PERFORMANCE OF BACTERIAL WILT TOLERANT TOMATO (*Lycopersicon esculentum* Mill.) GENOTYPES UNDER SHADE

BY

SMITHA. K

THESIS
Submitted in partial fulfilment of the requirement for the degree
MASTER OF SCIENCE IN HORTICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF AGRICULTURE
Vellayani
Thiruvananthapuram
2002

DECLARATION

I hereby declare that this thesis entitled "**Performance of bacterial wilt tolerant tomato (*Lycopersicon esculentum* Mill.) genotypes under shade**" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
25.7.02

Smitha.K
SMITHA. K
(99 – 12 – 21)

CERTIFICATE

Certified that this thesis entitled **"Performance of bacterial wilt tolerant tomato (*Lycopersicon esculentum* Mill.) genotypes under shade"** is a record of research work done independently by Ms. Smitha. K. (99 –12 - 21) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
25.7.02

Dr. V.A. CELINE,
(Chairman, Advisory Committee)
Associate Professor
Department of Olericulture
College of Agriculture, Vellayani
Thiruvananthapuram.

APPROVED BY

CHAIRMAN

Dr. V. A. CELINE
Associate Professor,
Department of Olericulture
College of Agriculture, Vellayani

5.8.02

MEMBERS

1. Dr. L. RAJAMONY
Associate Professor and Head,
Department of Olericulture
College of Agriculture, Vellayani.

5.8.02

2. Dr. I. SREELATHAKUMARY
Assistant Professor,
Department of Olericulture
College of Agriculture, Vellayani.

5.8.02

3. Dr. C. GOKULAPALAN
Associate Professor
Department of Plant Pathology
College of Agriculture, Vellayani.

5.8.02

EXTERNAL EXAMINER

Dr. S. NATARAJAN
Professor of Horticulture
Department of Vegetable Crops
Horticultural College and Research Institute
Tamil Nadu Agricultural University
Coimbatore.

5.8.02

ACKNOWLEDGEMENT

I bow my head before Lord Almighty who gave me the strength and courage to pursue this endeavor to completion.

It gives me immense pleasure to express my deep sense of gratitude and indebtedness to Dr. V. A. Celine, Associate Professor of Olericulture and Chairman of the Advisory Committee for the valuable guidance, expertise, supervision, patient and critical scrutiny of the manuscript, constructive suggestions and motivation throughout the study.

My sincere gratitude to Dr. L. Rajamony, Associate Professor and Head, Department of Olericulture, for his critical comments and constructive perusal of the manuscript.

I wish to place my sincere thanks to Dr. I. Sreelathakumary, Assistant Professor, Department of Olericulture for her valuable suggestions in the preparation of the thesis.

I take this opportunity to express my profound gratitude to Dr. C. Gokulapalan, Associate Professor, Department of Plant Pathology for his valuable suggestions, timely help and friendly approach.

My heartfelt thanks to Dr. Thomas George, Department of Soil Science and Agricultural Chemistry for his timely help and whole hearted co-operation during the chemical analysis of samples.

I gratefully acknowledge Mr. C. E. Ajith, Junior Programmer, Department of Agricultural Statistics for his co-operation during the statistical analysis of the data.

I wish to place my sincere thanks to all labourers especially Mr. Simon for their manual efforts in raising a successful crop.

I am thankful to Mr. Kishore B. Nair for his sincere co-operation in the neat preparation of this thesis.

I am happy to record my heartfelt thanks to my colleagues, Priya, Simi, Manju and Resmi for their co-operation during the study.

I remember with much gratitude the whole hearted help rendered by Anitha Chechi, Veena Vidhyadharan and Prita in the chemical analysis of samples.

My grateful thanks is due to my dear friends Sindhu, Anu, Ann and Kavitha for their timely help and affectionate words.

I wish to express my gratefulness to my loving friends Poornima Yadav, Sini chechi and Liya for their affection, valuable suggestions, constant encouragement, support and unforgettable help.

From the depth of my heart I wish to thank my dearest friend Renjusha for always being there. I fondly remember the warmth of love, care, unfailing moral support at life's exigencies, selfless help, genuine and sincere interest in my well being and above all the true spirit of friendship she always shows.

Lastly a word of appreciation to my beloved parents and sister to let me do what I want to do and for always showing faith in me which sustains me in all strange twists and turns of life. I also thank my brother-in-law for his constant encouragement and affection.

Smitha. K

SMITHA. K

INDEX

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is the world's most extensively grown vegetable after potato and sweet potato. The area under tomato in the world is 2.85 million hectares with a production of 77.54 million tonnes (Dalletregulu, 1997). In recent years, the production of the crop has tremendously increased due to its versatile uses in raw, cooked and processed forms as soups, sauces, ketchups, preserves, paste and puree. It tops the list of canned vegetables. Its status as an important protective food elevates tomato to an enviable position among all vegetable crops. Besides being an excellent source of vitamins A and C, tomato adds variety of colours and flavours to the foods.

The crop has tremendous potential in India. It ranks second in commercial importance in the country and finds a regular place in the daily diet of every human being. It is grown in an area of 0.32 million hectares with an annual production of 5.00 million tonnes (Reddy and Rao, 1999). The average yield per hectare is only 15.60 tonnes. So the improvement works on the crop are mainly concentrated on development of early high yielding varieties resistant to biotic and abiotic stresses.

Though tomato is one of the popular vegetables of Kerala, it is a disheartening fact that the area under cultivation in the state is very low. The main reason for this is the susceptibility of this crop to an array of

biotic and abiotic stresses. Fruit set is one of the key components deciding the final yield in tomato production (Picken, 1984). High temperature and humidity has detrimental effect on flowering, fruit set and quality of fruits. Under high temperature conditions pollen sterility, stigma exertion and drying of stigmatic fluid occurs which highly reduces the fruit setting.

Bacterial wilt caused by *Ralstonia solanacearum* (Smith) Yabuuchi *et al.*, is a major handicap to tomato cultivation in Kerala as the crop is highly susceptible to this disease. The warm humid tropical climate of the state coupled with acidic soil conditions favour the incidence of the disease. The losses accounted vary from 20 to 100 per cent (Bose and Rajan, 2000). Once the bacteria enter the root system, wilting of the plant results and consequently a complete loss of the crop. Since the bacteria are soil borne, chemical control of this disease is practically ineffective. Hence, to suit the conditions of Kerala, high yielding varieties for the state must be resistant to bacterial wilt.

Kerala possesses a unique system of homestead farming where a variety of perennial crops dominate. As the availability of open land is meagre in the state, farmers utilize the interspaces of perennial crops for growing vegetables. Estimates made at Central Plantation Crops Research Institute, Kasargod, have shown that light infiltration in coconut gardens ranged from 10 to 70 per cent. Shade tolerant genotypes, if identified, could be economically cultivated in the interspaces of coconut and other

perennials in homesteads where temperature and light intensity are lower than in the open. Thus, homesteads can be effectively utilized for the production of good quality tomato fruits. Moreover, there are reports of increased yield under shade in the crop (Smith *et al.*, 1984; El-Aidy, 1986).

Most of the tomato varieties for Kerala are evolved specifically for cultivation in the open. Their capacity to perform well in homesteads is crucially dependent on the ability to tolerate shade beneath canopy of tree crops. Varieties that can yield substantially even under shaded condition will be ideal for the homesteads of Kerala. Availability of such varieties could open new vistas in tomato cultivation in the state.

Taking all these into account the present investigation was carried out with the following objectives.

1. To identify shade and bacterial wilt tolerant genotypes of tomato.
2. To find out the optimum level of shade for tomato.
3. To study the morphological, anatomical and biochemical characters under shade.
4. To study the reaction towards diseases and pests under shade.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Tomato is one of the popular and extensively grown solanaceous vegetables in India. Varieties so far released in Kerala are evolved specifically for open condition. To suit the homesteads of the state where shade is a limiting factor, shade tolerant varieties get priority. Bacterial wilt disease is a major problem affecting tomato cultivation in our state. Hence, shade and bacterial wilt tolerant varieties must be released. Inspite of the wide spectrum of variability available in this crop, not much work have been done in this regard.

The available information on the effect of shade relevant to the present study is reviewed here under the following heads

2.1 Growth characters

2.2 Flowering characters

2.3 Fruit and yield characters

2.4 Reaction towards diseases, pests and physiological disorders

2.5 Anatomical characters

2.6 Biochemical characters

2.1 Growth characters

Solar radiation is considered as an essential component in biosphere activity *via* the photosynthetic performance of plants. The growth and development of crop at any time is determined by the amount of light

intercepted by the crop. Shade is reported to have a marked influence on the various growth characters like plant height, internodal length, number of primary braches and leaf area.

Experiments conducted by Deli and Tiessen (1969) to study the effect of light on young chilli plants maintained under low light intensity resulted in an increased growth and yield. Under high solar radiation, at an early stage of plant development, shading increased cell division and whole plant dry matter in pepper (Schoch, 1972). High temperature caused higher rates of transpiration which limited the growth of stems, roots and fruits in tomato (Stevens and Ruchid, 1978).

Heat stress induced all stages of crop growth, reduced the plant height significantly in all tomato cultivars compared to non-stressed plants (Arora and Pandita, 1982). Kamaruddin (1983) reported that tomato plants shaded with muslin were taller than unshaded plants mainly due to longer internodes. Magalhaes and Wilcox (1983) reported that heavy shading (50 – 67 %) of tomato plants grown with nitrate nitrogen only decreased the uptake of N, P, K, Ca and Mg while plants grown with ammonium nitrogen only tended to accumulate more N, P and K as shading increased. The growth of plants receiving ammonium nutrition under shade appeared normal, although dry weight was reduced. Shaded plants of tomato grew taller with more leaves in a given time with slightly greater internodal length (Smith *et al.*, 1984 and Thangam, 1998).

The effect of different levels of shading (0, 12, 26 and 47 %) on pepper grown under high solar radiation was investigated by Rylski (1986) during summer and winter. In both the seasons, when solar radiation was reduced, the plant height, number of nodes and leaf size increased.

Use of plastic tunnels (protected cultivation) to protect tomato plants from cool weather and frost damage increased transpiration rate (Abou-Hadid *et al.*, 1988a), plant height, leaf area and number of leaves (Abou-Hadid *et al.*, 1988b).

Rao and Sreevijayapadma (1991) observed that heat stress reduced the plant height compared to nonstressed plants in tomato. Kadam *et al.* (1991) stated that poor vegetative growth of tomato plants in summer might be due to high temperature which led to high transpiration and respiration.

Cockshull *et al.* (1992) reported that tomato plants under heavy shade were not significantly taller than those under unshaded condition. A field trial was conducted by El-Gizawy *et al.* (1993a) in tomato to study their performance under shading (0, 35, 51 or 63 %) provided by nets. They found that shading increased plant height and leaf area but reduced leaf number and dry weight.

Jung *et al.* (1994) reported that main stem and branch length of pepper increased significantly under shaded condition. Turner and Wien (1994) observed that the stress susceptible cultivar of pepper, Shamrock

recorded a larger reduction of net assimilation rate under low light stress than the more tolerant cultivar, Ace. Increase in plant height was also reported in tomato due to increase in the period of shading (Nasiruddin *et al.*, 1995).

In sweet pepper and tomato, assimilate supply for vegetative growth was varied by changing light intensity or plant density, fruit truss and leaf pruning. Area of individual leaves was increased with increasing light intensity, decreasing plant density or the removal of every other truss (Heuvelink and Marcelis, 1996). Yinghua and Jianzhen (1998) reported increased plant height due to shade in *Capsicum*.

Increased plant height, internodal length and leaf size was reported in different chilli species under shade by Sreelathakumary (2000).

2.2 Flowering characters

In tomato, production of flowers was most successful under conditions of abundant irradiation and mild temperature regimes. In the reproductive phase, low temperature in a range of 10^0C to 12^0C during the early stage of flower development caused cluster bearing (Calvert, 1966).

The number of flower buds and the degree of flower development were affected by light intensity, day length and irrigation. Higher night temperature and /or lower light intensities retarded the morphological development of flowers and induced heavy flower drop in tomato (Saito and Ito, 1967).

Wallace and Enriquez (1980) reported that when the temperature increased (24 / 18^{0}C to 33 / 27^{0}C day / night), there was decrease in days to first flower opening in beans. Number of days from sowing to flowering and percentage of flower drop increased in pepper as shade increased (Jeon and Chung, 1982). Papadopoulos and Tissen (1983) reported that flowering in tomato cv. Ohio MR-13 was delayed significantly at 24^{0}C / 8^{0}C (day and night) temperature, while marketable yield was not affected under green house condition.

Picken (1984) reported that warm day and cool night temperature extremes in high tunnel interfered with flower development and fruit set. Optimum growth and development of tomato occurred at (or) above 20^{0}C (Wolf *et al.*, 1986).

Shading was investigated as a factor to delay fruit development of sweet pepper by Rylski and Spigelman (1986a). They observed delay in fruit picking by about one month when plants were grown throughout the winter in screen houses and by eleven days, when they were covered only at a later stage of their development. In all experiments, fruit ripening and shrinking was slowed down due to shading leading to a larger yield of top quality fruits.

At high temperature condition, difference in the performance of cultivars for fruit set was attributed to the inherent variability in tomato genotypes (Anand *et al.*, 1986). Tomato responds to the average

temperature variation over the diurnal cycle and not the variation in the temperature (Gent, 1988).

Abdul-Baki (1991) observed that in tomato high temperature induced flower abscission which reduced fruit set and yield.

El-Gizawy *et al.* (1993a) observed delay in flowering in tomato as the shading level increased, whereas the number of flowers per plant decreased under all shading levels (35, 51 or 63 % shade) compared with full sunlight. In pepper, early screening resulted in taller, more open plants, delayed harvest and prolonged harvesting period compared with later screening. Harvest was delayed under screens giving high percentage of shade (Zuieli *et al.*, 1993).

Fruit set, days to harvest, number and weight of fruits per plant, weight and diameter of fruits of tomato was significantly influenced by shading (Sharma and Tiwari, 1993a). Rylski and Aloni (1994) reported that in the very early stage, flower development was highly sensitive to temperature in tomato. Romano and Leonardi (1994) observed that in tomato, days to flowering from transplanting was delayed by about four days by lower temperature *ie.*, thirty six days in green house. Nasiruddin *et al.* (1995) evaluated two varieties of tomato namely Roma and Marglobe under different periods of shading. They reported that shading delayed flowering in all the cases but insignificantly only in partial shading in comparison with full exposure. Abdul-Baki and Stommel (1995) reported

that the fruit set in tomato ranged from 41 to 84 per cent and from 45 to 91 per cent in heat sensitive and heat tolerant genotypes respectively. Low temperature influenced fruit set by affecting pollen viability.

Peet *et al.* (1996) reported that tomato fruit set and fruit weight per plant decreased as mean daily temperature increased from 25 to 29^{0}C. Deepa and Anbu (1996) observed that total number of flowers per plant ranged from 19 to 79 in summer and 170 to 209 in rabi season under Jorhat condition.

Lohar and Peat (1998) observed empty and persistent flowers without fruit set in 35 / 30^{0}C temperature regime in tomato.

2.3 Fruit and yield characters

Calvert and Slack (1980) reported increased fruit yield when night temperature was lowered in tomato.

Achhireddy *et al.* (1982) studied the effect of light on the growth rate of fruit wall plus placenta and seeds in chilli. They found that after 65 days of development, fruits held in the dark weighed 15 per cent less than those receiving light whereas the seed weight remained unaltered.

Arora *et al.* (1983) reported that plant survival in the field and yield per plant in tomato were higher on non-shaded plots which was attributed to higher temperature on the shaded plots and to the smothering effect of the shade plants. Smith *et al.* (1984) found that tomato yields were best under 15 per cent shade than 40 per cent shade and open.

Rylski and Spigelman (1986b) investigated the effect of different levels of shading (0, 12, 26 and 47 %) on yield of *Capsicum* under higher solar radiation during summer and winter. Shading inhibited the development of lateral shoots on the main stem of plant below the first flower. The changes in plant development due to shading affected fruit set, number of fruits per plant, fruit location on the plant, fruit development and yield. The lateral shoots, which developed under high light intensity, provided 25 per cent of the total yield whereas, only a few fruits were picked from the lateral shoots of plants under low light intensity. The lowest number of fruits per plant was obtained under 47 per cent shading. Under shading individual fruits were larger and had a thicker pericarp. The highest yield of high quality fruits was obtained with 12 and 26 per cent shade.

El-Aidy (1986) found higher yield in tomato plants grown under shade than those in the open field, but this trend could be reduced by increasing shade with 40 per cent shade being the best.

Ho and Hewitt (1986) reported that the competitive ability of tomato fruits for assimilates is assessed by their growth rate especially in relation to temperature.

The micro-climatic and eco-physiological effects of shading and pinching on *Capsicum* were reported by Hou *et al.* (1987). Fruit yield was highest when the plants were pinched and shaded with plastic film.

In tomato and sweet pepper grown in a green house with natural sunlight, 35 and 55 per cent shading, the light intensity decreased dry weight and fruit yield with greatest effect on tomatoes and least effect on sweet pepper (Zhong and Kato, 1988).

Shade studies on tropical crop *viz.* colocasia, coleus, cowpea, brinjal, amaranthus, cluster bean, bhindi and sweet potato were conducted in Kerala Agricultural University under 0, 25, 50 and 75 per cent shade levels (Nair, 1991). In all these crops, the yield was highest in open (0 % shade) and declined with increasing shade levels.

Stress during the fruiting stage would reduce the productivity in tomato (Rao and Sreevijayapadma, 1991).

Hedge *et al.* (1993) reported that among the different vegetable crops tried in coconut garden, snake gourd, amaranthus and brinjal in kharif, bottle gourd, ridge gourd and coccinia in rabi and amaranthus, brinjal and coccinia in summer, were found highly productive and economical.

El-Gizawy *et al.* (1993b) found increased number of fruits per plant and total yield in tomato. Highest yields were obtained under 35 per cent shading (2.46 and 4.12 kg m^{-2} in 1988 and 1989 respectively). Shading significantly improved the physical characteristics of fruits. The greatest weight, length, diameter and volume of fruits were obtained from plants grown under 35 per cent shading.

