in roots of LE79.

3.α- Tomatine : Vitamin C

The ratio ofα- tomatine/Vitamin C was more in the roots of LE79 than that in Pusa Ruby at all stages except in 15 and 75 days old plants. The ratio in the shoot also had the same trend except in 45 and 75 days old plants where Pusa Ruby had a higher proportion.

4. Vitamin C : total phenols

The ratio was higher in the roots of LE79 except in 60 days old plants. In the shoot the proportion was higher in Pusa Ruby except in 45 and 75 days old plants.

5. Vitamin C: O.D. phenols

The ratio of Vitamin C/O.D.phenols was higher in roots of LE79 at all stages. In shoots this proportion was higher in Pusa Ruby except in 45 and 75 day old plants.

Table 22. Relative proportion of different chemical constituents in root and shoot at different growth stages.

	Plant part	- Tomatine : Total phenols ratio		- Tomatine : O.D. phenols ratio		- Tomatine : Vit.C ratio	
		LE 79	PR	LE 79	PR	LE 79	PR
15th day	Root	14.1 : 1	10.73 : 1	119.1 : 1	99.26 : 1	60.4 : 1	67.15 : 1
	Shoot	4.47 : 1	1.86 : 1	15.12 : 1	6.9 : 1	13.8 : 1	4.8 : 1
30th day	Root	4.8 : 1	2.25 : 1	38.8 : 1	18.9 : 1	19.5 : 1	10.1 : 1
	Shoot	1.74 : 1	1.16 : 1	5.62 : 1	3.58 : 1	3.5 : 1	1.78 : 1
45th day	Root	7.49 : 1	3.06 : 1	76.19 : 1	32.3 : 1	48.3 : 1	36.82 : 1
	Shoot	2.62 : 1	1.54 : 1	9.64 : 1	7.03 : 1	7.34 : 1	8.44 : 1
60th day	Root	4.85 : 1	4.79 : 1	85.99 : 1	43.04 : 1	22.4 : 1	20.52 : 1
	Shoot	1.58 : 1	2.43 : 1	8.22 : 1	8.95 : 1	8.97 : 1	8.19 : 1
75th day	Root	5.99 : 1	3.58 : 1	55.04 : 1	46.5 : 1	26.6 : 1	33.14 : 1
	Shoot	1.62 : 1	1.91 : 1	7.00 : 1	6.53 : 1	7.17 : 1	11.2 : 1

Table 22. (Contd.)

	Plant part	Vitamin C: Total phenols ratio		Vit.C: O.D. phenols ratio		Total phenols: O.D. phenols ratio	
		LE 79	AR	LE 79	AR	LE 79	AR
15th day	Root	0.23 : 1	0.16: 1	1.97: 1	1.48: 1	8.4 :1	9.25: 1
	Shoot	0.32 : 1	0.39: 1	1.09: 1	1.44: 1	3.4 :1	3.70: 1
30th day	Root	0.25 : 1	0.22: 1	1.98: 1	1.97: 1	8.1 :1	8.80: 1
	Shoot	0.49 : 1	0.66: 1	1.60: 1	2.02: 1	3.2 :1	3.07: 1
45th day	Root	0.15 : 1	0.08: 1	1.57: 1	0.88: 1	10.2 :1	10.57: 1
	Shoot	0.33 : 1	0.18: 1	1.23: 1	0.83: 1	3.7: 1	4.56: 1
60th day	Root	0.22 : 1	0.23: 1	3.83: 1	2.10: 1	17.7: 1	8.98: 1
	Shoot	0.18 : 1	0.24: 1	0.92: 1	1.09: 1	5.2: 1	3.67: 1
75th day	Root	0.23 : 1	0.11: 1	2.07: 1	1.40: 1	9.2: 1	13.10: 1
	Shoot	0.23 : 1	0.17: 1	0.98: 1	0.58: 1	4.31:1	3.41: 1

6. Total phenols: O.D. phenols

The ratio of total phenols/O.D. phenols was higher in roots of Pusa Ruby than in L879 at all stages except in 75 days old plants. In the shoot, this ratio was higher in Pusa Ruby in 15 and 45 days old plants. The ratio was higher in 30, 60 and 75 days old plants of L879.

C. Shift in content of ∝- tomatine, total phenols, O.D. phenols and Vitamin C after artificial inoculation with *Pseudomonas solanacearum*

The increase/decrease in levels of ∝- tomatine, total phenols, O.D. phenols and Vitamin C in 60 days old plants of L879 (CL 32d-0-1-1-1-1-19 GS) and Pusa Ruby three days and seven days after artificial inoculation are presented in Tables 23a, 23b, 23c and 23d.

1. ∝- Tomatine

There was an increase in ∝- tomatine content three days after artificial inoculation in both L879 (1878.1 to 7000.6 ppm) and Pusa Ruby (1313.8 to 5696.3 ppm). The root content was also more in L879. The content showed a decrease in both the lines after seven days compared to three days after inoculation. The content was low in the roots and shoots of Pusa Ruby (4387.3 and 4208.7 ppm) compared to L879 (5165.4 and 5654.9 ppm respectively). Pusa Ruby succumed to artificial inoculation after seven days.

2. Total phenols

Total phenol contents in the roots and in whole plant of L&79 were low (329 and 677 ppm respectively) after three days of inoculation compared to uninoculated plants of L&79 (390 and 922.0 p.m respectively). Total phenols increased in Pusa Ruby (511. to 683.7 p.m) after three days of inoculation. Total phenols in roots of L&79 was higher (329 ppm) than that of Pusa Ruby (309 p.m), three days after inoculation, but the content was respectively 430 ppm and 898 ppm seven days after inoculation.

3. O.D. phenols

There was increase in O.D.phenolsin both L&79 and Pusa Ruby after inoculation. The O.D. phenols in root and shoot of L&79 recorded an increase of 299.1% and 117% and 454.1% and 111.6% respectively three and seven days after inoculation compared to 207.9% and 145.2% and 240.3% and 224.1% respectively in Pusa Ruby. The total content in whole plant was more in Pusa Ruby (282.4 p.m) compared to L&79 (202.6 ppm) after seven days of inoculation when Pusa Ruby succumbed to wilt.

4. Vitamin C

The total Vitamin C in Pusa Ruby was more than that in L&79 three and seven days after inoculation. The root content in L&79 was higher (521 and 725 ppm) than that in Pusa Ruby (415 and 602 ppm) at both the intervals.

Table 23a.∝- Tomatine content (ppm) in 60 days old plant on artificial inoculation

	Before inoculation		Three days after inoculation		Seven days after inoculation	
	LE 79	Pusa Ruby	LE 79	Pusa Ruby	LE 79	Pusa Ruby
Root	1891.9	1235.3	8639.4	6749.7	5169.4	4387.3
Shoot	1871.2	1553.1	6181.2	5169.6	5654.9	4208.7
Total	1878.1	1313.8	7000.6	5696.3	5493.1	4268.2

Table 23b. Total phenol content (ppm) in 60 days old plant on artificial inoculation

	Before inoculation		Three days after inoculation		Seven days after inoculation	
	LE 79	Pusa Ruby	LE79	Pusa Ruby	LE 79	Pusa Ruby
Root	390.0	258.00	329.00	309.00	480.0	898.00
Shoot	1183.0	637.00	851.00	871.00	699.5	1543.00
Total	922.0	511.00	677.00	683.70	626.3	1328.00

Table 23c. O.D. phenol content (ppm) in 60 days old plant on artificial inoculation

	Before inoculation		Three days after inoculation		Seven days after inoculation	
	LE 79	Pusa Ruby	LE 79	Pusa Ruby	LE 79	Pusa Ruby
Root	22.0	29.0	65.8	60.3	99.9	69.7
Shoot	227.5	173.5	266.2	252.0	254.0	388.8
Total	159.0	125.0	199.4	188.1	202.6	282.4

Table 23d. Vitamin C content (ppm) in 60 days old plant on artificial inoculation

	Before inoculation		Three days after inoculation		Seven days after inoculation	
	LE 79	Pusa Ruby	LE 79	Pusa Ruby	LE 79	Pusa Ruby
Root	84.3	60.2	521.0	415.0	725.0	602.0
Shoot	210.8	189.7	767.5	1243.0	692.0	1746.5
Total	168.6	148.5	685.0	967.0	703.0	1365.0

D. Shift in relative proportion of ∝- tomatine, total phenols, O.D. phenols and Vitamin C in roots and shoots of 60 days old plants of LE 79 (CL 32d-0-1-1-1-1-19 GS) and Pusa Ruby after artificial inoculation (Table 24).

1. ∝ - Tomatine: total phenols

The ratio of ∝- tomatine to total phenols increased in roots and shoots of both LE79 and Pusa Ruby on artificial inoculation. The ratio was higher in roots and shoots of LE79 than that in Pusa Ruby, three days and seven days after inoculation.

The increase in ratio of - tomatine to total phenol in roots of LE79 was 4.85:1 to 26.3:1 and 4.85:1 to 10.8:1 as against 4.79:1 to 21.8:1 and 4.79:1 to 4.89:1 in Pusa Ruby three days and seven days after inoculation respectively.

2. ∝- Tomatine: O.D. phenols

There was increase in this ratio three days after inoculation in both LE79 and Pusa Ruby and decreased in roots of both lines seven days after inoculation. Pusa Ruby, wilted seven days after inoculation, had higher ratio (62.9:1) compared to uninoculated plants (43.04:1). LE79 which remained healthy seven days after inoculation had a lower ratio in roots (51.7:1) compared to Pusa Ruby. LE79 had higher ratio (22.3:1) in the shoots compared to Pusa Ruby (10.8:1).

3.∝ - Tomatine: Vitamin C

The ratio of - tomatine to Vitamin C recorded a decrease in roots as well as in shoots of both LE79 and Pusa Ruby three days and seven days after inoculation. The wilted plants of Pusa Ruby, seven days after inoculation, had higher ratio in roots (7.3:1) but lower in shoots (2.4:1) compared to LE79, (7.13:1 and 8.2:1 respectively).

4. Vitamin C: Total phenols

This ratio increased in roots and shoots of LE79 and Pusa Ruby three days after inoculation. It decreased in roots seven days after inoculation. There was slight increase (0.9:1 to 1:1) in shoots of LE79 but it showed a decrease (1.4:1 to 1.1:1) in shoots of Pusa Ruby seven days after inoculation.

5. Vitamin C: O.D. phenols

Consequent to inoculation, the ratio increased in roots and shoots of both LE79 and Pusa Ruby. The increase was more, three days after inoculation compared to seven days after inoculation. The wilted plants of Pusa Ruby had a higher ratio in roots (8.6:1) and in shoots (4.5:1) compared to healthy plants of LE 79 (7.3:1 and 2.7:1 respectively).

6. Total phenols: O.D. phenols

On artificial inoculation this ratio narrowed down in both root and shoot of LE79 and Pusa Ruby, three days

Table 24. Relative proportion of different chemical constituents in root and shoot of 60 days old plant - before and after inoculation.

	Before inoculation				Three days after inoculation				Seven days after inoculation			
	LS 79		BR		LS 79		BR		LS 79		BR	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Tomatine: Total phenols	4.85:1	1.58:1	4.79:1	2.43:1	26.3:1	7.3:1	21.8:1	6.3:1	10.80:1	3.1:1	4.89:1	2.7:1
Tomatine: O.D. phenols	85.99:1	8.22:1	43.04:1	8.95:1	131.3:1	23.2:1	111.9:1	20.5:1	51.7 :1	22.3:1	62.9 :1	10.8:1
Tomatine: Vitamin C	22.4 :1	8.87:1	20.5 :1	8.2 :1	16.58:1	8.1:1	16.3:1	4.16:1	7.13:1	8.20:1	7.3 :1	2.4:1
Vitamin C: Total phenols	0.22:1	0.18:1	0.23:1	0.29:1	1.6:1	0.9:1	1.3:1	1.4:1	1.5: 1	1.0 :1	0.7 :1	1.1:1
Vitamin C: O.D. phenols	3.83:1	0.92:1	2.1:1	1.0 :1	7.9:1	2.9:1	6.9:1	4.0 :1	7.3: 1	2.7:1	4.6:1	4.5:1
Total phenols: O.D. phenols	17.7: 1	5.2:1	8.9 :1	3.67:1	5.0 :1	3.2:1	5.12:1	3.5:1	4.8: 1	2.7:1	12.9:1	3.7:1

after inoculation. The ratio was wider in Pusa Ruby compared to LE79 at three and seven days after inoculation. The wilted plants of Pusa Ruby had the ratio 12.9:1 in the roots and 3.97:1 in shoots compared to healthy LE79 (4.8:1 and 2.7:1 respectively) at the same time.

IV. Artificial inoculation studies with the Vellanikkara isolate of *Pseudomonas solanacearum* E.F. Smith

The data on the reaction of resistant LE79 (CL 32d-0-1-1-1-1-19 GS), susceptible (Pusa Ruby), and susceptible scion (Pusa Ruby) grafted on resistant root stock to artificial inoculation with Vellanikkara isolate of *Pseudomonas solanacearum* are presented in Table 25. The susceptible plants and the susceptible scion grafted on resistant root stocks wilted within three weeks of inoculation. The susceptible plants wilted more (70%) in 14 days time compared to grafted plants (35%). The resistant plants remained resistant throughout the observational period. New sprouts appeared on the resistant root stock of grafts whose scions already wilted and withered off.