To study the effect of shade in tomato, four shade treatments ranging from 1:1 (1 row of tomato: 1 row of maize) to 4:1 (4 rows of tomato : 1 row of maize) were tried. The treatment 1:1 proved significantly effective for fruit set, number of fruits per plant and yield (Sharma and Tiwari, 1993b).

Jung *et al.* (1994) reported that pepper plants set smaller fruits in proportion to the degree of shading. Warren and Anderson (1994) observed that marketable yield of bell pepper from plots shaded with spun bonded polypropylene row covers were equal to or greater than those from other treatments.

When tomato crop was grown in glass house, the single fruit size and fruit number were affected by season largely through direct effects of solar radiation on crop photosynthesis and glass house air temperature (Cockshull and Ho, 1995).

Shukla *et al.* (1997) reported the effect of subabul canopy on yield of vegetable like chilli, brinjal, cauliflower and okra. Yield of all vegetables was significantly lower when grown under shade than in open. Yinghua and Jianzhen (1998) reported highest yield in pepper under 30 per cent shade. No significant reduction in yield was noticed in different chilli species under mild shade of 25 per cent while dense shade of 50 and 75 per cent reduced the yield considerably (Sreelathakumary, 2000)

2.4 Reaction towards diseases, pests and physiological disorders

2.4.1 Diseases

2.4.1.1 Bacterial wilt

This is the most serious disease of tomato in Kerala. It is caused by *Ralstonia solanacearum* (Smith) Yabuuchi *et al.* The characteristic symptom of the disease is the drooping of leaves followed by wilting of plants. The vascular system becomes discoloured and there will be brown decay of the pith.

The disease was found to be favoured by high soil moisture which helped in dispersal of bacterial cells and increased the size of lenticels. A warm and wet soil was condusive to invasion of tissues and development of the disease (Singh, 1975).

Different tomato genotypes were reported to be resistant to bacterial wilt from Kerala Agricultural University like LE 79 (CL-32-d-o-19 GS) and plants from the segregating population of the cross Saturn X LE 79 (Celine, 1981; Kutty and Peter, 1986).

Bell (1981) stated that the factors which influenced resistance to bacterial wilt included intensity, duration and quality of light, moisture levels, nutrient levels and agricultural and industrial chemicals.

Tomato and brinjal isolates of bacterial wilt pathogen survived upto three years in fallow and upto unlimited period in cultivated land (Kishun, 1982). The bacterium was reported to invade the hosts through wounds,

usually below ground. It was found that relatively high soil temperature and soil moisture favoured the disease. It was also reported that the organism spread through irrigation water and rain water (Nair and Menon, 1983).

In tomato assessment of yield loss due to bacterial wilt was done by Kishun (1985; 1987). He reported that bacterial wilt reduced the yield of tomato upto 90.62 per cent.

Ho (1988) reported that the disease incidence in the field peaked in approximately ninth week after transplanting. High rainfall, especially towards the middle and end of growing season favoured high disease incidence.

Evaluation of tomato for summer season was done at College of Horticulture, Vellanikkara and it was found that tomato line LE 415 is the new source resistant to bacterial wilt and TMV with hot set character. Another line CAV 5 was found to be resistant against bacterial wilt with hot set nature (KAU, 1997).

2.4.1.2 *Fusarium* wilt

Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici* (Bruschi) is characterised by yellowing of leaves, vascular browning, stunting and ultimately wilting.

The intensity of light and day length usually found affecting plant growth and make the plants favourable or unfavourable media for disease

causing fungi, bacteria, viruses etc. Tomato grown under conditions of low light intensity became highly susceptible to wilt caused by *Fusarium oxysporum* f.sp. *lycopersici* while plants grown in strong light showed very little disease (Singh, 1975).

In an experiment *Lycopersicon hirsutum* PT 13448 and *Lycopersicon hirsutum* f. *glabratum* wir 4172 and *Lycopersicon peruvianum* EC 148898 were found nearly immune, *Lycopersicon esculentum* cvs. Columbia and Roma were found highly resistant while HS 110 expressed resistant reaction (Jalali *et al.*, 1989).

Forty eight entries of tomato were screened under disease stress conditions of *Fusarium oxysporum* f. *lycopersici* race 1. *Lycopersicon peruvianum*, *Lycopersicon hirsutum* f. *glabratum* and *Lycopersicon pimpinellifolium* were immune, highly resistant and susceptible respectively. Of the cultivated varieties, Walter exhibited the maximum susceptibility and Columbia, Roma, HS 110, Homestead, Flora Dada Sel 26, Sel 28, Sel 30 had low rating for wilt incidence. The resistance in these lines was reduced during summer (Banerjee *et al.*, 1990).

2.4.1.3 Tomato spotted wilt

Spotted wilt disease is one of the important viral diseases of tomato. The most characteristic symptom of the disease is browning of young leaves followed by cessation of growth. The infected leaves gradually become distorted and necrotic.

The disease was reported as both sap and insect transmissible. Four species of thrips were identified as vectors *viz.*, *Thrips tabaci*, *Frankliniella schultzei*, *Frankliniella occidentalis* and *Frankliniella fusca* (Sakimura, 1963).

Spotted wilt disease was first reported from India by Todd *et al.* (1975) from Nilgiri Hills. Some lines of red current tomato were found highly resistant. The cultivars Pearl Harbour and Manzana were reported resistant to this disease (Tiwari and Choudhury, 1994).

2.4.2 Insect Pests

2.4.2.1 Leaf miner

The serpentine leaf miner, *Liriomyza trifolii* (Burgess) is an exotic pest introduced recently into India causing economic damage to several crops including tomato. The pest was reported to inflict damage by punctures in the leaves for either oviposition or apparent feeding, and by mines in the leaf mesophyll. It was also reported that severely infested plants became completely defoliated (Viraktamath *et al.*, 1993).

Neither growth nor the yield was negatively affected by infestation levels upto 1092 and 458 mines per plant in glass house and field trials respectively in tomato. Crop loss upto 35 per cent was reported in summer (IIHR, 1998).

A green house experiment was carried out to study the effect of temperature on development, survival and reproduction of leaf miner. The

survival rates of the various immature stages were highest at 20 – 27.5^{0}C. No emergence of the pupa was noticed beyond 35^{0}C. Adult longevity decreased with increasing temperature and found that population growth index reached a peak at 27.5^{0}C (Chen *et al.*, 1999). It was found that only least possibility was there for the exposure of the harmful stage of the pest to outside environment and natural enemies because of its secluded nature. It was also reported that the pest can complete several generations in a year due to its short life cycle (Rosaiah, 2000).

Because of the ineffectiveness of the common insecticides and the protected nature of the harmful stage of the pest, proper control of the pest is difficult. Identification of pest tolerant or resistant varieties is needed. An experiment was conducted to evaluate the tomato variety Pusa Ruby and six hybrids for yield and resistance to insect pests. It was found that Pusa Ruby was less susceptible to leaf miner. Among hybrids Arjuna and Rupali were found moderately tolerant while Abinash II recorded the highest infestation (Chaudhuri *et al.*, 2000).

2.4.2.2 Fruit borer

Fruit borer, *Helicoverpa armigera* (Hubner) is a serious pest, in tropical and subtropical areas. Its attack is largely confined to the stem end portion of the fruit.

Losses upto 50 per cent in Tamil Nadu (Srinivasan, 1958), 65 per cent in Punjab (Singh and Singh, 1975) and 22 to 38 per cent in Karnataka (Tewari and Moorthy, 1984) have been reported due to pest attack.

Fery and Cuthbert (1974) screened 1,030 accessions of tomato (*Lycopersicon esculentum* Mill.) and noticed a high degree of variation in the degree of incidence among the genotypes. Cosenza and Green (1979) found that leaves and fruits of some tolerant breeding lines were less palatable to the pest than that of the susceptible varieties. Juvik and Stevens (1982) reported that the fruit skin, particularly the toughness of the pericarp was the principal source of resistance to this pest.

Tomato accessions 128, 133, 145, Heinz 137 and Sabour Prabha were less affected by this pest. Among wild species, *Lycopersicon hirsutum* f. *glabratum* was found highly resistant (Kashyap *et al.*, 1982; Kashyap and Verma, 1986).

Rath and Nach (1997) screened 112 tomato genotypes for resistance against fruit borer and reported that very poor response to feeding was observed in genotypes HT 64, hybrid No. 37 and PTH 106 which indicated less susceptibility to the pest.

Varghese (1998) reported that the hybrid Arka Alok x PKM–1 is free from fruit borer attack and diseases like mosaic. The relative performance of 13 tomato hybrid varieties against fruit borer infestation was studied in Uttar Pradesh during 1997. None of the plant varieties were found immune,

although considerable variability existed in their susceptibility to this pest. Two varieties Ellora and Chaitali exhibited a resistant reaction, while three varieties Heera, Commander and Ganga Kaveri were considered as moderately resistant (Lal *et al.*, 1999).

2.4.3 Physiological disorders

2.4.3.1 Fruit cracking

Yamashiti and Hayashi (1994) studied the year round production of tomato in water culture methods for prevention of fruit cracking during high temperature periods. They found that severe shading had little effect on fruit cracking and that it reduced fruit yield and quality.

2.4.3.2 Sun scald

Effect of shade on fruit yield and quality in sweet pepper was investigated by Rylski and Spigelman (1986b). They reported that shading in summer eliminated the sunscald damage. Shading also reduced shrinking of fruits and improved the quality.

2.5 Anatomical characters

Schoch (1972) reported that shading increased leaf surface, cell division and cell expansion in sweet pepper, *C. annuum*. Shade decreased the number of stomata per mm^2 and the percentage of stomata in relation to other cells.

An examination of the vascular bundle of mid rib of shaded leaves in cotton revealed that it was larger and thinner than that in non-shaded leaves (Dhopte *et al.*, 1991).

Buisson and Lee (1993) reported that stomatal density in papaya were reduced by reduction in irradiance. Sreekala (1999) also observed reduced stomatal percentage under shade in ginger.

2.6 Biochemical characters

2.6.1 Chlorophyll

An increase in chlorophyll content with increase in shade levels was reported in cotton (Bhat and Ramanujam, 1975), winged bean (Sorenson, 1984), tobacco (Anderson *et al.*, 1985), potato (Singh, 1988) and colocasia (Prameela, 1990).

Thangaraj and Sivasubramanian (1990) reported that low light intensity significantly increased the total leaf chlorophyll content in rice irrespective of varieties.

Chlorophyll a, Chlorophyll b, carotenoids and total pigment content of leaves of tomato was increased with increased shading (El-Gizawy *et al.*, 1993a). Shading caused profound increase in the content of chlorophyll b in okra, french bean, groundnut, rice, maize and hybrid napier (Singh, 1994).

Fahl *et al.* (1994) reported that chlorophyll a and b, protochlorophyll and total leaf chlorophyll contents increased in shade grown coffee plants

compared to those in full sunlight. Similarly, chlorophyll and carotenoid content of leaves of pepper found increased with increasing shade (Yinghua and Jianzhen, 1998).

2.6.2 Vitamin C

A variation of 15.00 to 19.12 mg $100g^{-1}$ in vitamin C content in tomato was reported by Kalloo (1989) while Kanthasamy and Balakrishnan (1989) found a range of 23.68 to 29.63 mg $100g^{-1}$ and 4.42 to 9.12 mg $100g^{-1}$ by Shoba and Arumugam (1991). Naniwal *et al.* (1992) observed a range of 20.10 to 31.02 mg $100g^{-1}$ of vitamin C cid in tomatoes.

El-Gizawy *et al.* (1993b) reported that in tomato with increased shading, vitamin C content and soluble solids decreased while fruit titrable acidity increased. Sharma and Tiwari (1993a) observed that tomato fruits harvested from shaded plants accumulated significantly higher vitamin C as compared to non-shaded plants. Extended shading period decreased the vitamin C content of fruits considerably (Nasiruddin *et al.*, 1995). Yanagi *et al.* (1995) reported that in both summer and autumn crops of tomato vitamin C and reducing sugar content of fruits significantly decreased with increased shading.

Yinghua and Jianzhen (1998) found that vitamin C content of pepper fruits decreased with the increase in shade. Soohyun *et al.* (1998) analysed the chemical constituents of fruits of red pepper (*C. annuum*) and reported

that the total amount of vitamin C in fruits was 121 mg per 100 g^{-1} of fresh weight.

2.6.3 Proline

Proline is a heat shock protein. Accumulation of proline under water stress has been reported in crops *viz.*, coffee (Vasudeva *et al.*, 1981), cocoa (Balasimha, 1982) tea (Rajasekhar *et al.*, 1988) and coconut (Voleti *et al.*, 1990).

Concentration of proline in cotyledons of radish grown in light was increased as an inverse function of the relative water content (Hervieu *et al.*, 1994).

Yao *et al.* (1998) in an experiment with three pepper (*C. frutescens*) varieties differing in heat tolerance found that when subjected to temperature of 35 to 40^{0}C for two to eight days, there was free proline accumulation in the leaves. He also found that there were significant differences between varieties.

Joonkook *et al.* (1998) reported high proline content in excised leaves of salt sensitive tomato compared to salt tolerant accessions.

2.6.4 Vitamin A

Gogoi (1980) observed a range of 382 to 450 IU of vitamin A content in tomato while Roberts (1987) reported a variation of 370 to 430 IU in the content of vitamin A in tomato fruits.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was carried out at the Department of Olericulture, College of Agriculture, Vellayani during the period 2000 – 2001. The location is at 8.5^0N latitude, 76.9^0E longitude and at an altitude of 29.0 m above MSL. The experimental site has a lateritic red loam soil.

3.1 Materials

Bacterial wilt tolerant tomato germplasm available in the Department of Olericulture, College of Agriculture, Vellayani was evaluated for shade tolerance. Ten promising lines with respect to bacterial wilt resistance and high yield were utilized for the study. A susceptible variety Fla 7156 was also grown along with the experimental plants so as to confirm the presence of the pathogen. The details of the genotypes and their sources are presented in Table 1.

3.2 Methods

Three separate experiments were carried out under 25 and 50 per cent shade along with open condition and the performance of genotypes was evaluated.

Statistical details

Design – RBD.

Table 1. Details of tomato genotypes used in the experiment

Accession No.	Genotype	Source	Fruit characters
LE 1	Xiang Fan Qui-1	Changsha City Institute of Vegetable Research, Changsha, China	Medium, globular
LE 2	Neptune	Gulf Coast Education and Research Centre, University of Florida.	Large, globular
LE 22	Mukthi	COH, Vellanikkara	Small, globular
LE 34	LE 16	ARS, Mannuthy	Small, globular
LE 38	CLN 2026 C	AVRDC, Taiwan	Medium, plum
LE 39	CLN 2026 D	AVRDC, Taiwan	Medium, oblong
LE 40	CLN 2026 E	AVRDC, Taiwan	Medium, oblong
LE 42	CLN 1466 P	AVRDC, Taiwan	Large, oblong
LE 44	CLN 1621 E	AVRDC, Taiwan	Small, oblong
LE 45	CLN 1621 F	AVRDC, Taiwan	Small, globular
LE 5	Fla 7156	Gulf coast Education and Research Centre, University of Florida	Medium, globular

Replications – 3.

Treatments – 10.

Number of plants per plot – 16.

Spacing – 60 x 60 cm.

The crop was raised as a transplanted crop and received timely management practices as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996). Black high density polyethylene net, fabricated for 25 and 50 per cent shade was used. The nets were spread at a height of 2.50 m from ground level and supported on G.I.pipes and iron poles. Care was taken to avoid natural shade in the experimental area.

3.2.1 Observations

Four plants were selected randomly from each plot and tagged for recording the biometrical observations.

3.2.1.1 Plant characters

3.2.1.1.1 Plant height (cm)

Height at flowering (cm)

Height of observational plants from ground level to the top most leaf bud at the time of first flowering. Average worked out and expressed in centimetres.

Height at harvest (cm)

Height of the plants from ground level to the top most leaf bud at the time of final harvest. Average was taken and expressed in centimeters.

3.2.1.1.2 Number of primary branches

Number of primary branches of the observational plants were counted and average was worked out.

3.2.1.1.3 Internodal length (cm)

Length between two nodes just below the fifth leaf from the top of the plant was recorded and the average expressed in centimetres.

3.2.1.2 Leaf characters

3.2.1.2.1 Leaf length (cm)

The fifth leaf from top of the selected plants was used for making the above observation. The length was measured as the distance from the base of the petiole to the top of the leaf and expressed in centimetres.

3.2.1.2.2 Leaf width (cm)

The width of the same leaf, used for recording the length was taken at the region of maximum width.

3.2.1.2.3 Leaf petiole length (cm)

Petiole length of the fifth leaf used for recording the leaf length was measured and expressed in centimetres.

3.2.1.3 Flowering characters

3.2.1.3.1 Days to flowering

Number of days from the date of transplanting to the first flowering of observational plants was recorded and the average obtained.

3.2.1.3.2 Days to fruitset

Four inflorescences were selected randomly and tagged from each observational plant and number of days taken from flowering to emergence of young fruits from the calyx was counted and average worked out.

3.2.1.3.3 Flowers per cluster

Number of flowers per cluster was recorded from the same inflorescences tagged for making observations on days to fruit set and found out the mean.

3.2.1.3.4 Percentage fruit set

Number of flower clusters of the same inflorescences tagged for recording days to fruitset was counted. Number of fruits present per inflorescence after two weeks of flowering was found out. Percentage fruitset was calculated using the formula.

$$\text{Percentage fruitset} = \frac{\text{Number of fruits / inflorescence}}{\text{Number of flowers / inflorescence}} \times 100$$

3.2.1.4 Fruit and yield characters

3.2.1.4.1 Fruit length (cm)

Ten fruits were selected at random from the observational plants. Length of the fruits was measured as the distance from pedicel attachment of the fruit to the apex using twine and scale. Average was taken and expressed in centimetres.

3.2.1.4.2 Fruit diameter (cm)

Diameter of the fruits was taken from the same fruits used for recording the fruit length. Fruits were cut transversely and diameter was measured at the maximum point. The average was worked out and expressed in centimetres.

3.2.1.4.3 Fruit weight (g)

Weight of fruits used for recording fruit length was measured and average was found out and expressed in grams

3.2.1.4.4 Fruits per plant

Total number of fruits produced per plant till last harvest was counted.

3.2.1.4.5 Yield per plant (g)

Weight of all fruits harvested from selected plants was recorded averaged worked out and expressed in grams per plant.

3.2.1.5 Reaction towards diseases and pests

3.2.1.5.1 Incidence of bacterial wilt

Daily observation of plants was done for incidence of bacterial wilt and recorded the number of plants wilted per plot.

3.2.1.5.2 Incidence of fusarium wilt

Fusarium wilt in tomato is caused by *Fusarium oxysporum* F. *lycopersici* (Bruschi). The accessions were closely monitored for the incidence of fusarium wilt.

3.2.1.5.3 Incidence of spotted wilt disease

A scoring procedure with 0 to 5 scale was adopted based on the extent of damage to the plants (Plate 1).

0 – No symptom

1 – Spots develop

2 – 25 per cent of leaf area infected

3 – 25 per cent to 50 per cent of leaf area infected

4 – 50 per cent to 75 per cent of leaf area infected

5 - > 75 per cent of leaf area infected and bud necrosis

3.2.1.5.4 American serpentine leaf miner

Number of leaves with mining symptoms and total number of leaves from each plant was counted. The percentage of infestation was worked out using the formula

Plate 1. Scoring scale for incidence of spotted wilt disease

$$\text{Percentage of infestation} = \frac{\text{Number of mined leaves}}{\text{Total number of leaves}} \times 100$$

Scoring procedure adopted was as follows

0 – no incidence

1 – upto 15 per cent infestation

2 – 15 per cent to 25 per cent infestation

3 – 25 per cent to 50 per cent infestation

4 – 50 per cent to 75 per cent infestation

5 – > 75 per cent infestation

3.2.1.5.5 Fruit borer

Number of fruits infested per plant was counted. The percentage infestation was worked out using the formula

$$\text{Percentage of infestation} = \frac{\text{Number of infested fruits per plant}}{\text{Total number of fruits per plant}} \times 100$$

Scoring was done as follows.

0 – zero per cent infestation

1 – upto 15 per cent infestation

2 – 15 to 25 per cent infestation

3 – 25 to 50 per cent infestation

4 – 50 to 75 per cent infestation

5 – > 75 per cent infestation

3.2.1.6 Physiological disorders

3.2.1.6.1 Fruit cracking

Cracking of the surface of fruits is a common occurrence in tomato and often results in great losses. Fruits were closely observed for symptoms of radial or concentric cracking.

3.2.1.6.2 Sun scald

Fruits were observed for symptoms of sun scald damage.

3.2.1.7 Anatomical characters

3.2.1.7.1 Stomatal percentage

Fifth leaf from the top of the plant was used for taking the observation. Leaf peels were taken from the upper surface of the leaf lamina with a fine razor. The peels were observed under the microscope and the number of stomata and total number of epidermal cells were counted to calculate the percentage of stomata.

$$\text{Stomatal percentage} = \frac{\text{Number of stomata}}{\text{Total number of epidermal cells}} \times 100$$

3.2.1.7.2 Vascular bundle

Fifth internodal region form the tip of first primary branch was used for taking stem sections. Each section was from an individual branch and

each branch from an individual plant. Hand sections were taken with a fine razor, observed under the microscope and counted the number of vascular bundles.

3.2.1.8 Biochemical characters

The chemical constituents of genotypes were analysed. The constituents estimated were chorophyll (a, b and total), proline, vitamin C and vitamin A.

3.2.1.8.1 Chorophyll a, chorophyll b and total chlorophyll

The photosynthetic pigments were estimated at vegetative stage in all genotypes by following the method of Sadasivam and Manikam (1992).

Five hundred milligrams of leaf sample was weighed and the leaf tissues were then ground with 10 ml of 80 per cent acetone using a pestle and mortar. The homogenate was centrifuged at 3000 rpm for ten minutes. The supernatant was collected and made up to 25 ml with 80 per cent acetone. The OD value of the extract was measured at 663 nm and 645 nm using 80 per cent acetone as the blank in the spectrophotometer. The amount of the pigment was calculated using the following formulae and expressed as milligram of pigment per gram of fresh leaf.

$$\text{Total chlorophyll} = 20.2\,(\text{OD at } 645) + 8.02\,(\text{OD at } 663) \times \frac{V}{1000 \times W}\ \text{mg g}^{-1}$$

$$\text{Chlorophyll } \underline{a} = 12.7\,(\text{OD at } 663) - 2.69\,(\text{OD at } 645) \times \frac{V}{1000 \times W} \text{ mg g}^{-1}$$

$$\text{Chlorophyll } \underline{b} = 22.9\,(\text{OD at } 645) - 4.68\,(\text{OD at } 663) \times \frac{V}{1000 \times W} \text{ mg g}^{-1}$$

where,

V = final volume of chlorophyll extract in 80 per cent acetone

W = fresh weight of tissue extracted

3.2.1.8.2 Proline

Genotypes were analysed for proline content during their vegetative stage.

Proline present in the leaves was extracted using sulphosalicylic acid. The extracted proline was made to react with ninhydrin in acidic condition to form a red colour and intensity was read at 520 nm (Sadasivam and Manikam, 1992).

Reagents

Acid ninhydrin

Aqueous sulphosalicylic acid (3 %)

Glacial acetic acid

Toluene

Proline

Procedure

One gram of the leaf sample was cut into small pieces and homogenised in a blender with 10 ml of 3 % aqueous sulphosalicylic acid. Filtered the homogenate. Took 2 ml of filtrate in a test tube and added 2 ml of glacial acetic acid and 2 ml acid ninhydrin. It was heated in the boiling water for one hour, then placed in an ice bath. Added 4 ml toluene to the reaction mixture and stirred. Separated the toluene layer and measured the colour intensity at 520 nm.

Amount of proline in the samples was calculated from the standard curve of pure proline and was expressed as micro-moles per gram tissue.

$$\mu \text{ moles per g tissue} = \frac{\mu g \text{ proline /ml} \times \text{ml toluene} \times 5}{115.5 g \text{ of sample}}$$

3.2.1.8.3 Vitamin C

Vitamin C content of the fruits was estimated at the full ripe stage by 2, 6- dichlorophenolindophenol dye method (Sadasivam and Manikam, 1992).

Reagents

3 % Metaphosphoric acid (HPO_3)

Ascorbic acid (standard)

2, 6-dichlorophenolindophenol dye

Procedure

Five grams of fresh fruits was extracted in an acid medium (3 % HPO_3) and titrated against 2, 6 – dichlorophenolindophenol dye to a pink colour which persisted for at least five seconds. Vitamin C content of sample was calculated using the formula.

$$\text{Vitamin C content in mg /100 g fresh fruit} = \frac{\text{Titre x dye factor x volume made up x 100}}{\text{Aliquot of extract taken x weight of sample taken}}$$

3.2.1.8.4 Vitamin A

Carotene content of fruits was estimated at the full ripe stage by following the method of Srivastava and Kumar (1994). Carotene values expressed in µg / 100 g were divided by 0.6 to get the Vitamin A content in I.U. (A.O.A.C, 1975).

Reagents

Acetone

Anhydrous sodium sulphate

Petroleum ether

Procedure

With the help of pestle and mortar crushed five grams of fresh fruit sample in 15 ml acetone added with a few crystals of anhydrous sodium sulphate. Decanted the supernatant into a beaker. Repeated the process twice and transferred the combined supernatant to a separating funnel, added 15 ml petroleum ether and mixed thoroughly. Discarded the lower

layer and collected the upper layer in a 100 ml volumetric flask, made up the volume to 100 ml with petroleum ether and recorded optical density at 452 nm using petroleum ether as blank.

$$\beta \text{ - carotene } (\mu g / 100 \text{ g}) = \frac{O.D \times 13.9 \times 10^4 \times 100}{\text{Weight of sample} \times 560 \times 1000}$$

$$\text{Vitamin A (I.U)} = \frac{\beta \text{ - carotene } (\mu g / 100 \text{ g})}{0.6}$$

3.2.2 Statistical analysis

The collected data were subjected to the analysis of variance to test the significant difference among the genotypes under each shade level for various traits as per Panse and Sukhatme (1978). Pooled analysis was done to test the significant difference among different shade levels.

RESULTS

4. RESULTS

Experimental data collected on morphological characters, yield and other yield attributes were analysed statistically and the results are presented in this chapter.

4.1 Plant characters

4.1.1 Height at flowering

The genotypes differed significantly for height at flowering under different shade levels (Table 2). Significant difference in height at flowering was noticed among the different shade levels also. Overall mean for height at flowering was 31.08 cm, 60.77 cm and 71.14 cm respectively in open, 25 and 50 per cent shade levels.

In the open, minimum height at flowering was in LE 1 (26.99 cm) which was on par with LE 42 (29.70 cm). LE 42 recorded minimum height at flowering under 25 (45.58 cm) and 50 (51.80 cm) per cent shade.

In the open, maximum height at flowering was recorded in LE 22 (35.50 cm), which was on par with LE 44 (33.62 cm), LE 40 (33.13 cm) and LE 34 (32.88 cm). Under 25 (85.28 cm) and 50 (95.51 cm) per cent shade also LE 22 had the maximum height at flowering.

General view of tomato genotypes grown under different shade levels

Plate 2

Plate 3

Plate 4

Comparison of plant growth under different shade levels.

Plate 5

Plate 6

Plate 7

Minimum pooled mean for height at flowering was observed in LE 42 (42.36 cm) and LE 22 recorded the maximum pooled mean (72.10 cm).

4.1.2 Height at harvest

Significant variation among genotypes for plant height at harvest was observed under different shade levels (Table 3). The plant height in all the genotypes showed an increasing trend with increase in shade level and there was significant difference in plant height among the shade levels (Fig.1, Plates 8 and 9). Minimum plant height of 53.75 cm was recorded in plants grown in open compared to 108. 63 cm under 50 per cent shade.

Among the genotypes LE 39 was the shortest plant in open (46.73 cm) whereas LE 42 was the shortest under 25 and 50 per cent shade levels, the plant height being 83.94 cm and 88.07 cm respectively.

LE 22 registered maximum plant height under open, 25 and 50 per cent shade with a height of 64.79 cm, 116.60 cm and 137.60 cm respectively.

LE 42 had the minimum pooled mean for plant height (74.51cm) while LE 22 (106.33 cm) registered the maximum.

4.1.3 Number of primary branches

There was significant difference among the genotypes for number of primary branches under all shade levels (Table 4). There was significant

Table 2. Height at flowering (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	26.99	65.71	78.34	57.01
LE 2	29.37	65.08	72.72	55.72
LE 22	35.50	85.28	95.51	72.10
LE 34	32.88	58.35	69.08	53.44
LE 38	28.00	52.15	68.36	49.50
LE 39	28.36	58.33	68.58	51.75
LE 40	33.13	60.50	70.00	54.55
LE 42	29.70	45.58	51.80	42.36
LE 44	33.62	57.61	67.20	52.81
LE 45	33.25	59.13	69.80	54.06
Mean	31.08	60.77	71.14	54.33
SE	1.260	1.834	1.909	3.349
CD (genotypes)	3.752	5.462	5.686	9.495
SE	1.834			
CD (shade levels)	5.201			

Table 3. Height at harvest (cm) of tomato genotypes under different shade levels

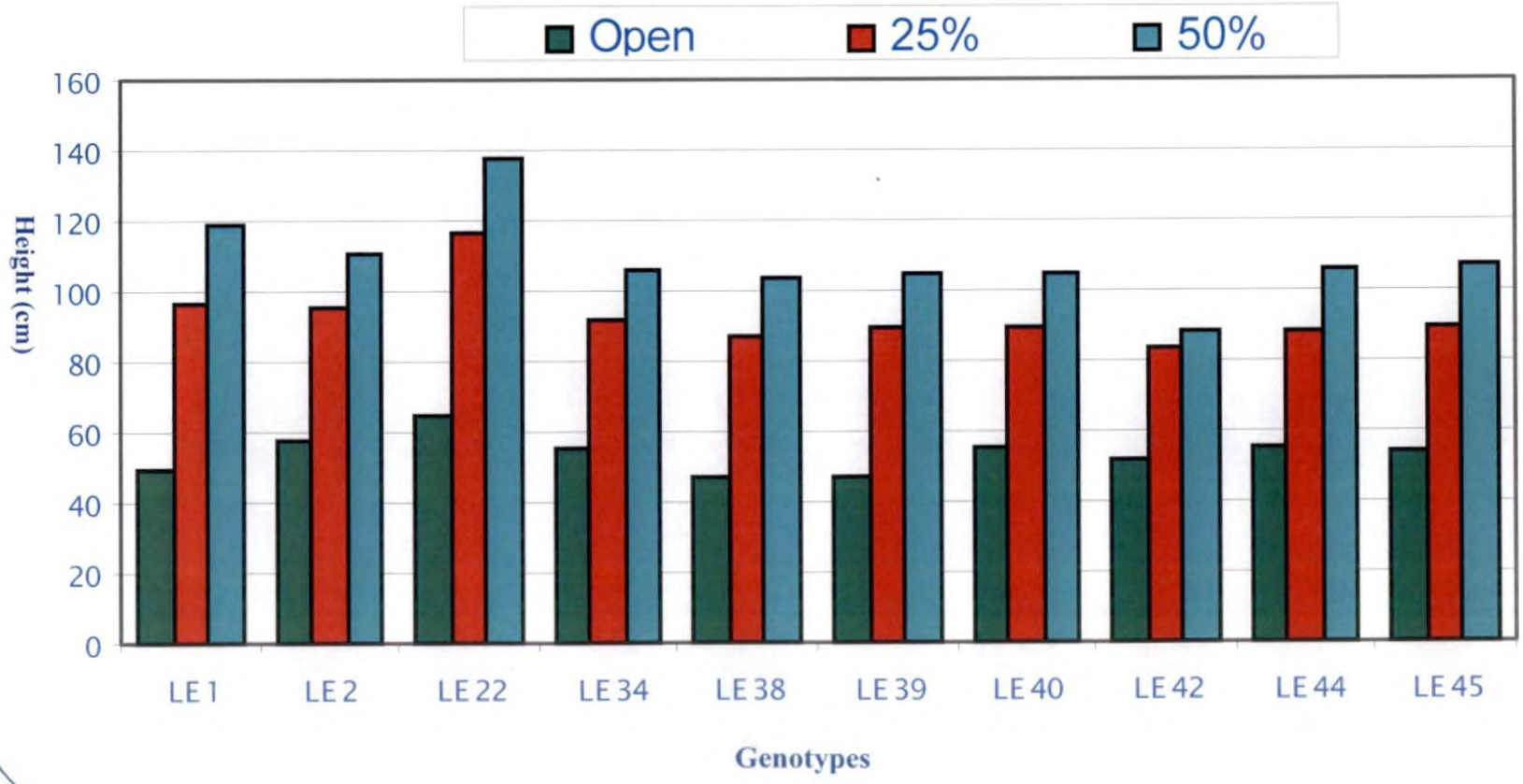
Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	48.90	96.20	118.47	87.85
LE 2	57.21	95.70	110.57	87.83
LE 22	64.79	116.60	137.60	106.33
LE 34	55.73	91.31	106.27	84.43
LE 38	47.17	86.76	103.86	79.26
LE 39	46.73	89.23	104.63	80.20
LE 40	55.33	89.65	105.04	83.34
LE 42	51.53	83.94	88.07	74.51
LE 44	55.64	88.22	105.30	83.05
LE 45	54.47	89.26	106.52	83.42
Mean	53.75	92.69	108.63	85.02
SE	1.631	2.282	2.154	3.106
CD (genotypes)	4.860	6.797	6.414	8.808
SE	1.701			
CD (shade levels)	4.824			

Plant height in open and under 50 per cent shade

Plate 8

Plate 9

Fig. 1 Effect of shade on plant height (height at harvest)



difference among the shade levels for number of primary branches which decreased with increase in shade. Maximum overall mean was in open (6.28), followed by 25 per cent shade (4.71) while 50 per cent shade had minimum number of primary branches (2.95).

Under all shade levels maximum number of primary branches was in LE 45 with 9.67, 7.50 and 3.75 in open, 25 and 50 per cent shade levels respectively. It was on par with LE 34 (9.67) in open, with LE 34, LE 40 (3.5 each) and LE 45 (3.33) under 50 per cent shade.

In open and 25 per cent shade, the minimum number of primary branches was in LE 42 (3.83 and3.08 respectively) whereas under 50 per cent shade, minimum number of primary branches was in LE 38 (2.33) which was on par with LE 42 (2.58).

Maximum pooled mean was recorded in LE 45 (6.97) and the minimum in LE 42 (3.17).

4.1.4 Internodal length

Variation in internodal length was observed among genotypes under all shade levels (Table 5). Significant variation was observed among different levels of shade for internodal length. The internodal length increased with an increase in level of shade. Maximum internodal length was observed under 50 per cent shade. Overall mean of internodal length due to shade level was maximum under 50 per cent (9.27 cm) followed by

25 per cent shade (7.76 cm). Minimum internodal length was recorded in plants grown in open condition (5.08 cm).

Internodes were longest in LE 22 in open (7.45 cm), 25 (9.79 cm) and 50 (11.93 cm) per cent shade level which was on par with LE 2 (8.74 cm, 10.82 cm) and LE 1 (8.24 cm, 10.66 cm) under 25 and 50 per cent shade levels.

Minimum internodal length was recorded by LE 39 (3.70 cm) in open, LE 42 under 25 (6.45 cm) and 50 (7.84 cm) per cent shade levels.

Maximum pooled mean for internodal length was recorded by LE 22 (9.72 cm) which was on par with LE 2 (8.57 cm). Minimum pooled mean was in LE 39 (6.08 cm).