Table 25. Artificial inoculation studies with the Vellanikkara isolate of *Pseudomonas solanacearum*

Trials	Materials	No.of plants	Plants wilted					
			7 days after inoculation		14 days after inoculation		21 days after inoculation	
			No.	%	No.	%	No.	%
I	LE 79 (CL 32d-0-1-1-1-1-19 GS)	30	-	-	-	-	-	-
	Pusa Ruby	30	13	43.30	21	70.00	30	100
	Pusa Ruby/LE 79	30	5	16.67	11	36.67	30	100
II	LE 79 (CL 32d-0-1-1-1-1-19 GS)	10	-	-	-	-	-	-
	Pusa Ruby	10	3	30.00	7	70.00	10	100
	Pusa Ruby/LE 79	10	-	0.00	3	30.00	10	100
I and II Pooled	LE 79	40	-	-	-	-	-	-
	Pusa Ruby	40	16	40.00	28	70.00	40	100
	Pusa Ruby/LE 79	40	8	20.00	14	35.00	40	100

DISCUSSION

DISCUSSION

Bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith limits tomato cultivation in the warm humid tropics. Management of the pathogen has not been practicable or economically feasible. Existence of many races, presence of varied virulent isolates within each race, fluctuations in the level of virulence as a function of soil temperature, pH, humidity etc. made the control of the pathogen, a cumbersome affair. Evolving bacterial wilt resistant lines with wider adaptability and desirable plant type is the obvious answer to this tangle. Many sources of resistance to wilt are reported. These sources are generally late to fruitset, small-fruited and low yielding. Development of early, large fruited and high yielding tomato lines suited for warm humid tropics would be an ambitious attempt in the right direction. The additive type of gene action reported in wilt resistance mandates for appropriate selection methods for varietal improvement. Ear to-row selection would be more effective in situations where attempts are made to evolve early, large fruited and high yielding lines with bacterial wilt resistance.

Relative efficiency of selection methods

The selection methods mass, pureline and single seed descent, were more effective *per se* to improve fruits/plant,

locules/fruit, yield/plant and fruit weight in all the three consecutive generations. Significant changes were observed for plant height in the first and third generations, days to flower in the first generation, days to fruitset in the second and third generations and days to first harvest in the first and second generations under these selection methods. The high variability present in the base population was utilized to the best advantage using the selection methods. In self pollinated crops like tomato, variability for plant characters can be fixed in one cycle of selection, provided no further gene segregation takes place (Chaudhary, 1968). The efficacy of selection methods like mass under additive and dominance variance (Singh and Singh, 1976), pureline under partial dominance (Hill, 1972) and SSD under several characters with different heritability values were under simultaneous selection (Caseli and Tigchellaar, 1975) were already reported.

Improvement in fruits/plant

SSD method of selection resulted in progenies with maximum fruits/plant (52.53) followed by mass selection (48.17) in the third generation. The selection methods mass, pureline and SSD were equally effective in the first generation also. A low heritability and a high genetic gain were recorded for mass, pureline and SSD selections. A higher realised heritability for mass and higher realised genetic gain for SSD selections were observed. Celine (1981) reported that progenies

developed through mass selection were superior to bulked progenies for fruits/plant. In the present study [illegible] selection had maximum fruits/plant followed by mass selection in the third generation. Tigchellaar and Casali (1972) suggested [illegible] method to improve fruits/plant.

Improvement in locules/fruit

[illegible] and mass selections had the highest locules/fruit (3.9 each) in the third generation followed by pureline selection (3.8). The three methods were equally effective in the first and second generations. High realised heritability and high realised genetic gain were recorded for mass selected progenies. Low realised heritability and high realised genetic gain were recorded in [illegible] and pureline selections. High heritability and high genetic advance were reported for locules/fruit (Nandpuri et al., 1976). Celine (1981) reported that selection response through mass selection was positive for locules/fruit in tomato. The realised genetic gains obtained through mass, [illegible] and pureline selection methods did not differ significantly from each other in the present study.

Improvement in yield/plant

[illegible] selections had maximum yield/plant (1.82 kg) followed by pureline selections (1.52 kg) and mass selections (1.49 kg) in the third generation. Realised heritability was

high for mass selections followed by S.D selections whereas realised genetic gain was the highest for S.D selections followed by pureline and mass selections. Trinklein (1975) reported that additive gene action is involved in the inheritance of total yield. Celine (1981) observed that progenies developed through mass selections were superior for total fruit weight/plant compared to bulks. Nandpuri et al. (1977) reported high heritability and high expected genetic advance for yield/plant. A high heritability associated with low expected genetic advance was observed in pureline selections in the present study. It indicated that high realised heritability was not always associated with high realised genetic gain.

Improvement in plant height

Pureline selections had the maximum plant height in first and third generations (74.9 and 76.6 cm respectively) followed by mass selections (64.3 and 75.7 respectively). S.D selections were the dwarfest in all the three generations. Realised heritability was high for pureline selections in first generation (>50%) and realised genetic gain was high for pureline selections in the first and third generations and low for S.D. Realise heritability and realised genetic gain were low for S.D selections. Nandpuri et al. (1977) reported high heritability for plant height. Singh and Singh (1980) indicated preponderance of additive gene action for plant height. Celine (1981) obtained a positive selection response

for plant height through bulk selection. A low heritability and high expected genetic advance were recorded for bulk selections in the third generations. SPD selections were dwarfer to mass, pureline and bulk selections. Nambouri et al. (1976) reported a negative association of plant height with yield in tomato. Selections through SPD, de facto, had maximum yield/plant compared to other selection methods.

Improvement in days to flower

Days to flower was the lowest for SPD selections in the third generation (53 days) followed by pureline (53.7 days) and mass (54.6 days) selections. They were significantly different from bulks (55.8 days). In the first generation mass and SPD selections had the lowest days to flower (60.3 and 61.4 days respectively) and were significantly different from pureline and bulk selections. Low heritability and low genetic advance indicated that days to flower was conditioned predominently by non-additive gene action as reported by Mittal and Singh (1978). Realised genetic gain was more for mass selections in the first generation and for SPD in third generation. This indicated that variability for days to flower could be fixed in one cycle of selection under mass while SPD selections needed still more number of cycles.

Improvement in days to fruitset

SPD selections were the earliest to set fruit in the

third generation (69.7 days) which was significantly different from other selections. Mass and pureline selections were on par with each other. Heritability and expected genetic advance as well as realised heritability and realised genetic gain were low for days to fruitset under all selection methods. The genotypic coefficient of variation was high for SSD selections followed by pureline and mass selections in the second generation. A high gcv associated with high heritability resulting in high genetic advance was reported for days to fruitset in tomato (Nandpuri et al., 1976). Celine (1981) found progenies developed through pureline selections were superior to bulking for days to fruitset. In the present study SSD selections were superior to mass, pureline and bulks, but with a low realised heritability and realised genetic gain.

Improvement in days to harvest

The SSD and mass selections in the first generation (102 days each), SSD selections in the second generation (95 days) and third generation (96.7 days) took the lowest number of days to first harvest. Heritability and expected genetic gain were low for all selections except SSD selections which had high genetic gain in the third generation. SSD selections also had high realised heritability in the second generation. Mass selections had the highest realised genetic gain in the second generation. Celine (1981) reported that mass selection was superior to reduce days to first harvest and realised

heritability for days to harvest was high (0.88). High heritability resulting in high genetic advance was reported by Mondpuri et al. (1976). They found that days to maturity were predominantly controlled by additive genes. But Kaul and Singh (1978) reported that early yield was predominantly controlled by non-additive gene action. Johnson and Hernandez (1980) found early fruiting was partially dominant. Singh and Singh (1984) observed a high non-additive variance for days to maturity. The present study indicated that high genetic advance was not always associated with high heritability.

Improvement in fruit weight

Mean fruit weight was maximum for [illegible] selections in the first and second generations (47.1 and 33.5 g respectively). This was significantly different from mass, pureline and bulk selections. In the third generation, maximum fruit weight was recorded in pureline selections (50.2 g) followed by [illegible] (43.3 g), mass (43.9 g) and bulk (36.5 g) selections. The mean fruit weight was the lowest for bulk selections in all the generations. Heritability and expected genetic advance as per cent of mean were high for all methods except bulk in all the three generations. The realised heritability was also high for [illegible] selections in the second and third generations (0.97 and 0.94 respectively) followed by pureline selection in the second generation (0.74). Maximum realised genetic gain was recorded for [illegible] selections in the first and

second generations (17.5 and 12.0 respectively) and pureline selections in the third generation (14.3) followed by S$_1$ (11.8) and mass selections (7.4). There was a gradational decrease in realised genetic gain under S$_1$ method from first to third generations. Srivastava and Sachan (1973) reported a high heritability and expected genetic advance for fruit weight in tomato. Celine (1981) reported that pureline selections had more percentage of large fruited plants. In the present study significant improvement in fruit weight was obtained through S$_1$ and pureline selections. Janoria (1976) correlated locules number with fruit weight. There was significant improvement in locules/fruit under S$_1$ and pureline selection methods. Mital and Singh (1978) reported that additive gene action was predominantly involved in fruit weight and locules/fruit (Nandpuri et al., 1976).

Improvement through traitwise selection

There was significant improvement in locules/fruit, days to flower, days to fruitset and days to harvest and fruit weight through traitwise selection.

Selections based on trait combination fruits/plant, yield/plant and plant height had more locules/fruit (4.2) in third generation. Selections based on one particular character will affect changes in associated characters as indicated by the result.

selections based on trait combination fruits/plant, yield/plant, locules/fruit and plant height had the lowest days to flower in the first generation (58.67 days). This was followed by selections based on fruits/plant (60.3 days). Selections based on the trait combinations fruits/plant, locules/fruit and plant height and yield/plant, locules/fruit and plant height took the lowest number of days (58 days each) followed by the trait combination yield/plant and locules/fruit (61.67 days) for fruit set in the second generation. Selections in the second generation, based on fruits/plant and locules/fruit were the first to harvest (92.80 days). In the third generation selections based on fruits/plant and yield/plant were the earliest to first harvest (96.27 days each) followed by selections based on trait combination yield/plant and plant height (97.67 days). The results indicate that selections based on different productive characters along with earliness to flower and to harvest would generate progenies early to flower and early to harvest. Nandpuri et al. (1976) found a significant negative correlation of fruits/plant with plant height and non-significant negative association with days to mature. Days to mature had a negligible direct effect as well as indirect effect on yield.

Maximum improvement in fruit weight was recorded in selections based on trait combination yield/plant and locules/fruit in all the three generations (52.2, 50.0 and 58.5 g

respectively) (Plate-V and VI). Selections based on yield/plant and locules/fruit would seem to effect improvement in fruit weight. Locules/fruit was significantly correlated with fruit weight (Janoria, 1976).

Significant differences were observed for various traits/trait combinations among selection methods for plant height, days to flower, days to fruitset, days to first harvest and fruit weight. The mass selections based on fruits/plant and yield/plant were the earliest to flower (58.0 and 58.4 days respectively) in the first generation. Single seed descent selections based on yield/plant, locules/fruit and plant height were the earliest to set fruits (68.6 days) in the third generation. Mass selections based on fruits/plant and yield/plant and yield/plant and plant height were the earliest to first harvest (86 days each) in the second generation followed by SSD selections based on yield/plant and locules/fruit, yield/plant and plant height and fruit/plant, yield/plant and locules/fruit. Fruit weight was significantly improved by SSD method of selection based on yield/plant and locules/fruit in the first, second and third generations (60.5, 67.5 and 62.4 g respectively) (Plate-VII and VIII). Singh and Singh (1976) opined that mass selection could be used to exploit both additive and dominant variances. Tigchellaar and Casali (1972) suggested SSD method was effective when several characters with different heritability

values were under simultaneous selection. In the present studies, earliness to flower and to harvest were obtained through mass selection. Selections based on different trait combinations were more effective under this method of selection to improve fruit weight, days to fruitset and days to harvest.

Selection response per se through traitwise selection

Selection response in fruits/plant

The trait combinations yield/plant and locules/fruit and that of fruits/plant and locules/fruit per se effected the highest realised genetic gain in the first and second generations (20.71 and 12.75 respectively). In the third generation selections based on yield/plant had the maximum realised genetic gain. The realised heritability was above 50% for selections based on the trait combination yield/plant and locules/fruit in the first and third generations (0.50 and 0.54 respectively) and for selections based on yield/plant it was 0.69 in the third generation. The results showed that yield was very much related to fruits/plant. Fruits/plant was reported as the main yield component (Srivastava and Sachan, 1973; Nandpuri, et al., 1977).

Selection response in locules/fruit

The trait combination yield/plant, locules/fruit and plant height effected the maximum realised genetic gain in the first and third generations (0.8 and 0.7 respectively)

followed by selections based on yield/plant in the second and third generations (0.7 and 0.6 respectively). Realised heritability was low for trait combination yield/plant, locules/fruit and plant height. Selections based on yield/plant had high realised heritability (0.94) in the first generation. Selections based on the combination fruits/plant and yield/plant recorded high realised heritability for locules/fruit (1.0, 0.60 and 0.80 in first, second and third generations respectively) and comparatively low realised genetic gain (0.5, 0.3 and 0.4 respectively). This indicated that simultaneous selection for fruits/plant and yield/plant should be done while selecting for higher locules/fruit.

Selection responses in yield/plant

The realised genetic gain was high for selections based on the combination yield/plant and locules/fruit in the first and second generations (0.728 and 0.327 kg respectively). In the third generation selections based on yield/plant had the highest genetic gain (1.143 kg). It was suggested that selections based on yield/plant would result in maximum genetic gain for yield/plant.

Selection responses in plant height

The selections based on trait combinations fruits/plant, locules/fruit and plant height in the first generation,

fruits/plant and yield/plant in the second generation and yield/plant and plant height in the third generation had the maximum genetic gain (16.64, 15.40 and 17.77 % respectively). The realised heritability was also above 5 % for selections based on $T_{1.3.4}$ (0.71), $T_{1.2}$ (0.62) and $T_{2.4}$ (0.67). Selections based on plant height would result in high genetic gain for plant height due to high heritability as reported by Nimbouri et al. (1977).