4.2 Leaf characters

4.2.1 Leaf length

Significant difference among the genotypes and between different shade levels was observed for leaf length (Table 6). An increase in leaf length was observed with an increase in shade levels. Maximum leaf length was recorded in plants grown under 50 per cent shade (27.32 cm) followed by 25 per cent (23.98 cm). Minimum leaf length was recorded by plants grown in open (19.87 cm).

Among the genotypes LE 2 recorded the maximum leaf length in open (25.16 cm) and 50 (32.52 cm) per cent shade level. Under 25 per cent

Table 4. Number of primary branches of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	5.08	4.08	2.75	3.97
LE 2	6.08	4.42	2.50	4.33
LE 22	8.33	5.75	3.33	5.81
LE 34	9.67	6.33	3.50	6.50
LE 38	4.17	3.50	2.33	3.33
LE 39	4.42	3.58	2.50	3.50
LE 40	5.58	5.42	3.50	4.83
LE 42	3,83	3.08	2.58	3.17
LE 44	5.83	3.42	2.75	4.00
LE 45	9.67	7.50	3.75	6.97
Mean	6.28	4.71	2.95	4.64
SE	0.324	0.339	0.258	0.543
CD (genotypes)	0.964	1.010	0.768	1.538
SE	0.0297			
CD (shade levels)	0.842			

Table 5. Internodal length (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	3.86	8.24	10.66	7.59
LE 2	6.15	8.74	10.82	8.57
LE 22	7.45	9.79	11.93	9.72
LE 34	5.86	8.20	9.12	7.73
LE 38	3.83	7.18	8.04	6.35
LE 39	3.70	6.61	7.94	6.08
LE 40	5.70	7.85	8.74	7.43
LE 42	4.29	6.45	7.84	6.20
LE 44	4.71	6.82	8.58	6.70
LE 45	5.21	7.76	9.05	7.34
Mean	5.08	7.76	9.27	7.37
SE	0.333	0.590	0.460	0.441
CD (genotypes)	0.993	1.757	1.370	1.248
SE	0.242			
CD (shade levels)	0.684			

shade LE 22 (30.28 cm) recorded the maximum leaf length which was on par with LE 2 (29.44 cm) and LE 42 (28.33 cm).

Minimum leaf length under all shade levels was recorded by LE 39 with 12.47 cm, 18.08 cm and 21.42 cm respectively in open, 25 and 50 per cent shade levels.

Maximum pooled mean for leaf length was registered by LE 2 (29.04 cm) which was on par with LE 42 (27.83 cm) and LE 22 (27.04 cm). Minimum pooled mean was recorded by LE 39 (17.32 cm).

4.2.2 Leaf width

Significant difference for leaf width was observed among the genotypes under all shade levels (Table 7). An increase in leaf width was noticed with an increase in shade levels in all genotypes. Maximum leaf width was registered in plants grown under 50 per cent shade. Overall mean leaf width was maximum under 50 per cent shade (18.22 cm) followed by 25 per cent shade (15.64 cm). Minimum leaf width was recorded by plants grown in open (13.10 cm).

LE 2 registered the maximum leaf width in open (14.78 cm) and under 25 per cent shade (18.42 cm). In open, LE 2 was on par with LE 42 (14.06 cm) and LE 22 (13.97 cm). Under 25 per cent shade it was on par with LE 44 (18.38 cm). Maximum leaf width under 50 per cent shade was registered by LE 22 (22.01 cm) which was on par with LE 2 (20.14 cm).

Minimum leaf width was recorded by LE 34 (10.99 cm) and LE 39 (11.72 cm) in open, by LE 39 (12.50 cm) under 25 and by LE 40 (16.00 cm) under 50 per cent shade levels.

The performance of genotypes varied significantly among different shade levels. LE 2 recorded the maximum pooled mean of 17.78 cm. Minimum pooled mean was registered by LE 39 (13.47 cm).

4.2.3 Leaf petiole length

Significant difference among the genotypes and between different shade levels was observed for leaf petiole length (Table 8). An increase in petiole length was observed with increase in the shade level. Overall mean of petiole length due to shade was maximum under 50 per cent shade (5.06 cm) followed by 25 per cent shade (4.48 cm). Minimum leaf petiole length was recorded from plants grown in open (3.94 cm).

LE 2 had the longest petiole under all the shade levels with 5.08 cm, 5.46 cm and 5.64 cm in open, 25 and 50 per cent shade level respectively. Under 50 per cent shade LE 2 was on par with LE 45 (5.48 cm) and LE 38 (5.39 cm).

LE 1 registered the lowest petiole length in open (3.08 cm) and 50 per cent shade (4.59 cm). Under 25 per cent shade LE 34 (3.93 cm) registered the minimum petiole length which was on par with LE 1 (4.09 cm).

Table 6. Leaf length (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	20.89	22.11	25.96	22.99
LE 2	25.16	29.44	32.52	29.04
LE 22	18.92	30.28	31.94	27.04
LE 34	19.29	21.82	25.23	22.11
LE 38	15.96	18.62	22.09	18.89
LE 39	12.47	18.08	21.42	17.32
LE 40	15.92	19.04	24.83	19.93
LE 42	23.46	28.33	31.71	27.83
LE 44	22.69	26.08	28.44	25.74
LE 45	23.95	25.99	29.11	26.35
Mean	19.87	23.98	27.32	23.72
SE	0.961	0.894	0.779	0.892
CD (genotypes)	2.863	2.662	2.320	2.523
SE	0.489			
CD (shade levels)	1.382			

Table 7. Leaf width (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	13.53	15.27	17.88	15.56
LE 2	14.78	18.42	20.14	17.78
LE 22	13.97	14.01	22.01	16.67
LE 34	10.99	16.00	18.42	15.14
LE 38	13.55	15.05	16.48	15.03
LE 39	11.72	12.50	16.19	13.47
LE 40	12.92	13.51	16.00	14.14
LE 42	14.06	15.50	17.56	15.71
LE 44	12.11	18.38	18.38	16.29
LE 45	13.32	17.75	19.17	16.75
Mean	13.10	15.64	18.22	15.65
SE	0.376	0.989	0.820	0.786
CD (genotypes)	1.119	2.944	2.441	2.223
SE	0.430			
CD (shade levels)	1.218			

Maximum pooled mean for petiole length of 5.40 cm was observed in LE 2 and minimum in LE 1 (3.92 cm).

4.3 Flowering characters

4.3.1 Days to flowering

Significant variation both among genotypes and between different shade levels was observed for days to flowering (Table 9 and Fig. 3). An increase in number of days to flowering was observed with an increase in shade level. Overall mean for days to flowering was minimum in open (31.74) followed by 25 per cent shade (33.89). Maximum days to flowering was registered under 50 per cent shade (41.58).

LE 1 was earliest for flowering in open (26.58) and 25 per cent shade (28.33). Under 25 per cent shade it was on par with LE 44 (29.83). Under 50 per cent shade LE 44 (35.83) was the earliest.

LE 2 was late in flowering in open (36.67) and 50 (54.50) per cent shade levels whereas under 25 per cent shade LE 40 (37.25) took maximum days to flowering.

The lowest pooled mean was recorded by LE 1 (30.56) which was on par with LE 44 (31.39) where as the highest pooled mean of 42.44 was recorded by LE 2.

Table 8. Leaf petiole length (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	3.08	4.09	4.59	3.92
LE 2	5.08	5.46	5.64	5.40
LE 22	3.09	4.38	4.96	4.14
LE 34	3.46	3.93	4.60	3.99
LE 38	4.50	4.91	5.39	4.94
LE 39	3.68	4.18	4.82	4.22
LE 40	4.30	4.75	5.15	4.73
LE 42	3.65	3.97	4.73	4.12
LE 44	4.31	4.67	5.25	4.74
LE 45	4.23	4.51	5.48	4.74
Mean	3.94	4.48	5.06	4.49
SE	0.169	0.145	0.131	0.144
CD (genotypes)	0.504	0.432	0.390	0.407
SE	0.752			
CD (shade levels)	0.223			

Table 9. Days to flowering of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	26.58	28.33	36.75	30.56
LE 2	35.67	37.17	54.50	42.44
LE 22	30.68	33.58	38.50	34.26
LE 34	31.58	33.33	38.50	34.47
LE 38	33.58	36.25	40.75	36.86
LE 39	30.25	33.67	42.17	35.36
LE 40	34.75	37.25	48.58	40.19
LE 42	33.83	35.33	39.00	36.06
LE 44	28.50	29.83	35.83	31.39
LE 45	32.00	34.17	41.17	35.78
Mean	31.74	33.89	41.58	35.74
SE	0.588	0.628	0.684	1.373
CD (genotypes)	1.752	1.85	2.037	3.892
SE	0.752			
CD (shade levels)	2.132			

Fig. 2. Effect of shade on plant and leaf characters (Percentage difference from overall mean in open)

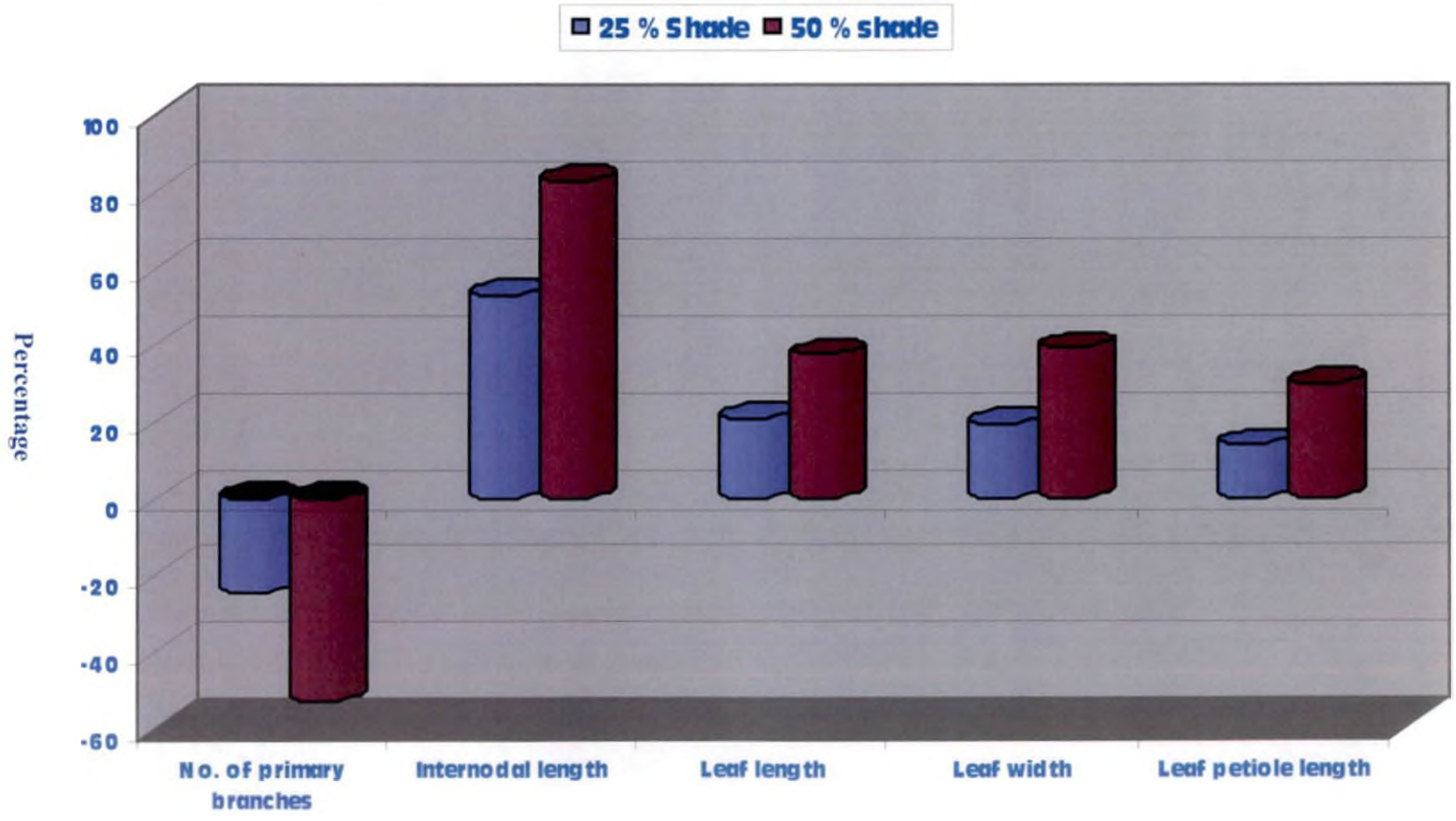
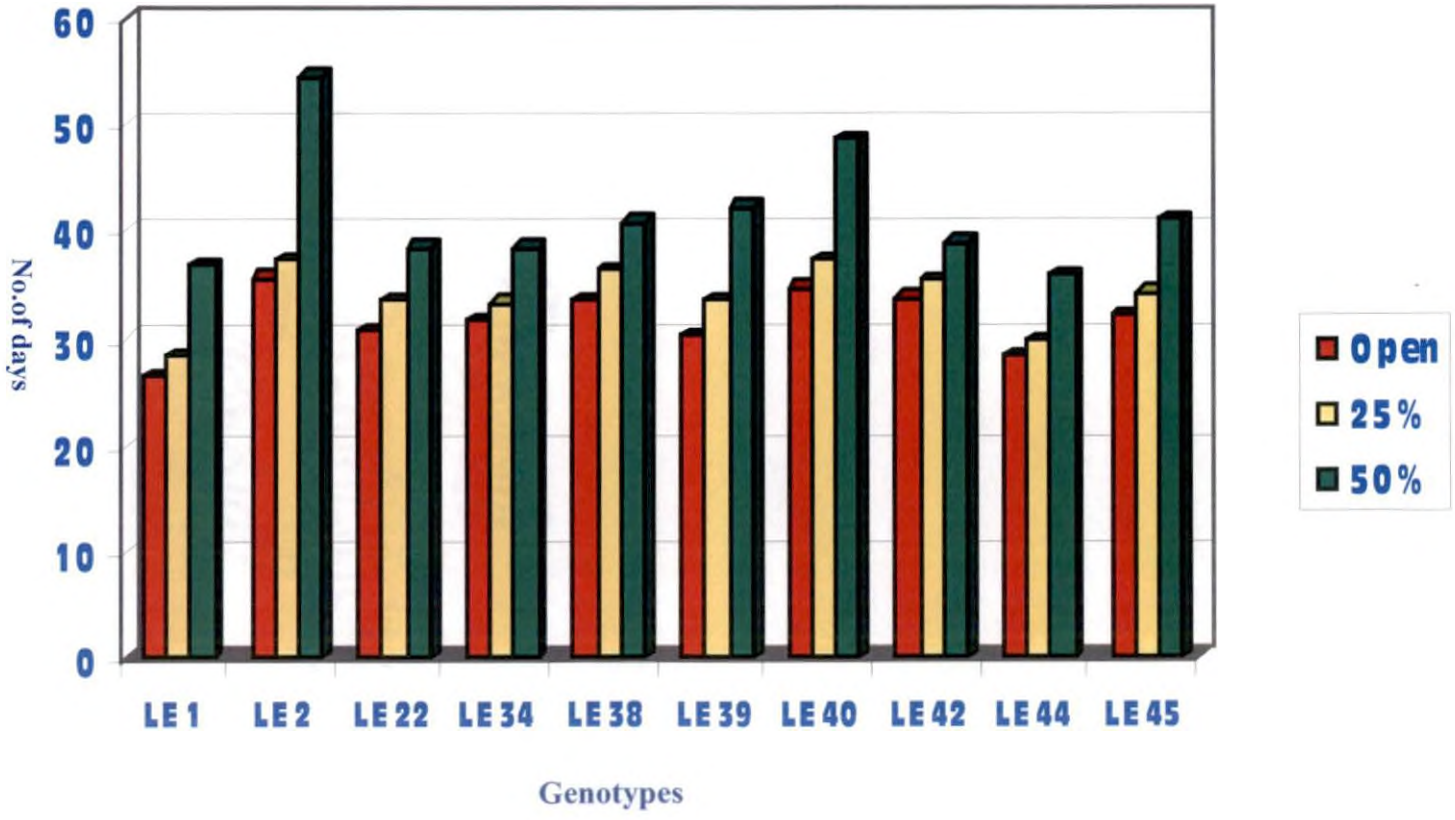


Fig. 3. Days to flowering in open, 25 and 50 per cent shade levels



4.3.2 Days to fruit set

Significant variation was observed among genotypes for days to fruit set (Table 10). But no significant variation was observed among different shade levels.

Minimum days to fruit set under all the shade levels was shown by LE 1, LE 40, LE 45 and LE 22 with 7.12, 7.31, 7.48, 7.54 respectively in open, 7.42, 7.42, 7.35, 7.33 respectively under 25 per cent shade and 7.38, 7.14, 7.25, 7.46 respectively under 50 per cent shade.

In open and under 50 per cent shade maximum days to fruit set was noticed in LE 38 (9.54, 9.46) and was on par with LE 39 (9.33, 9.21). Under 25 per cent shade maximum days to fruit set was recorded by LE 39 (9.38) and was on par with LE 38 (9.27).

Minimum pooled mean was in LE 40 (7.29), LE 1 (7.31), LE 45 (7.36) and LE 22 (7.45). Maximum pooled mean was in LE 38 (9.43) and LE 39 (9.31).

4.3.3 Flowers per cluster

There were significant difference among genotypes for flowers per cluster under all shade levels (Table 11). There was no significant variation between open and 25 per cent shade level with overall mean of 4.52 and 4.47 respectively. There was significant reduction in flowers per cluster under 50 per cent shade (3.36).

LE 45 had maximum flowers per cluster in open (6.00), 25 per cent (5.96) and 50 per cent shade level (4.11). In open, LE 45 was on par with LE 34 (5.46) and LE 40 (5.23). Under 25 per cent shade LE 45 was on par with LE 34 (5.52) and LE 22 (5.20). Under 50 per cent shade LE 45 was on par with LE 40 (3.94), LE 22 (3.88) and LE 34 (3.83).

Minimum number of flowers per cluster was shown by LE 2 in open (3.50), under 25 per cent (3.34) and 50 per cent (2.21) shade levels. It was on par with LE 42, LE 38, LE 1 and LE 39 in open (3.55, 3.86, 4.01 and 4.25 respectively) and under 25 per cent shade (3.74, 3.75, 4.02 and 4.11 respectively).

LE 45 had the maximum pooled mean of 5.36 for flowers per cluster which was on par with LE 34 (4.94) and LE 22 (4.76). The minimum pooled mean was in LE 2 (3.02).

4.3.4 Percentage fruit set

There was significant variation among genotypes for percentage fruit set under all shade levels (Table 12). There was no significant difference between open and 25 per cent shade with overall mean of 52.32 and 52.21 respectively. There was significant reduction in percentage fruit set under 50 per cent shade (41.54).

Under, all the shade levels maximum percentage fruit set was observed in LE 45 with values 55.87, 56.96 and 48.93 respectively in open,

111915

Table 10. Days to fruit set of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	7.12	7.42	7.38	7.31
LE 2	8.40	8.40	8.40	8.40
LE 22	7.54	7.33	7.46	7.45
LE 34	8.32	8.17	8.48	8.32
LE 38	9.54	9.27	9.46	9.43
LE 39	9.33	9.38	9.21	9.31
LE 40	7.31	7.42	7.14	7.29
LE 42	8.40	8.36	8.33	8.36
LE 44	8.35	8.23	8.27	8.29
LE 45	7.48	7.35	7.25	7.36
Mean	8.18	8.13	8.14	8.15
SE	0.142	0.108	0.121	0.113
CD (genotypes)	0.422	0.322	0.361	0.319
SE	6.175			
CD (shade levels)	0.175			

Table 11. Flowers per cluster of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	4.01	4.02	3.02	3.68
LE 2	3.50	3.34	2.21	3.02
LE 22	5.19	5.20	3.88	4.76
LE 34	5.46	5.52	3.83	4.94
LE 38	3.86	3:75	3.06	3.56
LE 39	4.25	4.11	3.17	3.84
LE 40	5.23	4.75	3.94	4.64
LE 42	3.55	3.74	3.02	3.43
LE 44	4.67	4.27	3.40	4.11
LE 45	6.00	5.96	4.11	5.36
Mean	4.52	4.47	3.36	4.13
SE	0.263	0.324	0.176	0.237
CD (genotypes)	0.784	0.965	0.524	0.671
SE	0.130			
CD (shade levels)	0.367			

25 and 50 per cent shade levels. In open, LE 45 was on par with LE 34 (54.90) and LE 22 (53.46) whereas under 25 per cent shade LE 45 (56.96) and LE 34 (55.08) were superior to LE 22 (53.09). Under 50 per cent shade, LE 45 (48.93) was superior to all other genotypes.

In open, 25 and 50 per cent shade, LE 2 had the minimum percentage fruit set with values 48.21, 47.90 and 35.00 respectively. Under 25 per cent shade LE 2 was on par with LE 38 (50.36).

Maximum pooled mean of 53.92 was recorded LE 45 while LE 2 recorded the minimum (43.70).

4.4 Fruit and yield characters

4.4.1 Fruit length

Significant difference among the genotypes for fruit length was observed under all the shade levels (Table 13). But there was no significant variation for fruit length among different shade levels. Overall mean for fruit length was 5.13 cm, 5.00 cm and 5.05 cm in open, 25 and 50 per cent shade levels respectively.

Maximum fruit length was recorded by LE 2 under all shade levels with 7.14 cm, in open and 7.35 cm each under 25 and 50 per cent shade levels. In open LE 2 was on par with LE 42 (6.63 cm).

Fruits were shorter in LE 22 with 3.16 cm, 3.00 cm and 2.97 cm under open, 25 and 50 per cent shade respectively.

Maximum pooled mean for fruit length was in LE 2 (7.28 cm) followed by LE 42 (6.59 cm). Minimum pooled mean was in LE 22 (3.04 cm) which was on par with LE 34 (3.29 cm) and LE 44 (3.56 cm).

4.4.2 Fruit diameter

Significant variation among genotypes for fruit diameter was observed under all shade levels (Table 14). No significant variation was observed among different shade levels for fruit diameter.

Maximum fruit diameter was in LE 2 in open, 25 and 50 per cent shade with 8.16 cm, 7.78 cm and 7.92 cm respectively. Under all the shade levels LE 2 was superior to other genotypes with respect to fruit diameter.

Minimum fruit diameter was observed in LE 44 in open (4.22 cm), 25 (4.17 cm) and 50 per cent (4.13 cm) shade levels. Under all the shade levels LE 44 was on par with LE 45 with 4.55 cm, 4.59 cm and 4.53 cm in open, 25 and 50 per cent shade levels respectively.

Maximum pooled mean for fruit diameter was in LE 2 (7.95 cm) and minimum pooled mean in LE 44 (4.17 cm).

4.4.3 Fruit weight

There was significant variation among genotypes for fruit weight under all shade levels (Table 15). But no significant variation was observed among the different shade levels.

Table 12. Percentage fruit set of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	51.29	51.69	39.51	47.50
LE 2	48.21	47.90	35.00	43.70
LE 22	53.46	53.09	46.02	50.86
LE 34	54.90	55.08	46.32	52.10
LE 38	50.90	50.36	41.29	47.52
LE 39	52.11	51.57	43.43	49.04
LE 40	52.57	52.39	44.10	49.69
LE 42	51.55	51.75	41.98	48.42
LE 44	52.34	51.27	43.22	48.94
LE 45	55.87	56.96	48.93	53.92
Mean	52.32	52.21	42.48	48.69
SE	0.844	0.930	0.812	1.651
CD (genotypes)	2.514	2.770	2.419	4.680
SE	0.904			
CD (shade levels)	2.564			

Table 13. Fruit length (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	5.43	5.32	5.13	5.29
LE 2	7.14	7.35	7.35	7.28
LE 22	3.16	3.00	2.97	3.04
LE 34	3.35	3.30	3.22	3.29
LE 38	6.39	6.01	6.48	6.29
LE 39	6.52	6.09	6.32	6.31
LE 40	5.14	5.13	5.28	5.18
LE 42	6.63	6.66	6.49	6.59
LE 44	3.63	3.48	3.57	3.56
LE 45	3.91	3.68	3.72	3.77
Mean	5.13	5.00	5.05	5.06
SE	0.204	0.206	0.256	0.197
CD (genotypes)	0.607	0.615	0.761	0.557
SE	0.108			
CD (shade levels)	0.305			

LE 2 had the maximum fruit weight under open (86.74 g), 25 (87.03 g) and 50 (88.75 g) per cent shade levels. LE 22 had the minimum fruit weight in open (30.80 g) 25 (31.35 g) and 50 (30.43 g) per cent shade levels.

Maximum pooled mean for fruit weight was recorded by LE 2 (87.51 g) and minimum by LE 22 (30.86 g).

4.4.4 Fruits per plant

Significant difference was observed among the genotypes for fruits per plant under all the shade levels (Table 16). No significant variation was observed for fruits per plant among open and 25 per cent shade. Overall mean of fruits per plant in open (20.57) was on par with that at 25 per cent shade (20.78). But number of fruits per plant reduced significantly under 50 per cent shade where the overall mean was only 7.74.

The genotype LE 45 had maximum fruits under all shade levels with 38.17, 37.67 and 16.00 respectively in open, 25 and 50 per cent shade. LE 34 was on par with LE 45 under 25 per cent (36.23) and 50 per cent (14.25) shade levels.

Minimum fruits per plant was recorded by LE 2 in all the shade levels with 6.25, 7.50 and 1.33 fruits in open, 25 and 50 per cent shade

respectively. The performance of genotype varied significantly among different shade levels.

LE 45 had the maximum pooled mean for fruits per plant (30.61) which was on par with LE 34 (28.10) and LE 22 (27.22). LE 2 had the minimum pooled mean of 5.03.

4.4.5 Yield per plant

There was significant variation among genotypes for yield under all shade levels and no significant variation was observed for yield per plant between open and 25 per cent shade (Table 17 and Fig. 5). Overall mean of yield in open (931.96 g) was on par with that at 25 per cent shade (924.60 g). But there was significant reduction in yield under 50 per cent shade. Under 50 per cent shade level the overall mean yield was 333.20 g.

The genotype LE 45 had maximum yield under all shade levels with 1523.51 g, 1670.37 g and 643.68 g respectively in open, 25 and 50 per cent shade.

Minimum yield was in LE 1 in open (512.15 g), in LE 38 under 25 (545.92 g) and in LE 2 under 50 (118.6 g) per cent shade.

LE 45 had the maximum pooled yield (1279.19 g) followed by LE 34 (1032.19 g) and LE 22 (878.50 g). LE 1 had the minimum pooled yield (421.52 g) which was on par with LE 38 (458.56 g), LE 2 (458.65 g), LE 42 (485.57 g) and LE 39 (601.98 g).

Table 14. Fruit diameter (cm) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	5.99	5.87	6.17	6.01
LE 2	8.16	7.78	7.92	7.95
LE 22	5.09	4.94	5.19	5.07
LE 34	5.17	4.89	5.06	5.04
LE 38	5.77	5.52	5.66	5.65
LE 39	5.75	5.80	5.68	5.74
LE 40	4.97	4.88	4.81	4.89
LE 42	6.88	6.92	6.93	6.91
LE 44	4.22	4.17	4.13	4.17
LE 45	4.55	4.59	4.53	4.56
Mean	5.66	5.54	5.61	5.60
SE	0.113	0.149	0.143	0.121
CD (genotypes)	0.337	0.445	0.424	0.343
SE	6.641			
CD (shade levels)	0.188			

Table 15. Fruit weight (g) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	53.23	52.55	51.66	52.48
LE 2	86.74	87.03	88.75	87.51
LE 22	30.80	31.35	30.43	30.86
LE 34	39.82	40.07	39.42	39.77
LE 38	61.01	59.94	60.42	60.46
LE 39	61.27	60.61	60.23	60.70
LE 40	50.98	50.45	50.22	50.55
LE 42	70.10	70.20	69.62	69.98
LE 44	38.18	37.78	38.25	38.07
LE 45	47.49	47.89	47.81	47.73
Mean	53.96	53.79	53.68	53.81
SE	0.601	0.695	0.873	0.654
CD (genotypes)	1.790	2.07	2.601	1.850
SE	0.358			
CD (shade levels)	1.013			

Fruit characters of tomato genotypes included in the study

Plate 11

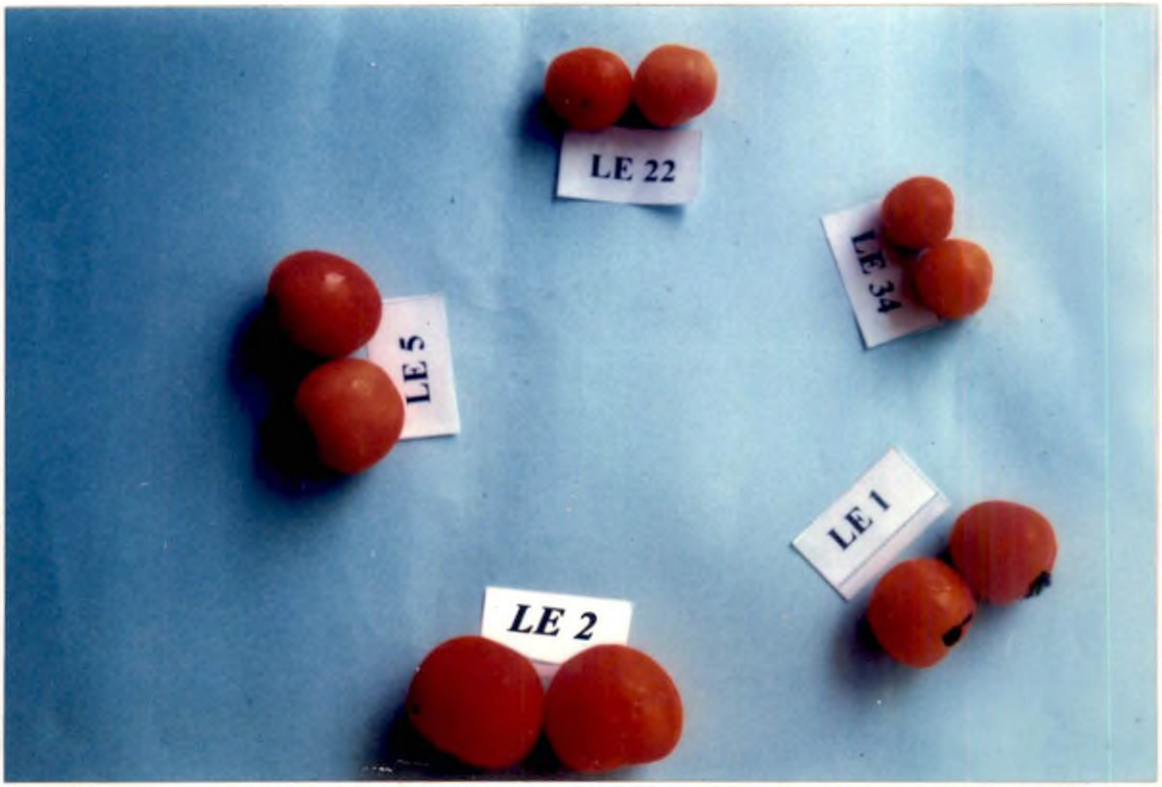


Plate 12

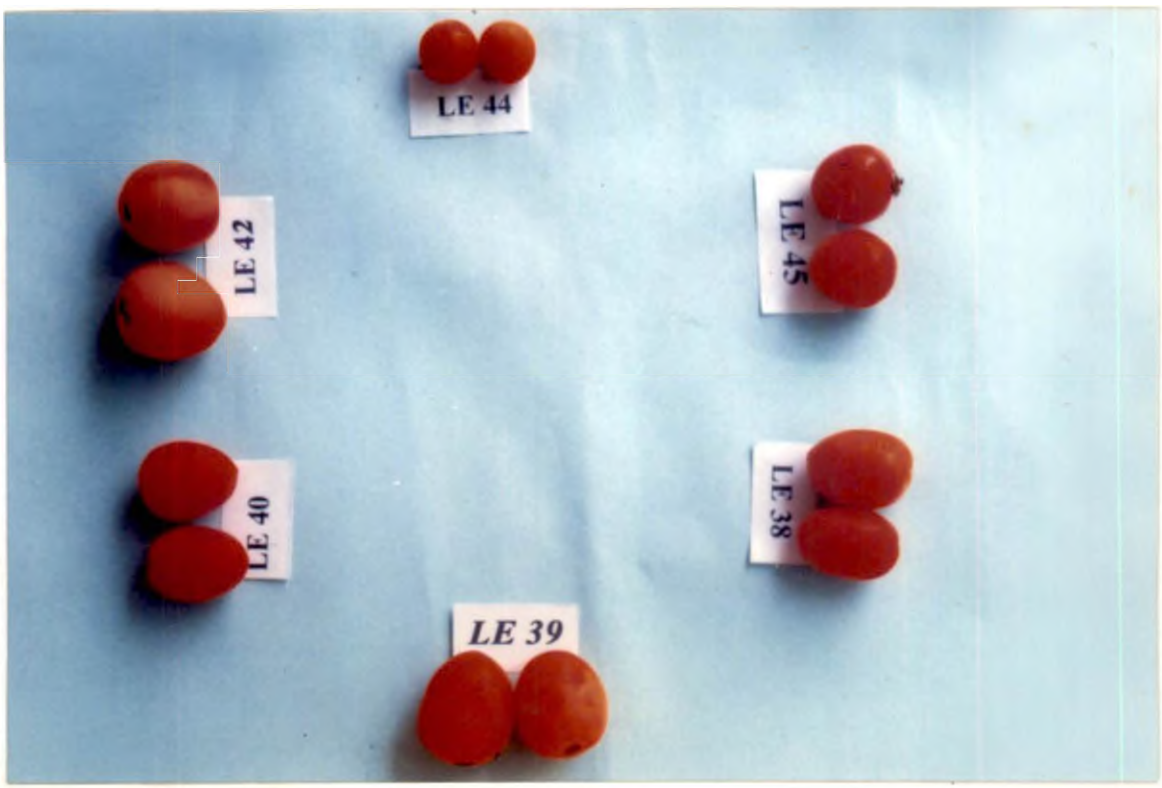


Table 16. Fruits per plant of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	8.75	10.75	3.50	7.67
LE 2	6.25	7.50	1.33	5.03
LE 22	34.17	33.83	13.67	27.22
LE 34	33.83	36.23	14.25	28.10
LE 38	10.08	9.50	3.67	7.75
LE 39	12.67	14.08	4.33	10.36
LE 40	29.25	27.92	9.92	22.36
LE 42	8.92	8.94	2.86	6.90
LE 44	23.58	21.33	7.83	17.58
LE 45	38.17	37.67	16.00	30.61
Mean	20.57	20.78	7.74	16.36
SE	0.862	1.074	0.658	2.373
CD (genotypes)	2.568	3.199	1.959	6.728
SE	1.300			
CD (shade levels)	3.685			

Table 17. Yield per plant (g) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	512.15	559.51	192.90	421.52
LE 2	607.47	649.89	118.60	458.65
LE 22	1114.29	1130.33	390.86	878.50
LE 34	1312.34	1288.67	495.56	1032.19
LE 38	604.26	545.92	225.50	458.56
LE 39	776.38	766.36	263.20	601.98
LE 40	1142.47	1031.55	401.71	858.58
LE 42	621.92	609.56	226.43	485.57
LE 44	1104.84	993.80	373.53	824.06
LE 45	1523.51	1670.37	643.68	1279.19
Mean	931.96	924.60	333.20	729.92
SE	45.336	66.808	33.025	72.622
CD (genotypes)	135.026	198.976	98.359	205.920
SE	39.78			
CD (shade levels)	112.79			