Selection response in days to flower

Realised genetic gain for earliness to flower was high for selections based on fruits/plant in the first and third generations (-2.47 and -2.73 respectively) followed by selections based on the combination yield/plant and locules/fruit in the second and third generations (-1.43 and -2.33 respectively). The selections based on the combination fruits/plant, yield/plant and locules/fruit recorded the highest realised heritability (0.87) and realised genetic gain (-7.3) in the first generation. The result indicated earliness to flower could be effected in the advanced generations through selections based on a few yield components associated with earliness.

Selection responses in days to fruit set

The selections based on fruits/plant had the maximum realised genetic gain in the first generation (-0.37). The trait combination fruits/plant, yield/plant, locules/fruit and plant height in the second generation (-8.60) and the combination of yield/plant, locules/fruit and plant height in the second and third generations (-8.60 and 1.10 respectively) had the maximum realised genetic gain.

Selection responses in days to first harvest

Selections based on the combination yield/plant and plant height had higher realised genetic gain in the second generation (-12.73). Similarly selections based on fruits/plant had high realised genetic gain in the third generation (-1.67) and high realised heritability in the second generation (0.76). Selections based on yield/plant also had higher realised genetic gain in the second and third generations (-9.67 and -1.53 respectively) and high realised heritability in the second generation (0.79). The selections based on plant height (T_4) and fruits/plant and yield/plant ($T_{1.2}$) had high realised heritability (0.96 and 0.78 respectively) and higher realised genetic gain (-9.27 and -10.47 respectively) in the second generation.

Selections based on T_1, T_2, T_4, $T_{1.2}$ and $T_{2.4}$ had high realised heritability and high realised genetic gain in the second generation only. This might be due to high variability in the initial generation which resulted in high genetic gain in the subsequent generation. Loss of genetic variability would tend to effect genetic gain negatively in the advanced generation (Muchibauer, et al. 1981). Nandpuri et al. (1976) found negative association between days to mature and fruits/plant.

Selection responses in fruit weight

The realised genetic gain in fruit weight was maximum in selections based on the combination yield/plant and locules/fruit in all the three generations (22.4, 23.5 and 22.0 g respectively) and its realised heritability was more than one. The selections based on yield/plant also had higher realised genetic gain and high heritability in all the three generations (0.63, 0.78 and 0.59 respectively). Selections based on yield/plant and locules/fruit had a definite influence on fruit weight. Janoria (1 76) ascribed high fruit weight to more locules/fruit. Fruit weight was negatively correlated with yield/plant (Srivastava and Sachan, 1973). Genes controlling yield/plant, locules/fruit and plant height are important in effecting fruit weight. The improved fruit weight of the progenies over their parents might be due to transgressive segregation.

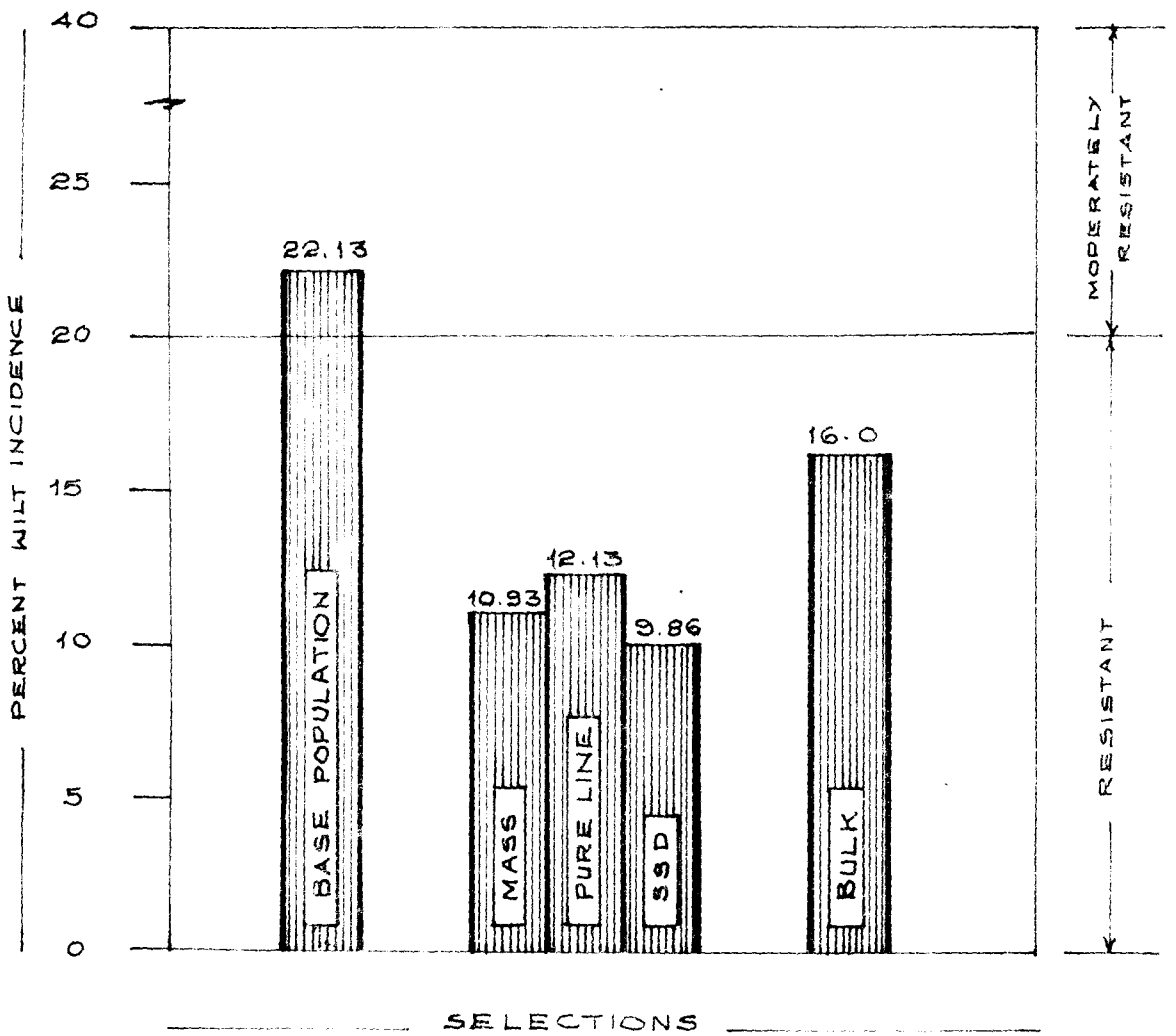
Evaluation for resistance to bacterial wilt

The level of resistance increased substantially in the advance generations. The mean wilt incidence in the base population of CA 326-0-1-19 (C0) was 22.13%. The lowest wilt incidence was recorded under T_1 selection in the third generation (4.36%) followed by mass selections (10.13%) and Pureline selections (12.13%) (Fig.1). The wilt incidence was lower than 10% for selections based on traits/trait combinations T_1, T_2, $T_{1.3}$, $T_{1.4}$, $T_{2.3}$, $T_{3.4}$, $T_{1.2.4}$ and $T_{2.3.4}$ under mass selection, T_3, T_4, $T_{1.2.3}$, $T_{1.3.4}$ and $T_{2.3.4}$ under pureline selection and T_1, T_2, T_3, T_4, $T_{1.2}$, $T_{1.3}$, $T_{2.3}$, $T_{2.4}$, $T_{1.2.3}$ and $T_{1.3.4}$ under the method of selection in the third generation which are termed highly resistant. New and Ho (1976) classified tomato genotypes into four groups based on reaction to Pseudomonas solanacearum. Plants with lesser than 2% wilt incidence were termed resistant. Nashaninov (1984) reported in Brinjal that the progenies developed through this method of selection had higher level of resistance to bacterial wilt. The percentage of wilt was more in the adult stage which highlighted the fact that the resistant lines could delay wilting expression. This observation was earlier stated by New and Ho (1976).

The resistance of the advance generation (C3) of L279 was further tested in multilocational trials. A survival of 94.5% of plants was observed in the trials covering all

Fig.1. Wilt reaction of genotypes evolved through selections

Fig: 1. WILT REACTION OF GENOTYPES EVOLVED THROUGH SELECTIONS



districts of Kerala (Fig.2). The artificial inoculation test with race1 isolate of Pseudomonas solanacearum at IIHR, Bangalore recorded 100% survival. These tests confirmed the improved resistance effected in the line.

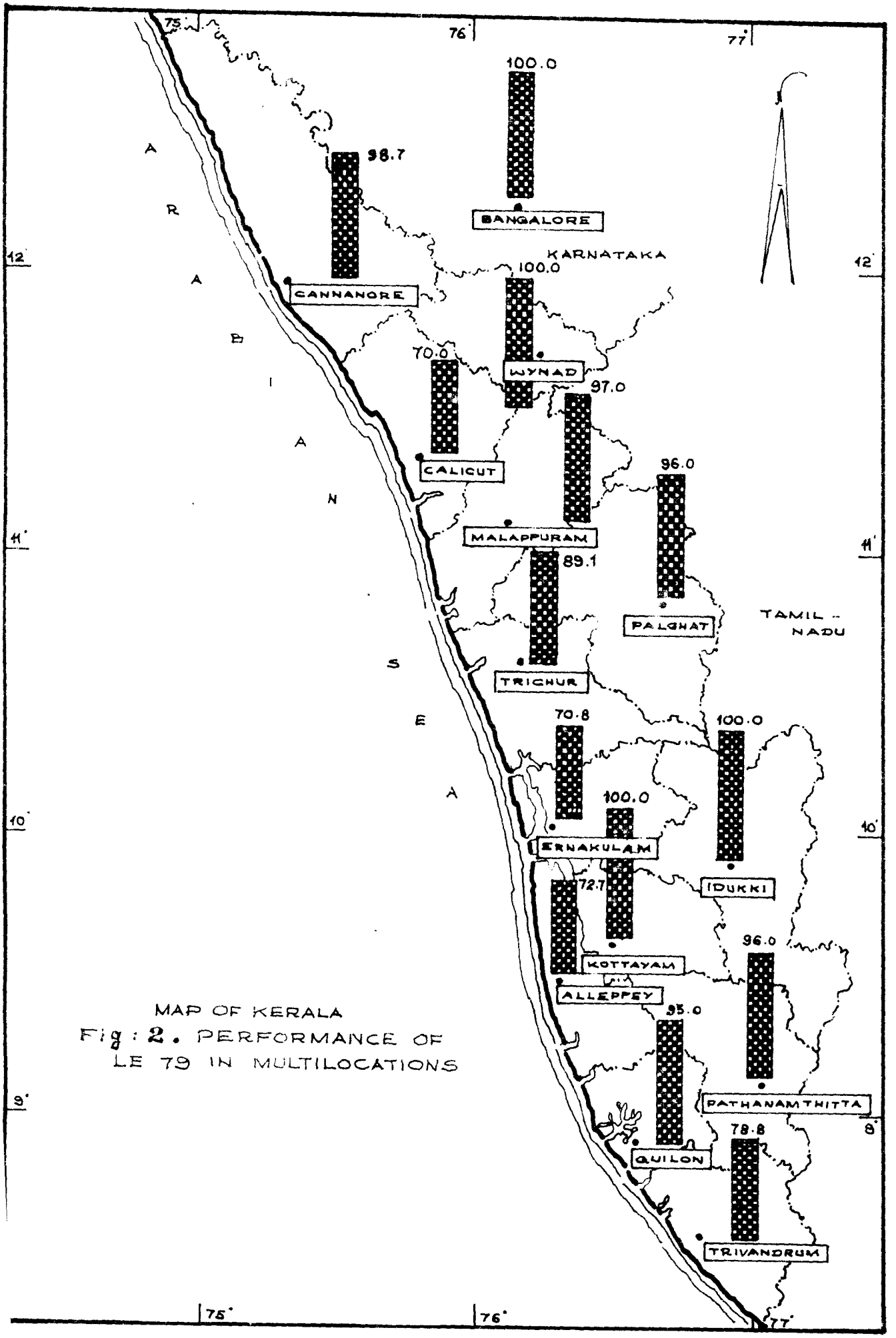
Genetic basis of wilt resistance

Inheritance of wilt resistance

Singh (1961) reported that resistance to bacterial wilt derived from Louisiana Pink was polygenic and recessive. Resistance from Lycopersicon pimpinellifolium (PI 127805 A) was partially dominant in seedling stage and recessive in mature plant stage (Acosta et al., 1964). They inferred that a fewer number of dominant genes were responsible for conferring resistance and indicated a pattern similar to resistance of Brassica campestris to cabbage yellows, wherein multigenic and monogenic resistance mechanisms are involved.

Scott (1966) stated that resistance in Lycopersicon pimpinellifolium to Pseudomonas solanacearum was controlled by a single pair of genes. Suzuki et al. (1964) were of opinion that resistance to Pseudomonas solanacearum appeared to be inherited quantitatively. Kelman (1975) reported that resistance to bacterial wilt was controlled by multiple recessive genes acting additively. Ferrer (1975) observed in a cross between resistant 126408 and susceptible Bonny Best

Fig.2. Performance of Le 79 in multilocations [Survival Per cent]



MAP OF KERALA

Fig: 2. PERFORMANCE OF LE 79 IN MULTILOCATIONS

or Floradel that resistance was polygenically inherited. Villareal and Lais (1978) endorsed the hypothesis of additive gene action for resistance to Pseudomonas solanacearum.

In the present studies the cross between resistant L&79 (CL32d-0-1-1-1-19 GS) with susceptible Pusa Ruby showed that the resistance in L&79 is monogenic and incompletely dominant with a penetrance of 72%. There was a survival of 12% plants in F_1 which indicated that the gene action was incompletely dominant.

The gene system operating in Carolina source of resistance as reported by many workers mentioned above were recessive and polygenic. The inoculation studies by Mew and H (1976) showed that the bacterial wilt resistance was either specific or non-specific indicating two types of resistance mechanism. The different gene systems for wilt resistance operating in tomato were further established by Tikoo et al. (1983). They observed that resistance in CRA 66 was conditioned by multiple recessive genes, while a single dominant gene controls resistance in 6t3-12-3 (VC 8-1-2-1). It is evident from the present studies that yet another bacterial wilt resistance mechanism - monogenic and incompletely dominant gene action - existed in L&79 (CL 32d-0-1-1-1-19 GS).

Association of wilt resistance with qualitative and quantitative characters

The wilt resistant line LE79 and susceptible line Puse Ruby had the yellow gel colour around the seed. This showed that the yellow gel colour around the seed cannot be construed as an indication for association with resistance to bacterial wilt. Acosta *et al*. (1964) reported a few resistant selections which had yellow gel colour around the seeds of the ripening fruits.

Acosta *et al*. (1964) reported that they could get no lines in resistant group with fruits of commercial quality. Report of University of West Indies (1968-69) indicated that resistance to *Pseudomonas solanacearum* had a close linkage with poor fruit characteristics. Annual Report of North Carolina University (1950-51) indicated that certain resistant lines in Hawaii had fruits, too small a size to be of any commercial value. Sunarjano (1980) observed that the resistant line Hawaii 7996 had very small fruits. A probability of 0.15 was only found for association between wilt resistance and fewer locules/fruit (≤ 3). This showed that small fruit size was not closely associated with resistance and there was possibility of getting larger fruits in resistant lines.

Biochemical bases of resistance

Levin (1976) classified chemical substances responsible for resistance to pathogen in to constitutive and induced. Constitutive resistance is based upon the presence of inhibitors prior to contact. Most of the resistances to bacteria, viruses, fungi and nematodes are induced. The line of demarcation between the two classes is not sharply defined. He further observed that chemical compounds which warded off disease incidence in a few species of plant included ∝-tomatine and solanine. These chemicals are highly toxic to small groups of specialised pathogens and thus rendered specific resistance. General resistance was conferred by compounds which deterred, repelled or were weakly toxic to most microorganisms. They included chlorogenic acid, tannin, coumerin etc. Kuc (1964) reported that inhibition of a microorganism might result from the cumulative effect of two or more compounds. Thapliyal and Nene (1967) opined that non-diffusible substances like tomatine and phenols have a key role in defence mechanism.

Tukalo (1958) found that ∝-tomatine content in plant varied with plant part. Kuhn et al. (1952) found the level of ∝- tomatine in Lycopersicon esculentum to be 3000 ppm and much of the variation in ∝- tomatine level was attributed to variety of plant and stage of development. Kuhn et al. (1950) observed tomatine content decreased with age. Sinden et al. (1978)

found the tomatine content affected by age and increased as the plant matured. Remadevi (1978) also found increased level of tomatine in resistant lines compared to susceptible lines and higher ∝- tomatine content in shoots than in roots. Juvick and Stevens (1982) also linked higher levels of ∝- tomatine with increased host resistance in tomato. Mohanakumaran et al. (1969) found that tomatine levels in roots of resistant cultivars increased following infection by bacterium whereas in roots of susceptible cultivars it remained constant or decreased.

In the present studies the root content and total plant content of ∝- tomatine were higher in LE 79, at all stages studied (Fig.3). In 15 days old seedling, the content was the maximum both in resistant LE79 as well as in susceptible Pusa Ruby. This is due to the fact that the resistance level in stem and roots increased rapidly during the first two weeks of seedling growth or when new shoots grew as referred by Bell (1981). The decrease in level of ∝- tomatine on maturity of plant was reported by Kuhn et al. (1957). The shoot had more ∝- tomatine content than roots in both lines as reported by Remadevi (1978). On artificial inoculation the content in root and shoot increased in both the lines after three days of inoculation and then showed a decrease after seven days (Fig.4). The extent of increase was more in resistant lines (1878.1 to 7000.6 ppm) compared to Pusa Ruby (1313.8 to 5696.3 ppm). A higher content was

Fig.3. Biochemical status of LE 79 and Pusa Ruby - before inoculation

Fig: 3. BIOCHEMICAL STATUS OF LE 79 AND PUSA RUBY-BEFORE INOCULATION

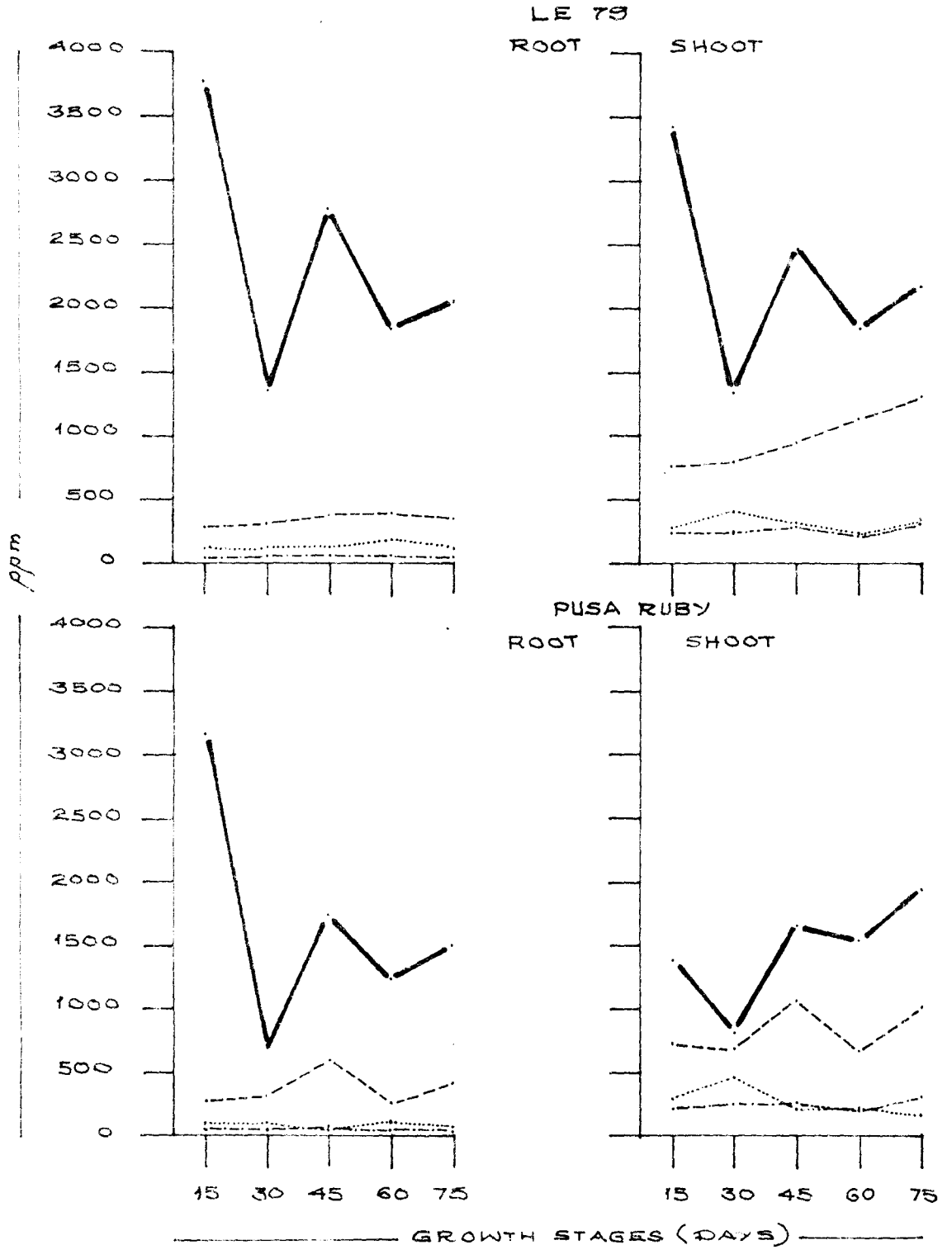
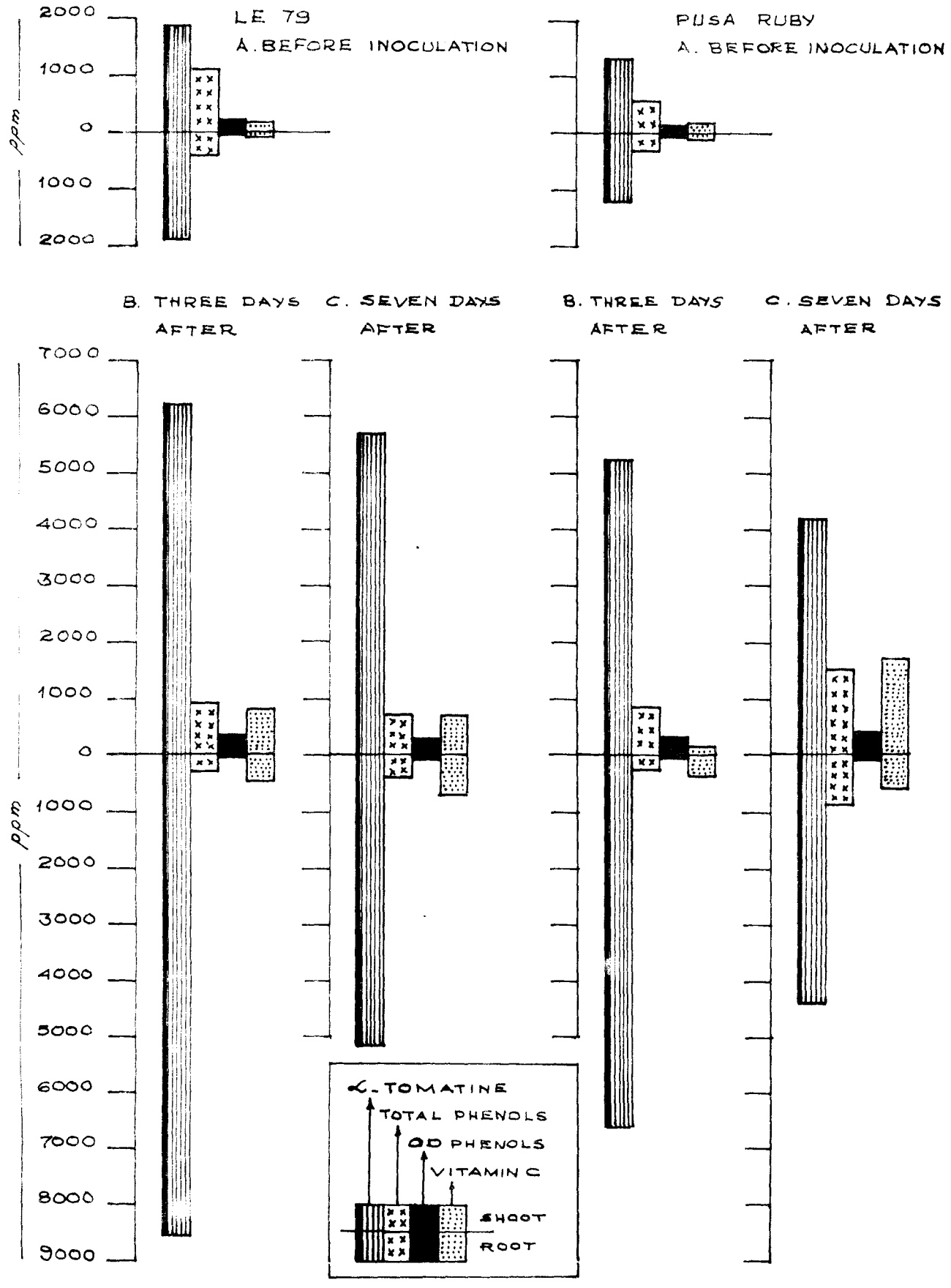


Fig.4. Biochemical status of L2 79 and Pusa Ruby - after inoculation

Fig: 4. BIOCHEMICAL STATUS OF LE 79 AND PUSA RUBY - AFTER INOCULATION



maintained in the roots and shoots of LE79 seven days after inoculation in constrast to Pusa Ruby which had a low level and wilted seven days after inoculation. The higher level ofα- tomatine in LE79 warded off the onslaught of pathogen. Irwing (1947) purported that resistant varieties were able to accumulate the chemical to sufficient level if the need arose. The increased level ofα- tomatine was not maintained in susceptible variety beyond the initial stage of infection in contrast to resistant line.

Protective role of preformed phenolics against disease incidence was already reported (Walker, 1923 and 1926). Lawsence and Gentur (1955) and Menon and Schachinger (1957) reported the role of phenolics in combating diseases in potato and tomato respectively. Thind *et al.* (1981) observed increased level of total phenolics in resistant genotypes and decreased levels in susceptible genotypes of chilli after infection by *Xanthomonas vesicatoria*. Kuc (1964) opined that bacteria are generally not sensitive to phenols as are fungi. In the present investigation, the resistant line had lower total phenols in the roots before and after inoculation compared to susceptible variety. The wilted plants of Pusa Ruby contained more total phenols than resistant plants. This may be due to the fact that total phenols are not directly inhibitory to *Pseudomonas solanacearum*. Mayer and Harel (1979) reported that quinons formed by the oxidation of phenolics are

toxic to extracellular enzymes produced by the pathogen. The lower level of total phenolics in the roots of the resistant line can be ascribed to the increased rate of oxidation of phenolics by oxidising enzymes, as these oxidising enzymes like catechol oxidase was reported to increase following infection. A higher α- tomatine level with low level of total phenols may also be inhibitory to Pseudomonas solanacearum. This line of thinking was initially proposed by Kuc (1964).