Fig. 4. Comparison of percentage fruit set and number of fruits per plant in open and 50 per cent shade level (percentage reduction from open)

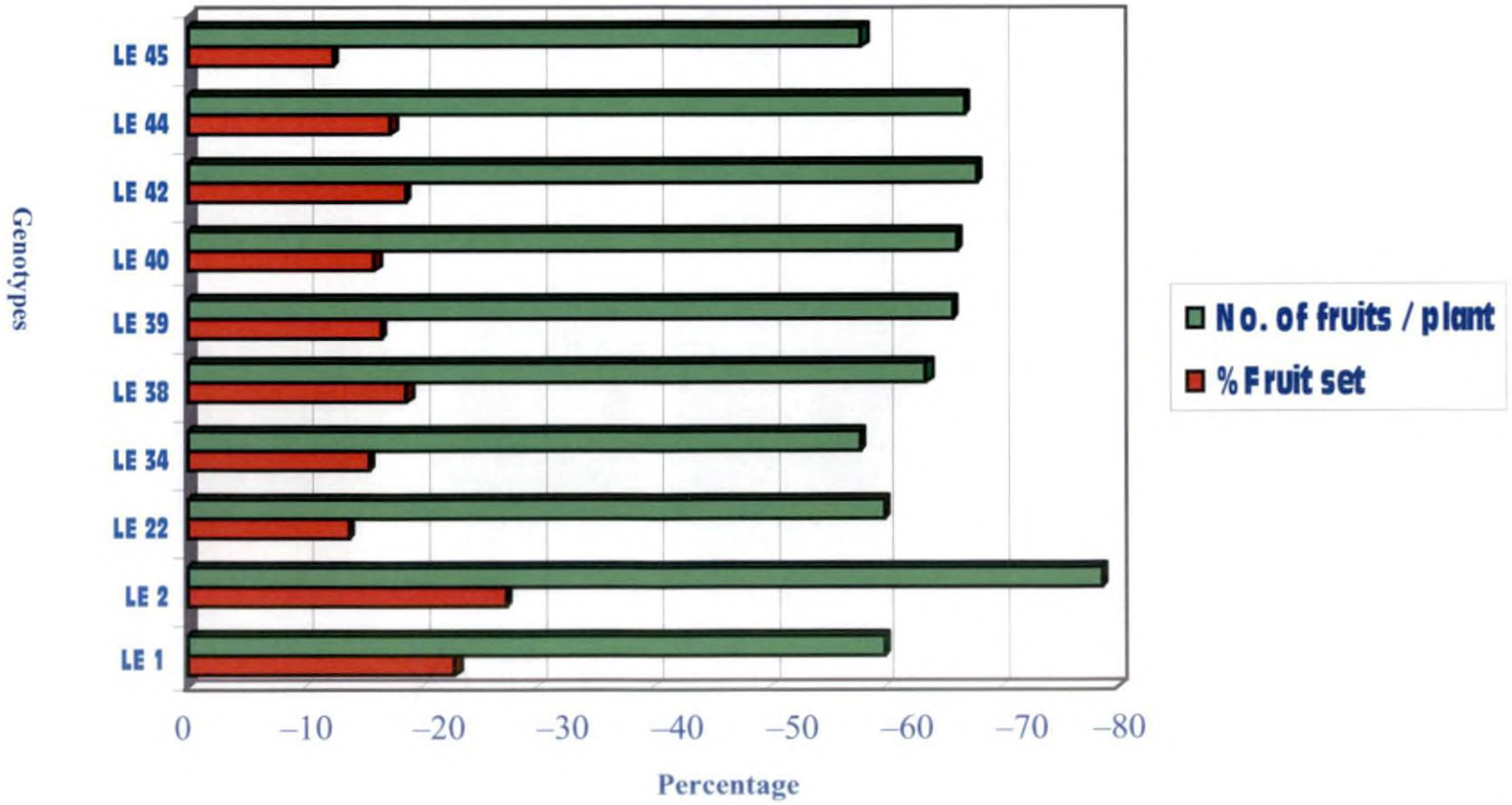
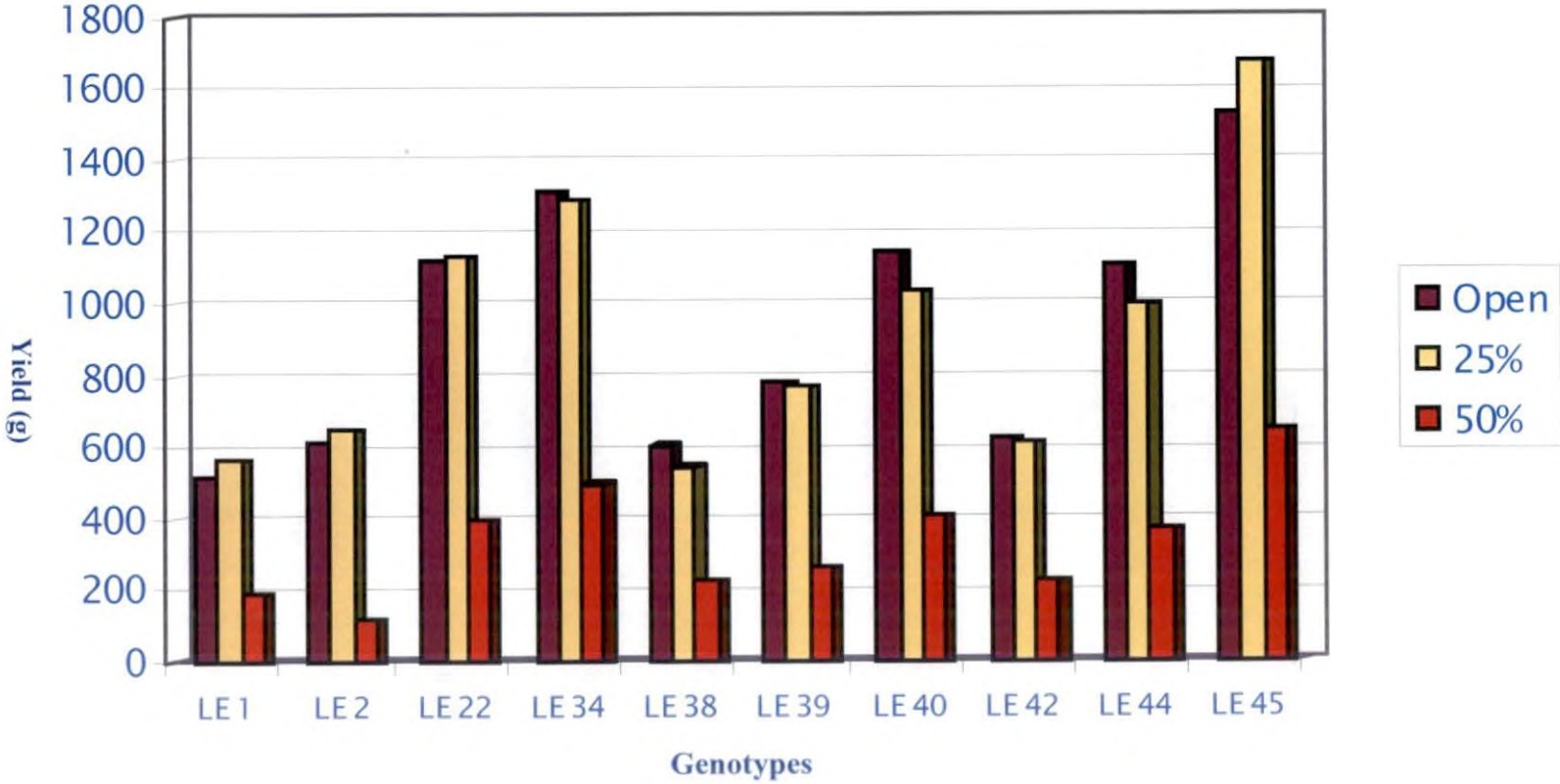


Fig. 5. Effect of shade on yield



Shade and bacterial wilt tolerant tomato genotypes

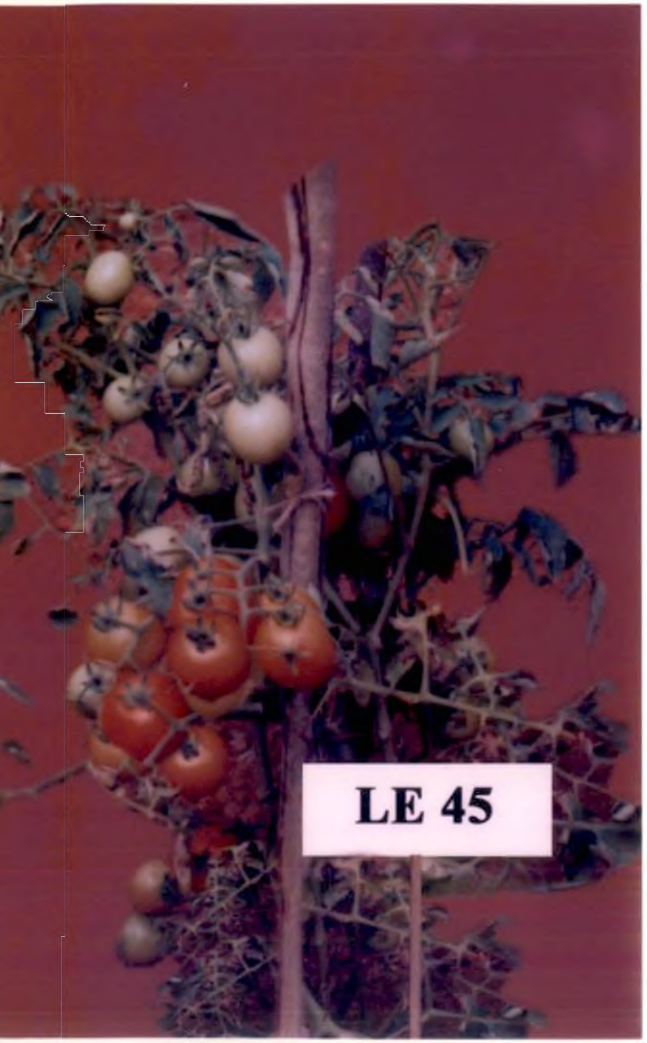


Plate 12

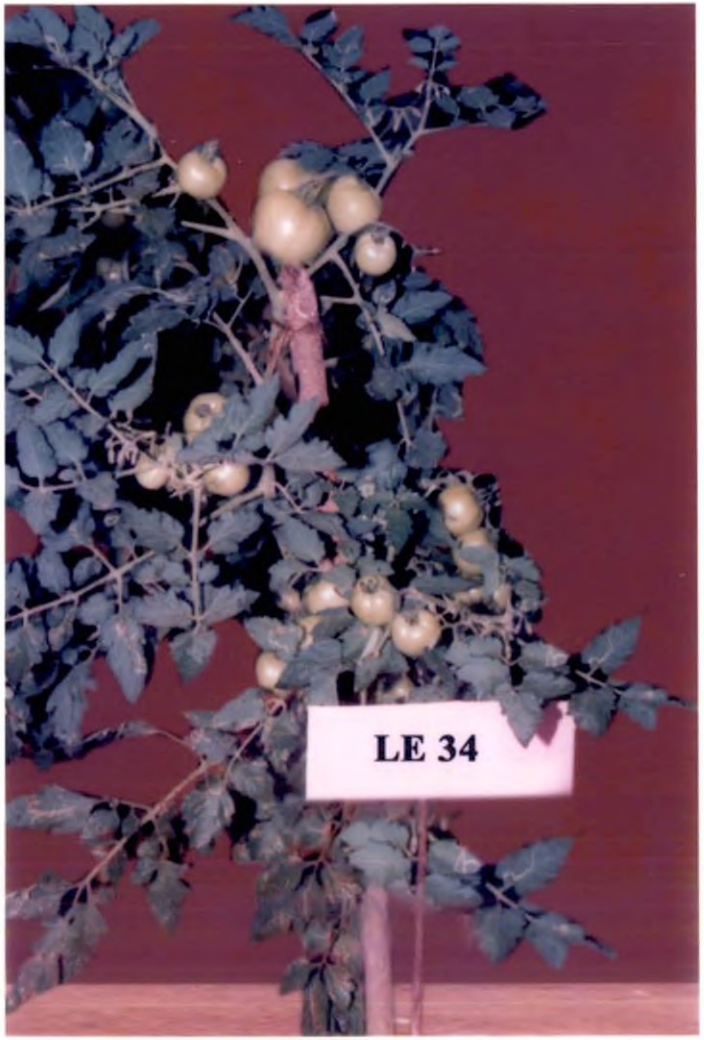


Plate 13

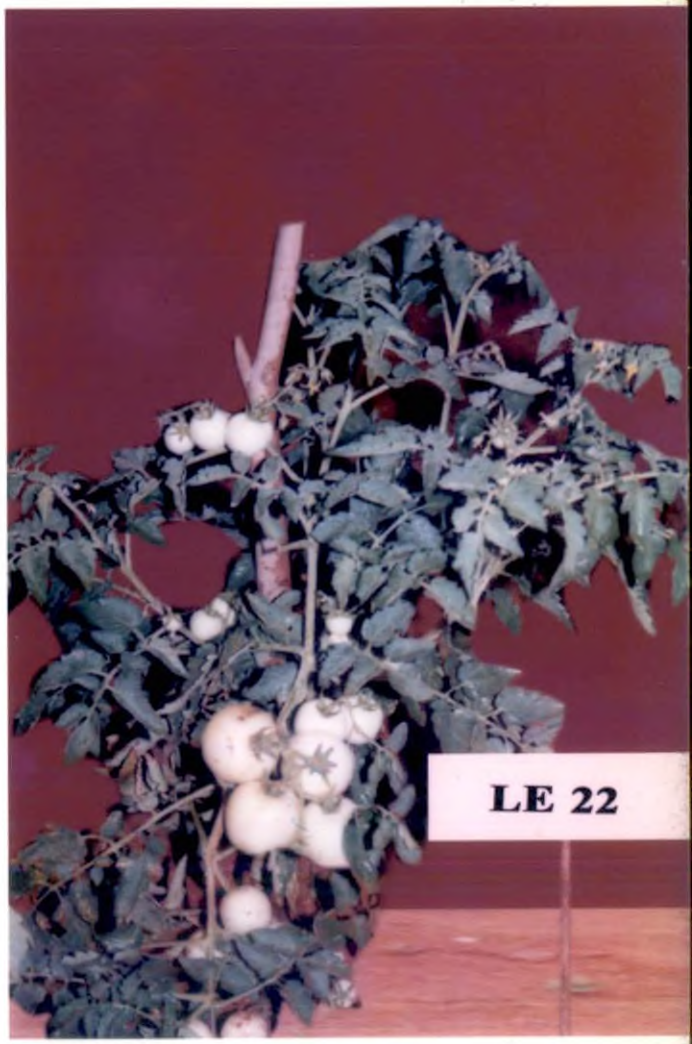


Plate 14

4.5 Reaction towards diseases, pests and physiological disorders

4.5.1 Diseases

4.5.1.1 Bacterial wilt

To assure the incidence of bacterial wilt diseases in the field a susceptible check variety namely LE 5 (Fla 7156) was planted in the field under all the shade levels. It was observed that non of the resistant genotypes were affected by the disease under all shade levels whereas, the susceptible variety completely succumbed to the disease irrespective of shade levels (Plate 15).

4.5.1.2 Fusarium wilt

No incidence of fusarium wilt was noticed in the present study hence observation was not possible.

4.5.1.3 Spotted wilt disease

There was significant variation in the incidence of spotted wilt both among the genotypes and between different shade levels (Table 18 and Fig. 6). Minimum score was under 50 per cent shade level (0.88) followed by 25 per cent shade (1.53). Maximum score was recorded in open (2.14).

LE 34 recorded the minimum score in open (1.33) and under 25 per cent shade level (0.92). Under 50 per cent shade level minimum score was recorded by LE 44 (0.50) which was on par with LE 34 (0.58).

Plate 15. Bacterial wilt incidence in the susceptible variety, LE 5

LE 1 and LE 22 had maximum incidence in open (3.58, 2.83 respectively) and under 25 per cent shade level (2.58, 1.92 respectively). Under 50 per cent shade maximum score was recorded by LE 1 (1.50) which was on par with LE 22 (1.33), LE 42 (1.00) and LE 2 (0.92).

LE 34 registered the minimum pooled mean of 0.94 where as maximum pooled mean was recorded by LE 1 (2.55).

4.5.2 Insect pests

4.5.2.1 Leaf miner

Significant difference both among the genotypes and between different shade levels was observed for incidence of leaf miner (Table 19 and Fig. 7). There was decrease in leaf miner incidence with increase in shade with 50 per cent shade level scoring the lowest value of 1.48 compared to 2.09 in open.

The lowest score was registered by LE 42 (1.33) in open condition and was on par with LE 2 (1.50). LE 2 registered the lowest score under 25 (1.08) and 50 (0.75) per cent shade which was on par with LE 42 under 25 (1.25) and 50 (0.92) per cent shade levels.

LE 45 and LE 44 recorded the maximum score in open (3.33, 3.17), 25 (2.67, 3.00) and under 50 (2.17, 2.58) per cent shade levels.

The minimum pooled mean was recorded by LE 2 (1.11) which was on par with LE 42 and LE 22 (1.17 each) whereas, the maximum pooled mean was shown by LE 44 (2.92) which was on par with LE 45 (2.72).

4.5.2.2 Fruit borer

There was significant difference both among the genotypes and between different shade levels for the incidence of fruit borer (Table 20 and Fig. 8). Fruit borer incidence was found to decrease with increase in shade levels with 50 per cent shade level having the minimum overall mean of 0.33. Maximum overall mean was in open (1.12).

LE 42 recorded the lowest score in open (0.67) and 25 per cent shade (0.33) and was on par with LE 1 and LE 2 in open (0.92, 0.83) and 25 per cent shade (0.52, 0.58). Under 50 per cent shade LE 1, LE 2 and LE 42 registered the lowest score of 0.08.

LE 22 registered the maximum score under open (1.58), 25 (1.33) and 50 (0.83) per cent shade levels.

LE 42 showed the minimum pooled mean of 0.36 followed by LE 2 (0.50) and LE 22 recorded the maximum pooled mean of 1.25.

Table 18. Incidence of spotted wilt disease in tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	3.58	2.58	1.50	2.55
LE 2	2.42	1.67	0.92	1.67
LE 22	2.83	1.92	1.33	2.03
LE 34	1.33	0.92	0.58	0.94
LE 38	2.25	1.50	0.83	1.53
LE 39	2.08	1.08	0.75	1.31
LE 40	1.92	1.50	0.67	1.36
LE 42	1.83	1.75	1.00	1.53
LE 44	1.50	1.25	0.50	1.08
LE 45	1.67	1.08	0.75	1.17
Mean	2.14	1.53	0.88	1.51
SE	0.322	0.253	0.304	0.265
CD (genotypes)	0.958	0.755	0.905	0.750
SE	0.145			
CD (shade levels)	0.411			

Table 19. Incidence of serpentine leaf miner in tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	1.42	1.33	1.00	1.25
LE 2	1.50	1.08	0.75	1.11
LE 22	1.42	1.08	1.00	1.17
LE 34	2.75	1.83	1.58	2.06
LE 38	1.67	1.58	1.42	1.56
LE 39	2.58	2.17	2.08	2.28
LE 40	1.75	1.67	1.33	1.58
LE 42	1.33	1.25	0.92	1.17
LE 44	3.17	3.00	2.58	2.92
LE 45	3.33	2.67	2.17	2.72
Mean	2.09	1.77	1.48	1.78
SE	0.260	0.195	0.267	0.217
CD (genotypes)	0.773	0.581	0.795	0.613
SE	0.119			
CD (shade levels)	0.334			

Fig. 6. Effect of shade on incidence of spotted wilt disease

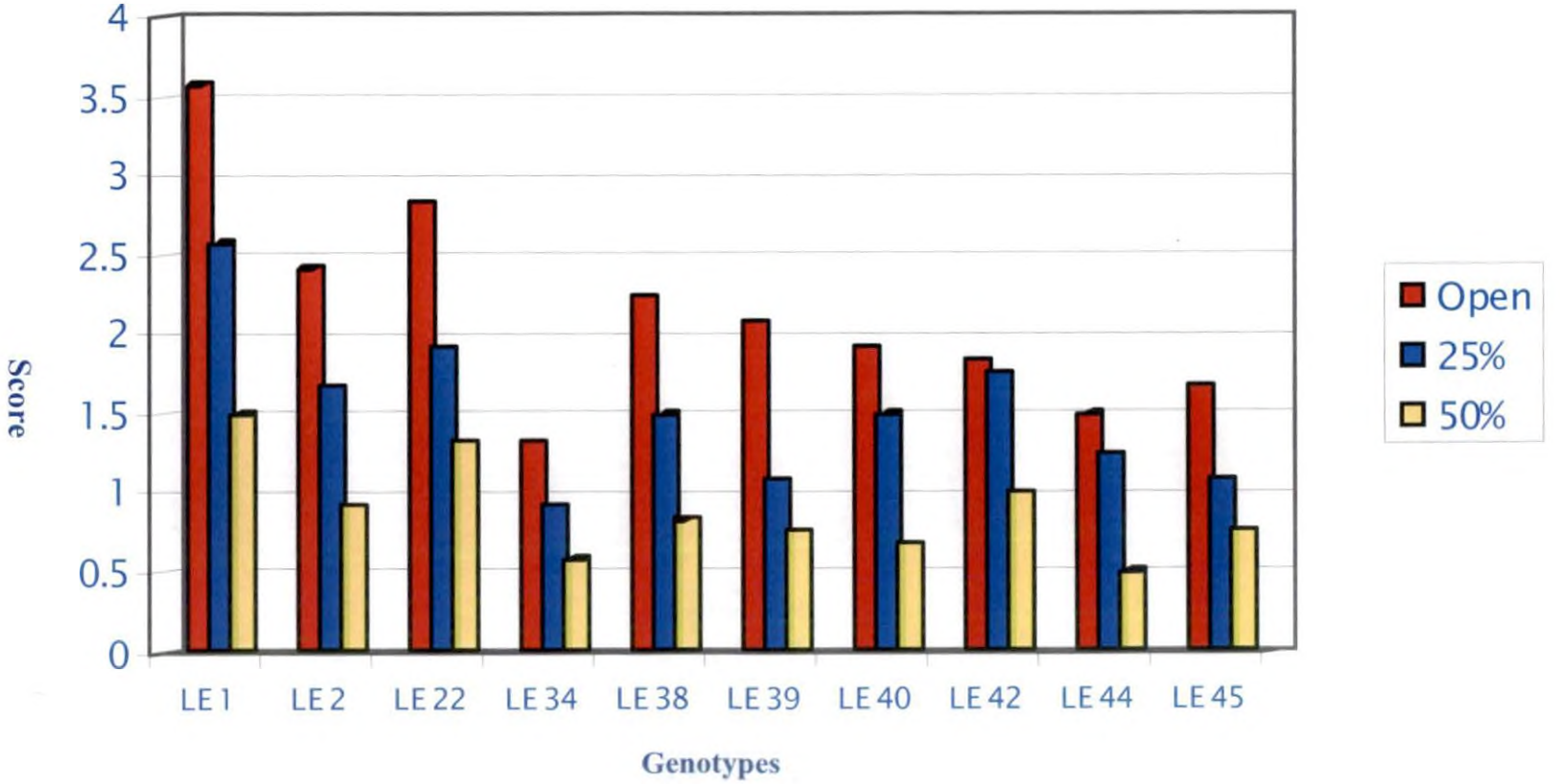
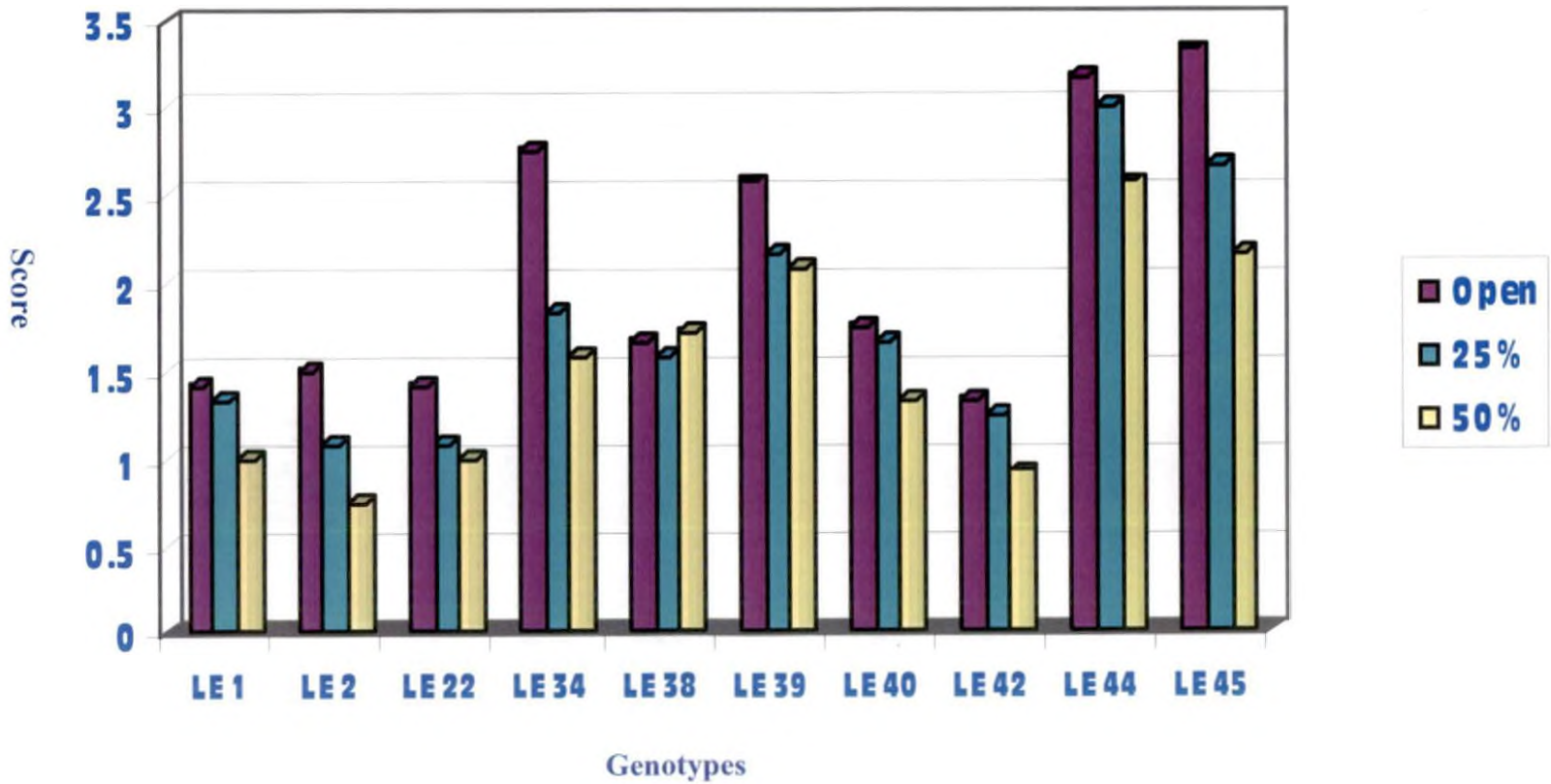


Fig. 7. Effect of shade on incidence of serpentine leaf miner, *Liriomyza trifolii* (Burgess)



4.5.3 Physiological disorders

No incidence of sun scald damage and fruit cracking was observed during the present study. Hence could not take observations on these aspects.

4.6 Anatomical characters

4.6.1 Stomatal percentage

There was significant variation for stomatal percentage both among the genotypes and among the shade levels (Table 21). All the genotypes grown in open had more stomatal percentage than those grown under 25 and 50 per cent shade levels. The overall mean stomatal percentage was highest in open (21.76) followed by 25 per cent shade (19.81). The lowest overall mean was recorded under 50 per cent shade level (15.69).

The genotype LE 45 recorded maximum stomatal percentage with values 26.60, 26.03 and 21.96 respectively in open, 25 and 50 per cent shade levels. LE 1 recorded the minimum stomatal percentage in open (16.41), 25 (15.42) and 50 (12.29) per cent shade levels.

LE 45 registered the maximum pooled mean of 24.86, LE 1 the minimum (14.71).

4.6.2 Vascular bundle

No significant variation for number of vascular bundles among the genotypes under all shade levels (Table 22). Overall mean in open (14.35)

Fig. 8. Effect of shade on incidence of tomato fruit borer, *Helicoverpa armigera* (Hubner)

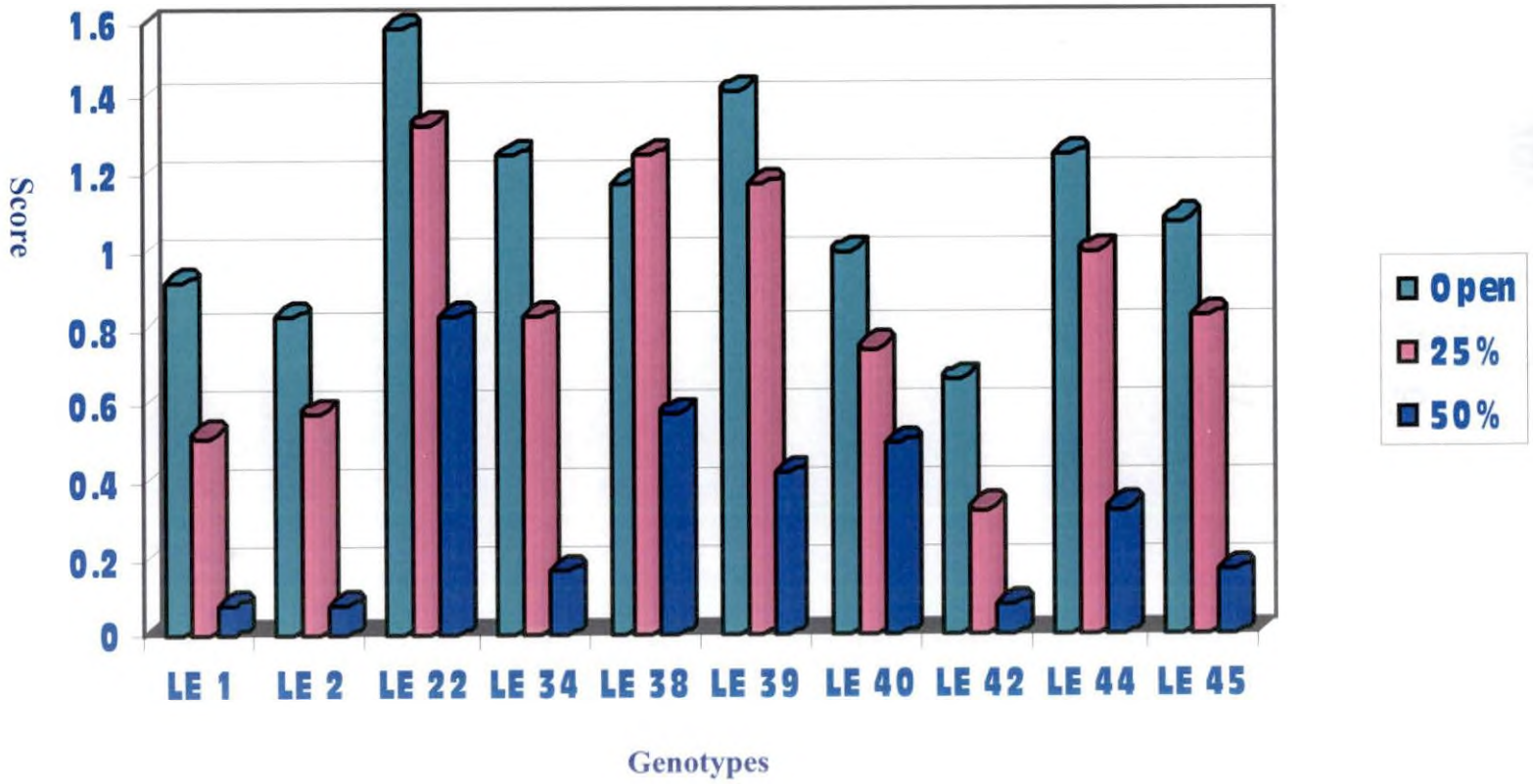


Table 20. Incidence of fruit borer in tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	0.92	0.52	0.08	0.51
LE 2	0.83	0.58	0.08	0.50
LE 22	1.58	1.33	0.83	1.25
LE 34	1.25	0.83	0.17	0.75
LE 38	1.17	1.25	0.58	1.00
LE 39	1.42	1.17	0.42	1.00
LE 40	1.00	0.75	0.50	0.75
LE 42	0.67	0.33	0.08	0.36
LE 44	1.25	1.00	0.33	0.86
LE 45	1.08	0.83	0.17	0.69
Mean	1.12	0.86	0.33	0.77
SE	0.111	0.161	0.121	0.120
CD (genotypes)	0.330	0.481	0.360	0.340
SE	6.586			
CD (shade levels)	0.186			

Table 21. Stomatal percentage of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	16.41	15.42	12.29	14.71
LE 2	22.51	21.71	16.90	20.38
LE 22	24.17	23.52	13.11	20.27
LE 34	22.96	21.36	12.37	18.90
LE 38	20.65	19.05	18.04	19.25
LE 39	20.35	16.61	15.33	17.43
LE 40	21.28	16.24	13.95	17.16
LE 42	19.48	18.34	16.47	18.09
LE 44	23.14	19.85	16.43	19.81
LE 45	26.60	26.03	21.96	24.86
Mean	21.76	19.81	15.69	19.09
SE	0.696	0.619	0.662	1.079
CD (genotypes)	2.074	1.842	1.971	3.058
SE	0.591			
CD (shade levels)	1.675			

and 25 per cent shade (14.00) were on par. Overall mean under 50 per cent shade (11.63) differed significantly from the other two shade levels.

In open the highest number of vascular bundles was recorded by LE 40 (15.36) and the lowest by LE 39 (13.67). Under 25 per cent shade the highest value was recorded by LE 34 (15.00), the lowest by LE 2 (12.89). Under 50 per cent shade the value ranged from 10.55 in LE 1 to 12.78 in LE 40.

Highest pooled mean (14.09) was recorded by LE 40 and lowest by LE 1 (12.48).

4.7 Biochemical characters

4.7.1 Chlorophyll

4.7.1.1 Chlorophyll a

Significant difference for chlorophyll a content was observed among genotypes under all shade levels (Table 23). There was also significant difference in chlorophyll a content among different shade levels. An increase in the content of chlorophyll a was observed as shade increases from open to 50 per cent. Maximum chlorophyll a content was observed under 50 per cent shade (0.620 mg g^{-1}) followed by 25 per cent shade (0.593 mg g^{-1}). Minimum value was recorded in open (0.540 mg g^{-1}).

In open LE 45 recorded the maximum chlorophyll a content of 0.578 mg g^{-1} and LE 45 was on par with LE 34 (0.571 mg g^{-1}), LE 22 (0.564 mg g^{-1}) and LE 44 (0.560 mg g^{-1}). Under 25 and 50 per cent shade levels, LE 45 and LE 34 were superior to all other genotypes with values 0.628 mg g^{-1} and 0.619 mg g^{-1} respectively under 25 per cent shade and 0.665 mg g^{-1} and 0.659 mg g^{-1} respectively under 50 per cent shade.

Minimum chlorophyll a content under all shade levels was recorded by LE 1 with values 0.522 mg g^{-1} in open, 0.559 mg g^{-1} under 25 per cent shade and 0.572 mg g^{-1} under 50 per cent shade. Under 25 per cent shade LE 1 was on par with LE 2 and LE 40 with a value of 0.571 mg g^{-1} each.