The total O.D. phenol content was more in the resistant line than in the susceptible variety at all stages (Fig.3). On artificial inoculation O.D.phenol content increased in both the lines (Fig.4). The root content of LE79 was higher than that of Pusa Ruby three and seven days after inoculation. Seven days after inoculation the total plant content was more in Pusa Ruby which was due to higher increase in shoot content. Pusa Ruby wilted seven days after inoculation which indicated that total content may not be important with regard to resistance. The very fact that O.D. phenol content increased and remained at a higher level on artificial inoculation in resistant line indicated that a higher O.D. phenol level in roots was associated with wilt resistance. Mahadevan (1970) observed that prohibitins were particularly effective at the point of entry and penetration of microorganism and the quantity of prohibitins in the plant part largely determined resistance to parasites.

Thomiyama (1963) observed that aromatic compounds like mono and dihydric phenols increased in most tissues invaded by parasites as a part of resistance mechanism.

Higher contents of vitamin C were observed in the fruits of tomato varieties resistant to fungal diseases (Voronia, 1971; Rattan and Saini 1979). There was reduction in vitamin C content in cucumber mosaic virus susceptible plants compared to resistant plants (Awasthi and Singh, 1975). The total vitamin C content in both L&79 and Pusa Ruby varied with plant age in the present study. The content in root was invariably higher in L&79 at all stages (Fig.3). On artificial inoculation also the root content was higher in L&79 at three and seven days after inoculation (Fig.4). The total content in Pusa Ruby was more and this was due to higher shoot content consequent to artificial inoculation. This indicated that it was not the total plant content, but the higher root content, important for imparting wilt resistance.

The higher total content of α- tomatine and vitamin C in roots of resistant line is significant on the fact that it will act inhibitory or toxic to pathogen at the point of entry into the host. Higher level of O.D. phenolsfound after artificial inoculation in resistant lines implicated its role in wilt resistance. Higher total phenols in the root of susceptible variety at wilted stage showed that it might be due to low rate of conversion of phenolics in susceptible

lines to products like quinons. The contents of these chemicals fluctuated with age which implied that the plant age is associated with resistance as reported by many workers (Winstead and Kelman, 1952; Coyne and Schuster, 1983).

Relative proportion of chemical constituents

The importance of the ratio among the concentrations of different chemicals was suggested in disease resistance (Thomiyama, 1963). The inhibition of a microorganism results from the cumulative effect of two or more compounds (Hampton, 1962; Kuc, 1964).

∝- Tomatine: total phenols ratio

The ratio of∝- Tomatine/total phenols was high in roots of LE79 at all stages studied before inoculation (Table 22). In shoot, the ratio did not show a particular pattern. The ratio after inoculation, increased in roots and shoots of both the lines (Table 24). A high ratio was maintained in roots of LE79 three and seven days after inoculation (26.3:1 and 10.8:1) compared to that of Pusa Ruby (21.8:1 and 4.89:1). Pusa Ruby wilted seven days after inoculation had low ratio, which indicated that a high∝- Tomatine/total phenols ratio was involved in wilt resistance.

∝- Tomatine: O.D. phenols ratio

The ratio was found higher in roots of L&79 at all stages before inoculation (Table 22). The ratio in the shoot varied with age. Consequent to inoculation, the ratio increased in roots of both the lines three days after inoculation but decreased seven days after inoculation (Table 24). The wilted plants of Pusa Ruby had higher ratio (62.9:1) compared to Pusa Ruby before inoculation (43.04:1) as well as L&79 after seven days of inoculation (51.7:1). This showed that there was a simultaneous increase of ∝- tomatine and O.D. phenols on infection in resistant line (Fig.4). Low levels of ∝- tomatine and O.D.phenols tended infection.

∝- Tomatine: Vitamin C ratio

This ratio was also high in roots of L&79 at all stages except in 15 and 75 days old plants. The ratio decreased in roots and shoots of both L&79 and Pusa Ruby three days and seven days after inoculation. The higher ratio in wilted plants of Pusa Ruby (7.3:1) compared to healthy L&79 (7.13:1) indicated higher increase in vitamin C in L&79 after inoculation. This brings about narrow tomatine/vitamin C ratio which implies the role of vitamin C in the wilt resistance mechanism. It is inferred that the relative proportion of Vitamin C to ∝- tomatine is important to impart resistance.

Vitamin C: total phenols ratio

A higher ratio was observed in roots of LE79. Artificial inoculation resulted in increase in the ratio in roots and shoots of both LE79 and Pusa Ruby three days after inoculation. The ratio increased more in roots of LE79 (0.22:1 to 1.6:1) compared to that in Pusa Ruby (0.23:1 to 1.3:1). The ratio went down seven days after inoculation, but to a greater extent in roots of Pusa Ruby (1.3:1 to 0.7:1) compared to that in LE79 (1.5:1 to 1.5:1). This showed that there was greater increase in vitamin C compared to total phenols in LE79 consequent to inoculation and that the role of Vitamin C in wilt resistance is further endorsed. A higher level of vitamin C with relatively lower level of total phenols have a role in wilt resistance.

Vitamin C: O.D. phenols ratio

This ratio was also found high in roots of LE79 compared to that in Pusa Ruby before and after inoculation. The ratio was higher three days after inoculation compared to seven days after inoculation. This showed that Vitamin C content increased to a greater extent compared to O.D. phenols. The wilted plants of Pusa Ruby had higher ratio in the root (8.6:1) compared to healthy plants of LE79 (7.3:1). This was due to the simultaneous higher increase of O.D.phenols in LE79. This

observation further endorsed the role of Vitamin C and O.D. phenols in the resistance mechanism.

Total phenols: O.D. phenols ratio

A high ratio was observed in the roots of Pusa Ruby compared to L879 at all stages except in 60 days old plants before inoculation. On artificial inoculation the ratio became narrower in both roots and shoots of L879 and Pusa Ruby three days after inoculation. This indicated greater increase in O.D. phenols compared to total phenols. The ratio was wider in Pusa Ruby at both the intervals indicating higher content of total phenols than O.D. phenols. The ratio in the roots of wilted plants of Pusa Ruby was 12.9:1 compared to that of healthy L879, 4.8:1. This showed, there was higher O.D. phenol content produced on inoculation compared to total phenols. The presence of higher level of O.D. phenols after inoculation may be due to the increased interconversion or biosynthesis of phenols, which can occur simultaneously. Barz and Hoesel (1979) opined that turnover of phenolic plant products may be due to interconversions which involved in biosynthetic sequences, catabolism and oxidative polymerization reaction. These three metabolic routes may occur simultaneously and their ratio will thus depend on various parameters regulating cellular metabolism. This also indicated that lines with more O.D. phenols and its higher production potential are important for wilt resistance.

It is inferred that wilt resistance was conferred not by a single chemical alone but a combined influence of different chemicals involved. The relative proportion of α- tomatine, total phenols, O.D. phenols, Vitamin C and possibly other chemicals are also involved in the biochemical resistance mechanism in tomato. The levels of different pathogen-inhibitory compounds like α- tomatine, phenols and vitamin C contained in the plant before infection are just not sufficient to combat the pathogen, which needs still higher level to prevail upon the pathogen as the infection progressed. This contingency was met by the increased level produced subsequently. The high content of these inhibitory compounds, de facto, present before infection portends the inherent resistance of plants against the wilt.

Inoculation studies

Grafted plants, Pusa Ruby on L&79, took longer time to wilt. Pusa Ruby, the susceptible variety, wilted more (7% susceptibility) in 14 days compared to grafted plants (35%). Susceptible as well as grafted plants completely wilted in three weeks time (Plate-IX). The resistance of L&79 was confirmed by the healthy sprouts produced from the root stocks even after the scion wilted off (Plate-X). The delay in wilting

of grafts could be attributed to influence of resistant rootstocks. Mew and Ho (1976) reported that the resistant stocks delayed expression of wilt symptoms. On increasing the inoculum density, the resistant varieties became moderately resistant. Kern (1952) opined that the presence of tomatine in sap from decapitated plants suggested possible transport from root to shoot.

In the present inoculation studies, the reasons for delay exhibited by grafted plants to show wilt symptoms need to be further investigated.

Plate - I. A view of tomato crop in the field.

Plate - II. Check plants (Pusa Ruby) showing susceptibility.

Plate - I

Plate - II

Plate - III. Average fruit weight under different selection methods after third generation

Mass	-	43.9 g
Pureline		50.8 g
SSD	-	48.3 g
Bulk	-	36.5 g

Plate -IV. Improved selections under different selection methods.

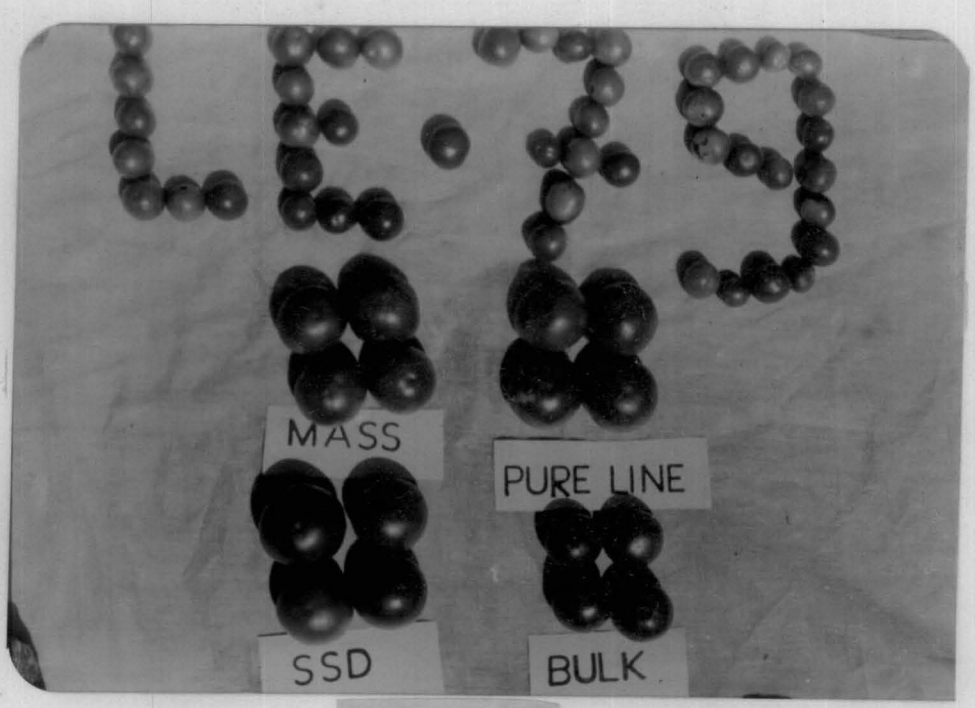


Plate - III

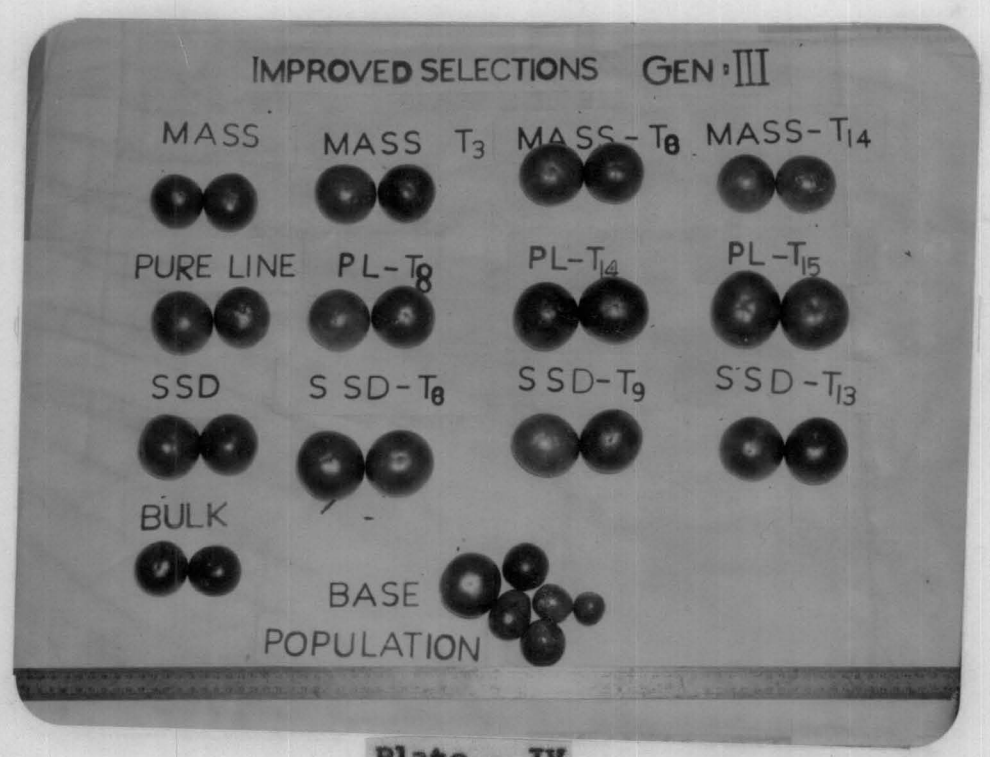


Plate - IV

Plate - V. LE 79 (CL 32d-0-1-19 GS) - Original
Fruit weight - 29.9 g.

Plate - VI. LE 79 (CL 32d-0-1-1-1-1-19 GS) - Improved
Fruit weight - 58.5 g.

Plate - V

Plate - VI

Plate-VII. Promising selection under single seed descent method.

Fruit weight - 62.4 g

Plate-VIII. Promising selection under single seed descent method.

Fruit weight - 57.8 g.

Plate - VII

Plate - VIII

Plate - IX. Wilt reaction on artificial inoculation.

Plate - X. Emergence of new sprouts from root stock of LE 79 (CL 32d-0-1-1-1-1-19 GS).

Plate - IX

Plate - X

SUMMARY

SUMMARY

Attempts were made to improve the tomato line CL 32d-0-1-19 GS for earliness and higher fruit weight along with resistance to bacterial wilt (*Pseudomonas solanacearum* E.F. Smith). Relative efficiency of selection methods - mass, pureline, single seed descent and bulk - was studied. Realised genetic advance through traitwise selections were recorded. The base materials were progressed through continuous selections for three generations. Genetic and biochemical bases of resistance to bacterial wilt were studied in detail. The resistance of the evolved line was tested and confirmed through multilocational trials, both in *vivo* and *in vitro*.

Selection methods - mass, pureline and SSD - were effective to improve fruits/plant, locules/fruit, yield/plant and fruit weight. SSD selections had higher realised genetic gain for fruits/plant (30.97), locules/fruit (0.5) and yield/plant (1.05 kg). SSD selections had higher realised genetic gain and higher realised heritability for days to first harvest. Mass selections recorded higher realised heritability (0.95) for fruits/plant and had high realised heritability (0.65) and realised genetic gain (0.5) for locules/fruit. High genetic advance was not

always associated with high heritability. Under mass selection, variability for days to flower could be fixed in one generation whereas it required more generations under SSD method.

Selections based on trait combination fruits/plant, yield/plant and plant height had significantly higher locules/fruit (4.2). Selections based on fruits/plant, yield/plant, locules/fruit and plant height were the earliest to flower (59 days). Days to first harvest were significantly reduced (96 days) through selections based on fruits/plant and yield/plant followed by yield/plant and plant height (98 days). Fruit weight was significantly improved by selections based on yield/plant and locules/fruit (58.5 g).

Mass selections based on fruits/plant and yield/plant were the earliest to flower in the first generation (58 days). SSD method of selection based on yield/plant, locules/fruit and plant height was the earliest to set fruit (68.6 days) in the third generation. Fruit weight was significantly imoroved by selections based on yield/plant and locules/fruit under SSD method (62.4 g). The SSD method was found more effective in tomato improvement when several characters were under simultaneous selection.

The selections based on fruits/plant, yield/plant and plant height and yield/plant *per se* had high realised genetic

gain for days to first harvest. Selections based on plant height *per se* and fruits/plant and yield/plant had high realised heritability (0.96 and 0.93 respectively) for days to first harvest. Selections based on yield/plant *per se* had high realised heritability (0.59) and selections based on yield/plant and locules/fruit had high realised genetic gain (22.0 g) for fruit weight. Transgressive segregants appeared through selections based on yield/plant and locules/fruit.

Evaluation for wilt resistance showed that the wilt incidence was the lowest for progenies evolved through S&D method (9.86%) followed by mass selection (10.93%), Pureline selection (12.13%) and bulk (16%). Wilt incidence was more in adult stage than in the juvenile stage. The multi-locational trials recorded a plant survival of 89.5%.

Crosses between LE79 (CL 32d-0-1-1-1-1985) and Pusa Ruby indicated a monogenic and incompletely dominant type of gene action. The resistant gene in LE79 had a penetrance of 72%. There was no association between yellow gel colour around the seed and disease resistance. Fewer locules (≤ 3) were not closely linked with resistance. There was higher probability for getting larger fruits in resistant lines.

Biochemical basis of resistance was studied by estimating the content of α- tomatine, total phenols, O.D. phenols and vitamin C in 15, 30, 45, 60 and 75 days old plants. Changes in levels of these chemical constituents were assessed by inoculating 60 days old plants. Fifteen days old seedlings recorded the highest content of α- tomatine in both resistant (LE79) and susceptible (Pusa Ruby) plants. The root and total content of α- tomatine were higher in LE79 than in Pusa Ruby at all stages. On artificial inoculation, the root and shoot content showed a greater increase in LE79 three days after inoculation. The content decreased in both the lines seven days after inoculation, but a higher level was maintained in LE79. Pusa Ruby wilted seven days after inoculation while LE79 remained healthy even after seven days of inoculation.

Total phenols were lower in roots of LE79 than in Pusa Ruby at all stages except in 60 days old plants. After artificial inoculation, total phenols were higher in roots and shoots of Pusa Ruby and wilted plants of Pusa Ruby had higher total phenols than in resistant plants.

Total O.D. phenol content was higher in LE79 than in Pusa Ruby at all stages. On artificial inoculation there was increase in O.D. phenolsin roots and shoots of LE79

three days after inoculation. A higher level was maintained in roots of LE79 seven days after inoculation. Pusa Ruby which had a higher content in shoots and a lower content in roots wilted seven days after inoculation. A higher O.D. phenols in root was involved in wilt resistance.

Vitamin C content was higher in roots of LE79 than in Pusa Ruby. On artificial inoculation also, a higher content was observed in roots of LE79 three days and seven days after inoculation.

The ratio of α- tomatine: total phenols was higher in roots of LE79 at all stages before inoculation. The same trend was maintained in LE79 three and seven days after artificial inoculation. The ratio was found low in the roots of wilted plants of Pusa Ruby. The ratio of α- tomatine: O.D. phenols was higher in roots of LE79 at all stages.

The ratio of α- tomatine: Vitamin C was higher in roots of LE79 than in Pusa Ruby before inoculation at all stages except in 15 and 75 days old plants. The ratio decreased on artificial inoculation due to higher increase of Vitamin C. The wilted plants of Pusa Ruby had higher α- tomatine: vitamin C ratio owing to lower level of vitamin C compared to α- tomatine.

The vitamin C: total phenolswas higher in roots of LE79 except in 60 days old plants. The ratio increased in roots and shoots of LE79 and Pusa Ruby three days after inoculation. The ratio decreased to a greater extent in roots of Pusa Ruby seven days after inoculation. There was higher increase in vitamin C content compared to total phenols in LE79 consequent to artificial inoculation.

Vitamin C: O.D.phenolsratio was higher in roots of LE79 at all stages before inoculation. On artificial inoculation the ratio increased in roots and shoots of both LE79 and Pusa Ruby. The ratio was found higher in roots and shoots of wilted plants of Pusa Ruby due to lower content of O.D.phenolscompared to vitamin C. Vitamin C and O.D.phenols were implicated in wilt resistance.

The ratio of total phenols O.D.phenolswas found higher in roots of Pusa Ruby than in LE79 at all stages except 60 days old plants. The ratio became narrower in roots and shoots of LE79 and Pusa Ruby three days after inoculation. There was greater increase in O.D.phenols compared to total phenols in the resistant line.

The artificial inoculation studies showed that LE79 was resistant to Vellanikkara isolate of Pseudomonas solanacearum E.F. Smith. Grafting of susceptible scion on resistant root stock delayed wilting of infected scion.

REFERENCES

REFERENCES

Aberdeen, J.S.C. 1946. Experiments in the control of bacterial wilt of tomatoes in South Eastern Queensland. Bul. Dept. Agric. Queensland 30: 1-5.

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

Acosta, J.C. 1964. Genetic analysis of bacterial wilt resistance and other characters in a tomato cross. Lycopersicon esculantum x Lycopersicon pimpinellifolium. Diss. Abstr. 25: Order No.64-2645. p. 746.

Acosta, J.C., Gilbert, J.C. and Quinon, V.L. 1964. Heritability of bacterial wilt resistance in tomato. Proc. Amer. Soc. Hort. Sci. 84: 455-462.

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

*Agarwal, G.P. and Bisen, P.S. 1978. Accumulation of phenols in tomato leaves by plant-fungi interaction. Natl. Acad. Sci. Lr. 1: 285-286.

Allison, P.V.B. 1952. Relation of solanine content of tomato fruits to colonization by Colletotrichum phomoides. Phytopathology 42: 1 (Abstr.).

Annual Report of Agriculture, 1950-51. Agriculture astride the century. School of Agriculture, North Carolina State College, North Carolina, 96 pp.

Arneson, P.A. and Durbin, R.D. 1967. Hydrolysis of tomatine by Septoria lycopersici: a detoxification mechanism. Phytopathology 57: 1358-1360.

Asha Sanker, M. 1984. Efficiency of four methods of selection in brinjal improvement in relation to resistance to bacterial wilt. M.Sc. (Hort.) thesis submitted to Kerala Agricultural University, Kerala. 55 pp.

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

Avdeyev, Y.I. 1979. Inheritance to concentric cracking. Tomato Genet. Coop. Reptr. 29: 20-21.

Averre, C.W. and Kelman, A. 1964. Severity of bacterial wilt as influenced by ratio of virulent to avirulent cells of Pseudomonas solanacearum in inoculum. Phytopathology 54: 779-785.

AVRDC, 1975. Genetic study of resistance to bacterial wilt. Tomato Reptr., 1975, pp.24-25.

AVRDC, 1978. Progress Report for 1977. Asian Vegetable Research and Development Centre, Taiwan, 90 pp.

AVRDC, 1980. Progress Report for 1980. Asian Vegetable Research and Development Centre, Taiwan, 110 pp.

Awasthi, R.N. and Singh, B.P. 1975. Influence of Cucumber mosaic virus on ascorbic acid and capsaicin content from the fruits of tolerant and susceptible varieties of chilli. Indian Phytopath. 28: 272-274.

*Baldacci, E. 1977. Diagnosis and diseases. Rivista di Patologia, Vegetale, IV 13: 5-20.

Barz, W. and Hoesel, W. 1979. Metabolism and degradation of phenolic compounds in plants. (In) Swain, T., Harborne, J.B. and Sumere, C.F.V.(eds), Recent advances in phytochatology, Vol.12.Plenum Press, Newyork, pp.339-340.

Badekar, H.S. 1977. Reactions of four tomato cultivars to different mixtures of isolates of Pseudomonas solenacearum. Veg. Sci. IV: 1-5.

*Beech, F.W. and Carr, J.G. 1955. A survey of inhibitory compounds for the separation of yeasts and bacteria in apple juices and ciders. J. Genl. Microbiol. 12: 85-94.

*Belalcarzar, C.S., Uribe, G.M. and Thurston, Y.H.D. 1968. The investigation of hosts of Pseudomonas solenacearum in Colombia. Rev. just. Colomb Agropec. 3: 37-46.

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

Bhatia, I.S., Uppal, B.S. and Bajaj, K.L. 1972. Study of phenolic contents of resistant and susceptible varieties of tomato in relation to early blight disease. Indian Phytopath. 25: 231-35.

*Bhuller, B.S., Bajaj, K.L., Bhatia, I.S. 1972. Studies on the phenols of resistant and susceptible varieties of chillies in relation to anthracnose disease. Phytopath.Z. 75: 236-240.

Boerma, H.R. and Cooper, R.L. 1975. Comparison of three selection procedures for yield in soybeans. Crop. Sci. 15: 225-229.

Brim, C.A. 1966. A modified pedigree method of selection in soybean.Crop. Sci. 6: 220.

Buddenhagen, I.W. 1960. Strains of Pseudomonas solanacearum in indigenous hosts in banana plantations of Costa Rica and their relationship to bacterial wilt of bananas. Phytopathology 50: 660-664.

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

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

Buddenhagen, I.W. 1968. Banana diseases in the pacific area. Plant Prot. Bul. F.A.O. 16: 17-31

*Burton, G.W. 1952. Quantitative inheritance in grasses. 6th Int. Grassld. Cong. Proc. 1: 177-183.

*Bustinza, F. 1947. Tomatine. Farm nueva 12: 15-16.

Butler, L. 1962. The effect on fruit size of the genes on chromosome 2 of the tomato. Genetics 47: 946 (Abstr.).

*Butler, L. 1973a. Fruit size inheritance in the tomato. Can. J. Genet. and Cytol. 15: 655.

Butler, L. 1973b. Tomato fruit-size segregation in F2 selection. Genetics 74: 336.

*Butler, L. 1976. The inheritance of some quantitative characters in the tomato. Genet. Agraria 30: 261-274.

Casali, V.W.D. and Sigchellaar, E.C. 1975. Breeding progress in tomato with pedigree selection and single seed descent. J. Amer. Soc. Hort. Sci. 100: 362-367.

Celine, V.A. 1981. Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt. Master's thesis submitted to Kerala Agricultural University, Kerala, 69 pp.

Chattopadhyay, S.B. and Mukhopadhyay, N. 1968. Outbreaks and New Records. Plant Prot. Bul. F.A.O. 16: 52-53.

Chaubey, C.N. 1979. Mass selection for seed yield in toria. Indian J. Genet. 39: 198-200.

Chaudhary, R.C. 1968. Introduction to plant breeding. (1st edn.) Oxford and IBH Publishing Co., New Delhi, pp.70-79.

Cheema, D.S. 1982. Studies on improvement of chillis for resistance to antracnose and cercospora leaf spot disease. Ph.D. thesis. University of Agricultural Sciences, Bangalore.

Chester, K.S. 1950. Nature and prevention of plant diseases. (2nd edn.). MacGraw Hill Book Co. Inc. New York, 525 pp.

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

Chupp, C. and Sherf, A.F. 1960. Vegetable Diseases and their control. The Ronald Press Co., New York, 695 pp.

Coyne, D.P. and Schuster, M.L. 1983. Genetics and Breeding for Resistance to Bacterial pathogen in vegetable crops. HortScience 18: 30-36.

Cruickshank, I.A.M. 1963. Phytoalexins. Ann. Rev. Phytopath. 1: 351-374.

*Daly, P. 1973. Studies of 3 tomato varieties tolerant to Pseudomonas solanacearum. Agron. Trop. 28: 29-33.

Das, C.R. and Chattopadhyay, S.B. 1955. Bacterial wilt of egg plant. Indian Phytopath. 8: 130-135.

*Dukes, P.D., Morton, D.J., and Jenkins, S.F. 1965. Infection of indigenous hosts by Pseudomonas solanacearum in South Georgia. Rev. Appl. Mycol. 45: 121 (Abstr.).

Falconer, D.S. 1981. Introduction to quantitative Genetics (2nd edn.). Oliver and Boyd, Edinburgh, pp.170-187.

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

Federal Biological Institute of Agriculture and Forestry in Berlin and Brunswick, 1976. Ann. Reptr. 140 pp.

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

Fontaine, T.D., Irving, G.W.Jr., Ma, R., Poole, J.B. and Doolittle, S.P. 1948. Isolation and partial characterization of crystalline tomatine - an antibiotic agent from the tomato plant. Arch.Biochem. Biophy. 18: 467-475.

Galleqly, M.C. and Walker, J.C. 1949. Relation of environmental factors to bacterial wilt of tomato. Phytopathology 39: 936-946.

*Ghgy Jr., A.G. 1958. (In) Roddick, J.G. 1974. Steroidal glycoalkaloids - tomatine. Phytochemistry 13: 9-25 P.

Goodman, R.N., Kirlay, Z. and Zaittin, M. 1967. The biochemistry and physiology of infectious plant disease. Van Nostrand Co., Princeston, New Jersey, pp.354.

Goth, R.W., Peter, K.V. and Webb, R.E. 1983. Effect of root knot nematode in bacterial wilt of tomato. Phytopathology 73: 966 (Abstr.).

Grafius, J.E. 1965. Shortcuts in plant breeding. Crop. Sci. 5: 377.

Graham, K.K. and Yap, T.C. 1976. Studies on bacterial wilt. I. Inheritance of resistance to Pseudomonas solanacearum in tomato. Malaysian Agric. Res. 5: 1-8.

Graham, K.M., Tan H., Chong, K.V., Yap, T.C. and Vythilingam, S. 1977. Breeding tomatoes for low lands of Malaysia. Res. Pub. Malaysian Appl. Biol. 1: 34.

*Hampton, R.E. 1962. Changes in phenolic compounds in carrot root tissue infected with Thielaviopsis basicola. Phytopathology 52: 413-415.

Harrison, D.S. 1961. Bacterial wilt of potatoes. 1.Field symptoms of the disease and studies on the casual organism. Pseudomonas solanacearum variety asiaticum. Aust. J. Agric. Res. 12: 854.

Hayward, A.C. 1961. Geographical variation in Pseudomonas solanacearum J. Appl. Bact. 24: 5-11.

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

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

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

Hildebradt, A.C. 1950. Some important galls and wilts of plants and the inciting bacteria. Biol. Rev. 14: 259-272.

*Hill, W.G. 1971. Theory of limits of selection with line crossing. (In) Kojima, K.I. (ed.), Biomathematics. Springer-Verlag, Berlin, pp. 210-245.

Husain, A. and Kelman, A. 1956. Mode of pathogenesis of Pseudomonas solanacearum. Phytopathology 45: 16 (Abstr.).

Husain, A. and Kelman, A. 1957. Presence of pectic and cellulolytic enzymes in tomato plants infected by Pseudomonas solanacearum. Phytopathology 47: 111-112.

Husain, A. and Kelman, A. 1958. Relation of slime production to mechanism of wilting and pathogenicity of Pseudomonas solanacearum. Phytopathology 48: 155-165.

*IITA, 1978. Annual Report, International Institute of Tropical Agriculture, Ibadan, Nigeria, vi.130 pp.

*IRAT, 1970. Annual Report of the IRAT. Agron. Trop. 27 (1): 183 (Abstr.).

Irwing, Jr. G.W. 1947. The significance of tomatine in plant and animal diseases. J. Wash. Acad. Sci. 37: 293-296.

Ishizaka, N. Sato, N. and Tomiyama, K. 1971. Some observations on behaviour of the newly recognized fungistatic substance rishitin. Res. Bul. Hokkaido Natl. Agric. Expt. Sta. No.99, 62-66.

Janoria, M.P. 1976. Note on the variation in flesh content and its relationship with weight, locule number and length: breadth ratio of fruits in tomato. Indian J. Agric. Sci. 46: 237-238.

Jenkins, Jr. S.F., Mortan, D.J. and Dukes, P.D. 1967. Comparison of techniques for detection of Pseudomonas solenacearum in artificially infested soils. Phytopathology 57: 25-27.

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

Johnson, C.E. and Hernandez, T.P. 1980. Heritability studies of early and total yield in tomatoes. Hort Science 15: 280.

Juvick, J.V. and Stevens, M.A. 1982. Inheritance of foliar α- tomatine content in tomatoes. J. Amer. Soc. Hort. Sci. 107: 1061-1065.

*Kann, F. 1977. Recent state of affairs and outlook for using varietal resistance to bacterial wilt in tomato. Nouvelles Agronomiques des Antilles et dela Guyane, 3: 622-625.

*Kann, F. and Laterrot, H. 1977. Demonstration of the relationship in tomato between resistance to vascular diseases - bacterial wilt and pathotype 2 of Fusarium wilt. Annales de Amelioration des Plantes. 27: 25-34.

*Kelman, A. 1953. The bacterial wilt caused by Pseudomonas solanacearum. A literature review and bibliography. North Caroline Agric. Expt. Sta. Tech. Bul. 99, 194 pp.

Kelman, A. 1954. The relationship of pathogenecity of Pseudomonas solanacearum to colony appearance in tetrazolium chloride medium. Phytopathology 44: 693-695.

Kelman, A. 1967. Inoculation with a wilt - inducing phytopathogenic bacterium. Laboratory Exercises in plant pathology. American phytopathological society: 3340 pilot Knob Road, St. Paul MN 55121, pp.5-7.

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

Kelman, A. and Sequeria, L. 1965. Root to root spread of Pseudomonas solanacearum. Phytopathology, 55: 304-309.

Kerala Agricultural University, 1981. Package of Practices Recommendations. Director of Extension, Kerala Agricultural University, Vellanikkara, India, pp. 172-173.

*Kern, H. 1952. On the relations between the alkaloid content of different tomato varieties and their resistance to Fusarium lycopersici. Phytopath. Z. 19: 351-382.

Keshwal, R.L. and Joshi, L.K. 1976. Variation in Pseudomonas solanacearum. Indian J. Microbiol. 16: 94-97.

*Khristov, A. 1968. Bacterial wilt, a dangerous disease of tomato and other plants in Bulgaria. Gradinarstvo, 13: 27-28.

Krausz, J.P. and Thurston, H.D. 1975. Break down of resistance to Pseudomonas solanacearum in tomato. Phytopathology 65: 1272-1274.

*Kubicki, B. and Michalska, A.M. 1978. Transgression of early yield in hybrids of early forms of tomato. Genet. Polon. 19: 291-307.

Kuc, J. 1964. Phenolic compounds and disease resistance in plants. (In) Runneckles, V.C. (ed) Phenolics in Normal and Diseased fruits and vegetables. Plant Phenolic group of N. American Symp. Proc Imperial Tobacco Co., Montreal. pp. 63-81.

Kuc, J. 1968. Biochemical control of disease resistance in plants. World Rev. Pest Control 7: 42-55.

Kuc, J. and Rahe, J.E. 1970. Factors affecting gene expression as key to disease resistance in plants. Arq. Inst. Biol. S. Paulo 37: 1-7.

*Kuhn, H., Low, I. and Gauke, A. 1950. The alkaloid glycoside of Lycopersicon esculentum and its action upon larvae of the potato bug. Chem. Ber. 83: 448-452.

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

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

Lawsence, A.S. and Gestur, J. 1955. The inhibitory effect of phenolic compounds on the growth of Streptomyces scabies as related to the mechanism of scab. Phytopathology 45: 626-28.

Levin, A.D. 1976. The chemical defenses of plants to pathogens and herbivores. Ann. Rev. Ecol. Syst. 7: 121-53.

Libman, G., Leach, J.G. and Adams, R.E. 1964. Role of certain plant-parasitic nematodes in infection of tomatoes by Pseudomonas solanacearum. Phytopathology 54: 151-153.

Lin, C.Y. 1979. Studies on resistance of tomato to bacterial wilt disease caused by Pseudomonas solanacearum E.F.Smith. Diss. Abstr. Intl. B 40: 533.

*Logano, T.J.C. 1965. Bacterial wilt (Moko) of plantain caused by Pseudomonas solanacearum. Agric. trop. 21: 557-562.

Lucas, G.B., Sasser, J.N. and Kelman, A. 1954. The effect of root knot nematode on the expression of Granville wilt resistance in tobacco. Phytopathology 44: 497.

*Lum, K.V. and Wong, H.K. 1976. Control of bacterial wilt of tomatoes in low lands through grafting. MARDI Res. Bul. 4: 28-33.

Mahadevan, A. 1970. Prohibitins and disease resistance. Phytopath. Z. techr. 68: 73-80.

Mahadevan, A. 1973. Theoretical concepts of disease resistance. Acta. Phytopath. 8: 391-423.

Mahadevan, A. and Sridhar, R. 1982. Methods in physiological plant pathology. (2nd edn.). Sivakami publications, Indira Nagar, Madras, 316 pp.

*Matta, A., Gentile, I.A. and Giai, I. 1968. Variations in soluble phenol content induced by F. oxysporum f. lycopersici. in susceptible and resistant tomato plants. Ann. Fac. Sci. Agric. Uni. Torino. 4: 17-32.

Mayer, A.M. and Harel, E. 1979. Polyphenol oxidases in plants. Phytochemistry 18: 193.

*Menon, R., and Schachinger, L. 1957. Die Rolle des phenols beider Widerstandsfahigkeit von Tomatenpflansen gegen infektionen. Ber. Otsch. Bot. Ges. 70:11-20.

Mew, T.W. and Ho, W.C. 1976. Varietal resistance to bacterial wilt in tomato. Plant Dis. Reptr. 60: 264-268.

Mew, T.W. and Ho, W.C. 1977. Effect of soil temperature on resistance of tomato cultivars to bacterial wilt. Phytopathology 67: 907-911.

Miller, J.H. 1940. Plant disease notes for Georgia. Plant Dis. Reptr. 24: 258.

Mital, R.K. and Singh, H.N. 1978. Genetics of yield and its components in tomato. Indian J. Agric. Sci. 48: 159-162.

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

Muchibauer, F.J., Burnell, D.G., Bogyo, T.P. and Bogyo, M.T. 1981. Simulated comparisons of single seed descent and bulk population breeding methods. Crop Sci. 21: 572-577.

Muller, K.O., 1959. Hypersensitivity. (In) Horsfall, J.G. and Dimond, A.E. (eds). Plant pathology - an advanced treatise, Academic Press, New York, pp.469-519.

Nandpuri, K.S., Kanwar, J.S. and Lal, R. 1976. Correlation, path analysis and regression studies in tomato. Veg Sci. 3: 37-40.

Nandpuri, K.S., Kanwar, J.S. and Lal, R. 1977. Variability, path analysis and discriminant function selection in tomato. Haryana J. Hort Sci. 6: 73-78.

Narain, A. and Mohapatra, B.N. 1973. Factors controlling resistance of chilli leaves to Colletotrichum capsici. Indian Phytopath. 26: 364-65.

*Okabe, N. 1969. Population changes of Pseudomonas solanacearum and soil microorganisms in artificially infested natural field soils. Fac. Agric. Bul. Shimooka Univ. 19: 1-29.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical methods for Agricultural workers (3rd edn.). ICAR, New Delhi-1. pp.68-75, 187-202.

Park, M. and Fernando, M. 1938. The relative resistance of some tomato varieties to bacterial wilt (Bacterium solanacearum) Trop. Agric. 91: 333-337.

Peach, K. and Tracey, M.V. 1955. Modern methods of plant analysis. Vol.III, Springer - Verlang, Berlin, pp.689-693.

Pegg, K.G., Moffett, M.L. and Colbran, R.C. 1974. Diseases of ginger in Queensland. Agric. J. Queensland 100: 611-618.

Peter, K.V. and Rai, B. 1976a. Potentialities for genetic improvement of yield and yield components in elite tomato germplasm. Pantnagar J. Res. 1: 98-103.

Peter, K.V. and Rai, B. 1976b. Genetic divergence in tomato. Indian J. Genet. 36: 379-384.

Pierce, L.C. 1977. Impact of single seed descent in selecting for fruitsize, earliness and total yield in tomato. J. Amer. Soc. Hort. Sci. 102: 520-522.

Ponnuswamy, V. and Muthukrishnan, C.R. 1980. A study of inter and intra generation correlation coefficients in F_2 and F_3 generation of tomato. South Indian Hort. 28 (3): 39-43.

Prasad, A. and Prasad, R. 1977. Variability and correlation studies in tomato (Lycopersicon esculentum Mill.) Indian J. Agric. Sci. 47: 80.

*Prokoshev, S.M., Petrochenko, E.I. and Baranova, V.Z. 1952. Variability of tomatine content in tomato leaves. Doklady Akad. Nauk. S.S.S.R. 83: 261-264.

Rajanna, A., Lal, G. and Peter, K.V. 1977. Heterozygote advantage as a function of genetic divergence in tomato. Indian J. Agric. Sci. 47: 434-437.

Rao, C.R. 1973. Linear statistical influence and its application. (2nd edn.). John Wiley and Sons, New York, pp. 412-414.

Rao, M.V.B. 1977. Races of Pseudomonas solanacearum. Indian J. Plant Prot. 5: 38-39.

Rao, M.V.B., Sohi, H.S. and Tikoo, S.K. 1975. Reactions of wilt resistant tomato varieties and lines to Pseudomonas solanacearum in India. Plant Dis. Reptr. 59: 734.

Rath, P.K. and Addy, S.K. 1977. Variation in Pseudomonas solanacearum causing bacterial wilt of tomato. Indian Phytopath. 30: 502-506.

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

*Ravise, A. and Tangury, J. 1971. Relations between phenolic constituents of different Lycopersicum Mill. species and their resistance to several species of Phytophthora. de Bary. Comptes Rendus Hebdomadaires des sciences de l Academic des sciences. D 272: 1252-1255.

Remadevi, L. 1978. Bacterial wilt of tomato in Kerala - host range and survival of the pathogen and control. Ph.D. thesis submitted to Kerala Agricultural University, Vellanikkara, 168 pp.

Report of the Faculty of Agriculture, University of West Indies 1968-69. pp.15+55+112.

*Revilla, M., V.A. and Vargas, R.L.A. 1967. Moko disease of banana in peru. Rev. appl. Mycol.47: 357.

Roddick, J.G. 1974. The steroidal glycoalkaloid - tomatine. Phytochemistry 13: 9-25.

Russel, G.E. 1978. Plant Breeding for pest and disease Resistance. Butterworths, London, pp.190-193.

*Sakai, R. and Takemori, K. 1964. Relation between physiological factors related to phenols and varietal resistance of potato to late blight. II. Experiments with potato tubers. Ann. Phytopath. Soc. Japan 29: 120-127.

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

*Schaub, I.O. and Baver, L.D. 1944. Research and Farming. (In) 67th Rptr. North Carolina Agric. Expt. sta. No.4, pp.27-31.

Sequeria, L. and Kelman, A. 1962. The accumulation of growth substances in plants infected by Pseudomonas solanacearum. Phytopathology 52: 439-448.

*Serere Research Station 1970-71. Annual Report Part I & II. Serere Research Station, Plant. Breed. Abstr. 44: Abstr. 6459.

*Sicho, V. 1956. Tomatine in food industry. Priimysl. potravin 7: 223-224.

*Sicho, V. and Mrhova, O. 1961. Effect of tomatine on enzymatic system of Escherichia coli. Tagungsber. Deut. Akad. Landwirtschaftswiss. Berlin 27: 291-295.

Sinden, S.L., Schalk, J.M. and Stoner, A.K. 1978. Effects of day length and maturity of tomato plants on tomatine content and resistance to colorado potato beetle. J. Amer. Soc. Hort. Sci. 103: 596-600.

*Singh, K. 1961. Inheritance of North Carolina type of bacterial wilt resistance in tomato. Lycopersicon esculentum L. Master's thesis, University of Hawaii, Honolulu, 91 pp.

Singh, G. and Bedi, P.S. 1976. Phenolic and sugar contents of gram cultivars resistant and susceptible to Operculella podwickii. Indian Phytopath. 29:191-192.

Singh, R.K. and Chaudhary, B.D. 1979. Biometrical methods in quantitative genetic analysis. (Revised edn.). Kalyani Publishers, Ludhiana, pp.9-10.

Singh, A. and Singh, H.N. 1976. Genetics of quality components in chilli. Indian J. Genet. 36: 84-85.

Singh, R.R. and Singh, H.N. 1980. Notes on variance components in tomato. Indian J. Agric.Sci. 50: 361-363.

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

Sohi, H.S., Rao, M.V.B., Rawal, R.D. and Keshun, R. 1981. Effect of crop rotation on bacterial wilt of tomato and egg plant. Indian J. Agric. Sci. 51: 572-573.

Som, M.G. and Chaudhary, B. 1976. Changes in phenol content of resistant and susceptible lines of tomato in response to leaf curl virus infection. J. Soc. expt. Agric. 1: 53-54.

Sonoda, R.M., Augustine J.J. and Volin, R.B. 1979. Survival and yield in late fall of tomato lines with partial resistance to bacterial wilt. Res. Reptr. Agric. Res. Centre, Fort Pierce No.RL 1979-5, 5 pp.

Sonoda, R.M., Augustine, J.J. and Volin, R.B. 1980. Bacterial wilt of tomato in Florida; history, status, and sources of resistance. Fla. State Hort. Soc. Proc. 92: 100-102.

Srivastava, L.S. and Sachan, C.P. 1973. Genetic parameters, correlation coefficient and path coefficient analysis in tomato. Indian J. Agric. Sci.43:604-607.

*Stefanovakrusteva, L. 1980. Relation between some vegetative characters and yield in determinate tomato varieties. Abstr. Bulgarian Sci. Literature. A 25, Abstr.443.

Stoessl, A. 1969. Antifungal compounds produced by higher plants.(In) Recent advance in phytochemistry Vol.3. Meredith corporation, New York, pp.165-171.

*Sumarjono, H. 1980. Increasing tomato production, disease resistant varieties show promise. Indonesian Agric. Res. Devlpmt. J. 2: 5-7.

*Suzuki, I., Sugahara, Y., Kotani, A., Tadaka, S. and Shimada, H. 1964. Studies on breeding egg plants and tomatoes for resistance to bacterial wilt I. Investigation on method of evaluating the resistance and on source of resistance in egg plants and tomatoes. Hort. Res. Sta. Ser. Bul. A No.3: 77-106.

Swarup, V. 1977. Breeding procedures for cross-pollinated vegetable crops. ICAR, New Delhi, pp.10-11.

*Temiz, K. 1968. Investigations on the role of plant parasitic nematodes in the infection of tomato varieties with Pseudomonas solanacearum. Yalova Bahce Kulturleri Arastima Ve Egitim Merkezi Dergisi, 1: 17-18.

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

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

Thomiyama, K. 1963. Physiology and biochemistry of disease resistance of plants. Ann. Rev. Phytopath. 1: 295-324.

Tigchellaar, E.C. and Casali, V.W.D. 1972. Application of the method of single seed descent to tomato improvement. Hort Science 7: 350.

Tikoo, S.K., Anand, N. and Kishun, R. 1983. Presence of two independent genetic systems for resistance to bacterial wilt (Pseudomonas solanacearum). 15th Intl. Cog. Genet. Proc. Abstr. 1338.

Trinklein, D.H. 1975. Estimation of combining ability and reciprocal effects for several tomato characters. Diss. Abstr. Int. B 36: 1010B -1011 B.

*Tukalo, E.A. 1968. (In) Roddick, J.G. 1974. Tomatine accumulation in some tomato varieties. Sborink Nauch Trudov Dnepropetrovsk. Med. Inst. 6: 371-375.

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

Vaughan, E.K. 1944. Bacterial wilt of tomato caused by Phytomonas solanacearum. Phytopathology 34: 443-458.

Villareal, R.L. and Lai, S.H. 1978. Reaction of 3 tomato cultivars, their F_{1s} and 3 way crosses to two isolates of bacterial wilt. Hort Science 13: 366.

*Villareal, R.L., Santiago, R.F., Viri, D.V. and Quebral, F.C. 1970. Cross protection to Pseudomonas solanacearum in tomato. Philipp. Agric. 53: 519-526.

*Voronia, M.V. 1971. Some characteristics of the changes in activity of peroxidase and ascorbic acid in the tissues of green house tomatoes. Trudy Po prikladhoi Botanike Genetike i selektsii 45: 209-215.

*Walker, J.C. 1923. Disease resistence to onion smudge. J. Agric. Res. 24: 1019-1039.

*Walker, J.C. 1926. Botrytis neck rot of onions. J. Agric.Res. 33: 893-928.

Walker, J.C. 1952. Diseases of vegetable crops (1st edn.). McGrow Hill Book Co, New York. 529 pp.

Weaver, J.G. 1944. Seeking a tomato resistant to bacterial wilt. Res. Farm. North Carolina Prg. Rept. 1: 11.

*Wilski, A., Giebel, J. and Glowinkowska, A. 1968. Phenolic compounds in roots of potatoes susceptible and resistant to Heterodera rostochiensis. Prace nauk. inst. Ochron. Roslin. 10: 205-214.

Winstead, N.N. and Kelman, A. 1952. Evaluation of resistance in tomato to Pseudomonas solanacearum. Phytopathology 42: 628-634.

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

Zehr, E.I. 1970. Isolation of Pseudomonas solanacearum from abaca and banana in philipoines. Plant Dis. Reptr. 54: 516-520.

*Zhuchenko, A.A., Samovel, A.P. and Korol, A.B. 1979. Linkage between loci controlling quantitative characters and marker loci. II. Effect of three tomato chromosomes on variation in five quantitative characters in the back cross progeny. Genetika, USSR 15: 672-683.

*Originals not seen

APPENDIX

APPENDIX - I

Months	Atmospheric temperature (C)		Soil temp.	RH (%)	Rainfall (mm)
	Max.	Mini.			
September 81	29.0	22.3	29.30	85.0	528.8
October 81	29.6	22.8	28.90	80.0	136.7
November 81	31.3	22.0	29.40	71.0	80.2
December 81	31.2	21.6	30.30	63.0	-
September 82	30.9	24.0	30.91	78.5	67.4
October 82	32.0	23.1	30.25	76.5	277.8
November 82	31.4	23.9	29.36	70.0	98.4
December 82	31.9	23.2	29.66	58.5	5.2
February 83	34.5	22.7	33.93	64.0	Nil
March 83	36.2	23.8	35.92	65.0	Nil
April 83	36.2	25.8	37.11	65.5	Nil
May 83	35.1	25.5	35.49	68.5	37.8
September 83	29.5	23.4	28.62	84.0	494.6
October 83	31.2	23.1	30.62	77.0	149.8
November 83	31.8	22.3	30.27	71.0	60.2
December 83	31.2	23.9	29.92	63.0	24.4

Source: Meteorological Observatory, Vellanikkara.

SELECTION EFFICIENCY AND GENETIC AND BIOCHEMICAL BASIS OF RESISTANCE TO BACTERIAL WILT IN TOMATO

S. RAJAN

DOCTOR OF PHILOSOPHY IN HORTICULTURE

COLLEGE OF HORTICULTURE

ABSTRACT

Bacterial wilt (*Pseudomonas solanacearum* E.F. Smith) is a major disease of tomato. Attempts were made to improve a reportedly resistant line CL 32d-0-1-19GS for higher fruit weight and better plant type through four selection methods - mass, pureline, single seed descent and bulk. Genetic and biochemical bases of resistance were also studied. Resistance of the evolved line was tested *in vivo* and *in vitro*.

Mass, pureline and SSD methods of selection were effective to improve fruits/plant, locules/fruit, yield/plant and fruit weight. SSD method resulted in higher realised genetic gain for fruits/plant (30.97) locules/fruit (0.5) and yield/plant (1.05 kg). Higher genetic advance and high realised heritability were recorded for days to first harvest in SSD selections. Mass selection had higher realised heritability (0.95) for fruits/plant and high realised heritability (0.65) and realised genetic gain (0.5) for locules/fruit. Fruit weight was improved through pureline selection.

Selections based on trait combination fruits/plant, yield/plant and plant height significantly effected higher locules/fruit (4.2). Selections based on trait combination

fruits/plant, yield/plant, locules/fruit and plant height were the earliest to flower (59 days). Days to first harvest were significantly reduced (96 days) through selections based on fruits/plant and yield/plant followed by yield/plant and plant height (98 days). Fruit weight was significantly improved by selections based on yield/plant and locules/fruit (58.5 g). Selections based on yield/plant had high realised heritability (0.59) and realised genetic gain (22.0 g) for fruit weight. Fruit weight was significantly improved by selections based on yield/plant and locules/fruit under SSD method (62.4 g). Transgressive segregants appeared through selections based on yield/plant and locules/fruit.

SSD selections had the lowest incidence of wilt (9.86%). Multilocational trials revealed a survival of 89.5% of plants under normal disease stress.

Evaluation of generations from L879 (CL 32d-0-1-1-1-1985) x Pusa Ruby Cross indicated a monogenic and incompletely dominant type of gene action for wilt resistance. There was no association between yellow gel colour around the seed and disease resistance. No close linkage between resistance and a fewer locules/fruit was observed.

The resistant line (L879-CL 32d-0-1-1-1-1-19 GS) had higher total and higher root content of α- tomatine than the

susceptible line Pusa Ruby. α- Tomatine content increased and maintained at a higher level in resistant line even-though the infection progressed consequent to artificial inoculation. Pusa Ruby wilted seven days after inoculation. Total phenol content was higher in roots of Puse Ruby before and after inoculation. The wilted plants of Pusa Ruby had higher content in root and shoot. The O.D.phenols content was more in the resistant line before and after inoculation. Vitamin C content was also more in roots of LE79 before and after inoculation.

A higher ratio of α- tomatine: total phenols, α- tomatine: O.D. phenols and α- tomatine: Vitamin C were found in roots of LE79 before inoculation. The wilted plants of Pusa Ruby had lower ratio of α- tomatine: total phenols and α- tomatine: Vitamin C. A higher increase in O.D. phenols and Vitamin C content on infection was observed in resistant line. The ratio of Vitamin C: total phenols was higher in roots of LE79 before infection and the ratio increased in both the lines initially on infection and then decreased but to a greater extent in Pusa Ruby. A higher increase in vitamin C content compared to total phenols was observed in LE79 on infection. A low ratio of total phenols: O.D. phenols was related to resistance in LE79.

Inoculation *in vitro* confirmed the resistance of L879 to Vellanikkara isolate of *Pseudomonas solanacearum* E.F. Smith. Grafting of susceptible scion on L879 delayed wilting of scion even on artificial inoculation.