Maximum pooled mean for chlorophyll a content was recorded by LE 45 (0.624 mg g^{-1}) and LE 34 (0.616 mg g^{-1})). Minimum pooled mean was recorded by LE 1 (0.551 mg g^{-1}) and LE 2 (0.563 mg g^{-1}).

4.7.1.2 Chlorophyll b

There was significant variation among the genotypes for chlorophyll b content (Table 24). Significant difference existed among different shade levels too. Maximum chlorophyll b content was recorded under 50 per cent shade (0.754 mg g^{-1}) followed by 25 per cent shade (0.675 mg g^{-1}) and minimum in open (0.618 mg g^{-1}).

Under all the shade levels maximum chlorophyll b content was recorded by LE 45 and LE 34 with values 0.651 mg g^{-1} and 0.633 mg g^{-1}

Table 22. Number of vascular bundles of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	13.89	13.00	10.55	12.48
LE 2	14.22	12.89	11.00	12.70
LE 22	15.26	14.12	12.22	13.87
LE 34	14.11	15.00	11.67	13.59
LE 38	14.11	13.90	11.44	13.15
LE 39	13.67	14.44	11.71	13.27
LE 40	15.36	14.12	12.78	14.09
LE 42	13.78	14.33	11.33	13.15
LE 44	15.00	13.89	11.56	13.48
LE 45	14.11	14.33	12.00	13.48
Mean	14.35	14.00	11.63	13.33
SE	0.510	0.419	0.656	0.506
CD (genotypes)	1.518	1.249	1.955	1.431
SE	0.2772			
CD (shade levels)	0.784			

Table 23. Chlorophyll a content (mg g^{-1}) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	0.522	0.559	0.572	0.551
LE 2	0.540	0.571	0.585	0.565
LE 22	0.564	0.611	0.643	0.606
LE 34	0.571	0.619	0.659	0.616
LE 38	0.552	0.592	0.607	0.584
LE 39	0.555	0.596	0.626	0.592
LE 40	0.544	0.571	0.585	0.567
LE 42	0.547	0.586	0.598	0.577
LE 44	0.560	0.604	0.637	0.600
LE 45	0.578	0.628	0.665	0.624
Mean	0.540	0.593	0.620	0.590
SE	0.0604	0.0041	0.0043	0.0050
CD (genotypes)	0.179	0.0121	0.0129	0.0141
SE	2.7216			
CD (shade levels)	0.0077			

respectively in open, 0.698 mg g^{-1} and 0.694 mg g^{-1} respectively under 25 per cent shade and 0.916 mg g^{-1} and 0.843 mg g^{-1} respectively under 50 per cent shade. In open and under 25 per cent shade levels LE 45 and LE 34 were on par with LE 22 with values 0.628 mg g^{-1} in open and 0.692 mg g^{-1} under 25 per cent shade.

Under all the shade levels minimum chlorophyll b content was registered by LE 1 with 0.516 mg g^{-1} in open, 0.637 mg g^{-1} in 25 per cent shade, 0.674 mg g^{-1} under 50 per cent shade.

Maximum pooled mean for chlorophyll b content was recorded by LE 45 (0.755 mg g^{-1}) and LE 34 (0.723 mg g^{-1}) and minimum by LE 1 (0.609 mg g^{-1}).

4.7.1.3 Total chlorophyll

There was significant variation among the genotypes for the total chlorophyll content (Table 25). Significant difference existed between different shade levels too. Maximum total chlorophyll content was recorded under 50 per cent shade (1.372 mg g^{-1}) followed by 25 per cent shade level (1.269 mg g^{-1}) and minimum in open (1.171 mg g^{-1}).

LE 45, LE 34 and LE 22 recorded maximum total chlorophyll content in open and 25 per cent shade with values 1.229 mg g^{-1}, 1.204 mg g^{-1}, 1.194 mg g^{-1} respectively in open and 1.326 mg g^{-1}, 1.313 mg

g^{-1}, 1.303 mg g^{-1} respectively under 25 per cent shade. Under 50 per cent shade LE 45 (1.581 mg g^{-1}) was superior to all other genotypes.

Under all shade levels, LE 1 recorded minimum total chlorophyll content with 1.038 mg g^{-1} in open, 1.196 mg g^{-1} under 25 per cent and 1.246 mg g^{-1} under 50 per cent shade level.

Maximum pooled mean for total chlorophyll content was recorded by LE 45 (1.379 mg g^{-1}) and LE 34 (1.340 mg g^{-1}) and minimum by LE 1 (1.160 mg g^{-1}).

4.7.2 Proline

Significant difference among genotypes for proline content was observed under all shade levels (Table 26). There was also significant difference among the shade levels. Proline content was found to decrease with increase in shade. Highest proline content was recorded from plants grown in open condition (1.92 µg g^{-1}). Lowest proline content was registered under 50 per cent shade level (1.61 µg g^{-1}).

LE 39 had the maximum proline content of 2.03 µg g^{-1}, 1.92 µg g^{-1} and 1.78 µg g^{-1} respectively in open, 25 per cent and 50 per cent shade levels and was on par with LE 38 (2.02 µg g^{-1}) in open and with LE 45 (1.77 µg g^{-1}) under 50 per cent shade. Minimum proline content under all shade levels was in LE 2 with values 1.78 µg g^{-1}, 1.49 µg g^{-1} and 1.39 µg g^{-1} respectively in open, 25 and 50 per cent shade levels.

Table 24. Chlorophyll b content (mg g^{-1}) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	0.516	0.637	0.674	0.609
LE 2	0.624	0.664	0.692	0.660
LE 22	0.628	0.692	0.792	0.704
LE 34	0.633	0.694	0.843	0.723
LE 38	0.623	0.669	0.699	0.664
LE 39	0.630	0.681	0.780	0.697
LE 40	0.620	0.661	0.698	0.660
LE 42	0.627	0.674	0.707	0.669
LE 44	0.628	0.678	0.738	0.681
LE 45	0.651	0.698	0.916	0.755
Mean	0.618	0.675	0.754	0.682
SE	0.0069	0.0046	0.0047	0.0175
CD (genotypes)	0.0206	0.0.137	0.0140	0.4926
SE	9.5923			
CD (shade levels)	0.0272			

Table 25. Total chlorophyll content (mg g^{-1}) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	1.038	1.196	1.246	1.160
LE 2	1.161	1.235	1.277	1.224
LE 22	1.194	1.303	1.435	1.310
LE 34	1.204	1.313	1.502	1.340
LE 38	1.175	1.261	1.306	1.247
LE 39	1.185	1.277	1.406	1.289
LE 40	1.164	1.232	1.283	1.226
LE 42	1.174	1.260	1.305	1.246
LE 44	1.188	1.283	1.376	1.282
LE 45	1.229	1.326	1.581	1.379
Mean	1.171	1.269	1.372	1.273
SE	0.0123	0.0082	0.0086	0.0222
CD (genotypes)	0.0366	0.0245	0.0256	0.0629
SE	1.2141			
CD (shade levels)	0.0344			

Maximum pooled mean for proline content was in LE 39 (1.91μg g^{-1}) which was on par with LE 45 (1.87 μg g^{-1}) and LE 38 (1.85 μg g^{-1}). Minimum pooled mean was in LE 2 (1.55 μg g^{-1}) which was on par with LE 1 (1.61 μg g^{-1}).

4.7.3 Vitamin C

Significant difference was observed for vitamin C content among genotypes under all shade levels (Table 27). Significant difference existed between different shade levels too. Overall mean vitamin C content was maximum under 25 per cent shade (28.18 mg 100 g^{-1}) followed by open condition (26.43 mg 100 g^{-1}). Minimum overall mean vitamin C content was recorded under 50 per cent shade (23.69 mg 100 g^{-1}).

LE 22 had maximum vitamin C content with 30.06 mg 100 g^{-1}, 31.25 mg 100 g^{-1} and 25.91 mg 100 g^{-1} respectively in open, 25 and 50 per cent shade levels. Minimum vitamin C content in open and under 50 per cent shade was in LE 2 with 24.10 mg 100 g^{-1} and 22.38 mg 100 g^{-1} respectively. Under 25 per cent shade LE 1 had the minimum vitamin C content (26.2 mg 100 g^{-1}) which was on par with LE 2 (26.75 mg 100 g^{-1}).

Highest pooled mean for vitamin C was in LE 22 (29.07 mg 100 g^{-1}) minimum in LE 2 (24.41 mg 100 g^{-1}).

Table 26. Proline content (μg g^{-1}) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	1.82	1.58	1.42	1.61
LE 2	1.78	1.49	1.39	1.55
LE 22	1.93	1.82	1.71	1.82
LE 34	1.86	1.77	1.67	1.77
LE 38	2.02	1.87	1.65	1.85
LE 39	2.03	1.92	1.78	1.91
LE 40	1.85	1.62	1.45	1.64
LE 42	1.99	1.79	1.68	1.82
LE 44	1.92	1.76	1.53	1.74
LE 45	1.95	1.89	1.77	1.87
Mean	1.92	1.75	1.61	1.76
SE	0.005	0.006	0.005	0.031
CD (genotypes)	0.014	0.016	0.015	0.087
SE	1.675			
CD (shade levels)	0.047			

Table 27. Vitamin C content (mg 100 g^{-1}) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	25.52	26.20	23.23	24.98
LE 2	24.10	26.75	22.38	24.41
LE 22	30.06	31.25	25.91	29.07
LE 34	27.69	29.07	25.48	27.41
LE 38	27.02	28.54	23.79	26.45
LE 39	28.40	29.34	24.95	27.56
LE 40	25.67	26.92	22.72	25.10
LE 42	26.17	29.12	22.69	25.99
LE 44	25.08	27.07	22.99	25.05
LE 45	24.54	27.55	22.80	24.96
Mean	26.43	28.18	23.69	26.10
SE	0.480	0.334	0.550	0.439
CD (genotypes)	1.429	0.995	1.637	1.242
SE	0.241			
CD (shade levels)	0.680			

4.7.4 Vitamin A

Significant difference was observed among the genotypes for vitamin A content under all shade levels (Table 28). No significant variation was observed for vitamin A content in open and 25 per cent shade. Overall mean in open (261.56 IU) was on par with 25 per cent shade (259.68 IU). But vitamin A content reduced significantly in 50 per cent shade (246.17 IU).

In open and under 25 per cent shade maximum vitamin A content was recorded by LE 42 with 276.70 IU and 275.21 IU respectively. Under 25 per cent shade LE 42 was on par with LE 34 (274.63 IU). Under 50 per cent shade LE 34 (270.82 IU) was superior to other genotypes.

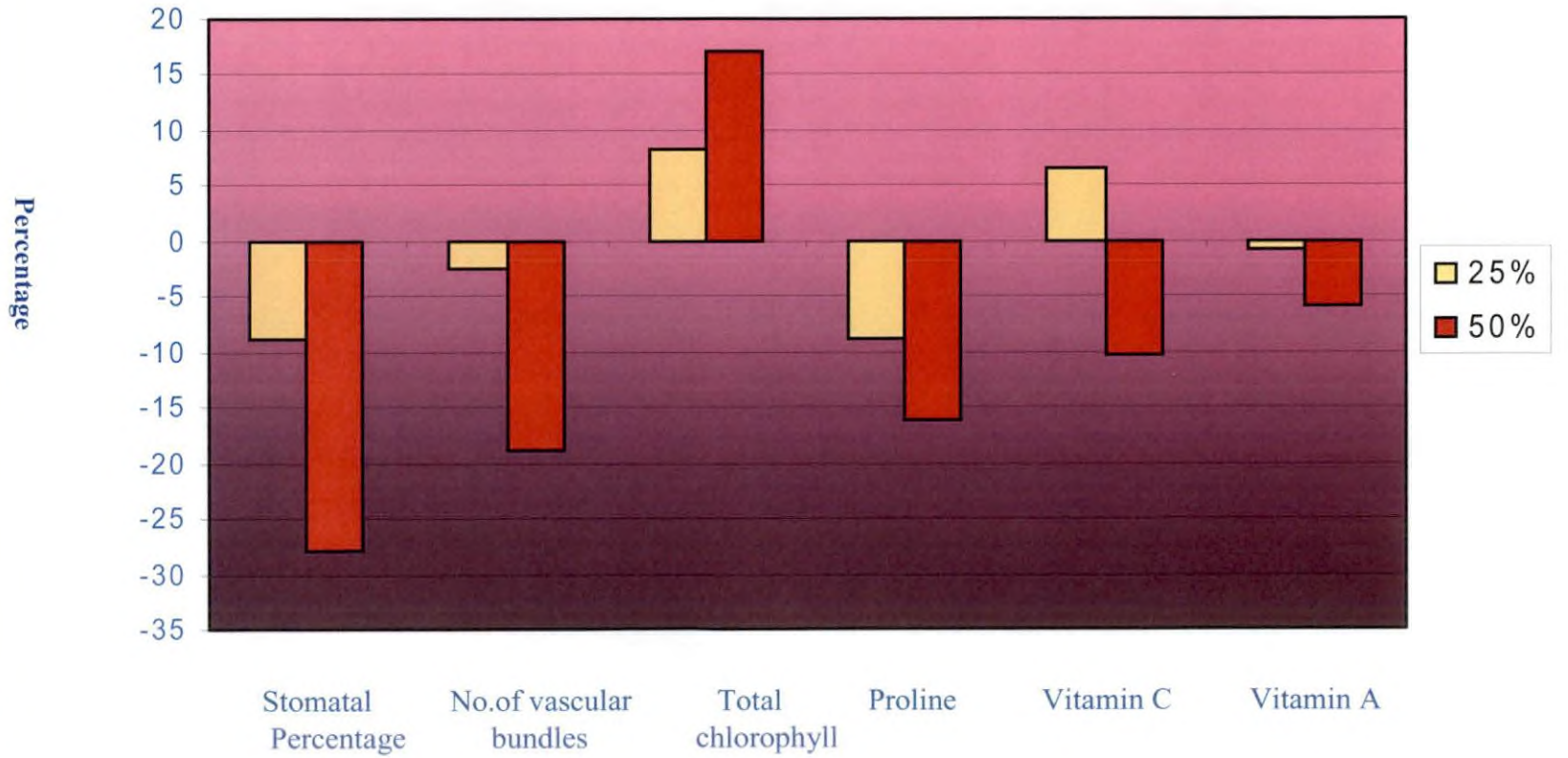
Minimum vitamin A content under open (250.44 IU) and 25 per cent shade (247.89 IU) was in LE 38. Under both the shade levels LE 38 was on par with LE 39 (250.89 IU and 248.12 IU). Under 50 per cent shade, LE 38 and LE 39 recorded the minimum vitamin A content of 230.00 IU each.

Maximum pooled mean was for LE 34 (273.44 IU) and LE 42 (273.05 IU) whereas the minimum was recorded by LE 38 (242.77 IU).

Table 28. Vitamin A content (IU) of tomato genotypes under different shade levels

Treatments	Level of shade			
	Open	25 %	50 %	Mean
LE 1	262.22	260.49	240.17	254.29
LE 2	265.56	264.78	242.20	257.51
LE 22	268.09	265.03	243.92	258.84
LE 34	274.86	274.63	270.82	273.44
LE 38	250.44	247.89	230.00	242.77
LE 39	250.89	248.12	230.00	243.00
LE 40	253.85	252.65	246.02	250.84
LE 42	276.70	275.21	267.23	273.05
LE 44	258.26	254.13	244.00	252.13
LE 45	254.76	253.89	246.17	251.61
Mean	261.56	259.68	246.17	255.75
SE	0.438	0.529	0.587	8.203
CD (genotypes)	1.305	1.576	1.749	23.259
SE	4.493			
CD (shade levels)	12.739			

Fig. 9 Effect of shade on anatomical and biochemical characters (Percentage difference from overall mean in open)



DISCUSSION

5. DISCUSSION

Shade is one of the most important limiting factors reducing the yield of vegetables in the homesteads of Kerala. Although tomato is a preferred vegetable of Keralites, their requirement is mostly met by the supply from the neighbouring states. Major reasons for this situation are limited availability of land, high temperature and humidity which ultimately affect the fruit yield and quality. Moreover, the high susceptibility of the crop to bacterial wilt disease limits its cultivation in the state. Hence, the present investigation was carried out to identify promising shade and bacterial wilt tolerant tomato genotypes suitable for the partially shaded coconut gardens of Kerala.

5.1 Plant characters

Present study revealed that shading has marked influence on plant height, internodal length and number of primary branches in tomato. Photosynthesis is the most important physiological process necessary for crop growth and productivity. Effect of low light intensity on crop growth and development is due to its impact on photosynthesis, as light is the most essential requirement for photosynthesis.

Significant variations for plant height and internodal length were observed among genotypes under all shade levels. This is due to the inherent variability that exists among tomato genotypes.

Plant height and internodal length were found to increase with increase in shade level. Height at harvest in open was 53.75 cm while that under 25 and 50 per cent shade levels was 92.69 cm and 108.63 cm respectively. Internodal length also showed an increasing trend from 5.08 cm in open to 9.27 cm under 50 per cent shade.

Similar results of increasing plant height and internodal length in tomato due to shade were also reported by Buitatar and Janse (1983), Kamaruddin (1983), Smith *et al.* (1984), El-Abd *et al.* (1994), Nasiruddin *et al.* (1995), and Thangam (1998).

The stem elongation under shade may be due to growth substances formed under etiolated condition (Nasiruddin *et al.*, 1995). Positive response to height under shade may be due to increased synthesis of GA. Janardhan and Murty (1980) reported such an increase in plant height under low light intensity which was attributed to higher content of GA in rice.

Schoch (1972) and Muthuvel (1999) opined that under shaded condition cellular expansion and cell division are stimulated resulting in greater plant height under shade compared to open. On the other hand, high rate of transpiration and respiration in open leading to deficiencies of carbohydrates and water may be resulted in retarded cell division and enlargement and there by reduced height in open (Meyer *et al.*, 1973).

Under shade, plant stem showed a tendency to elongate resulting in longer internodes (Meyer and Anderson, 1952). Hence the internodes were shorter in full sunlight and showed an increasing trend with increase in level of shade and increase in plant height.

There was significant difference both among genotypes and among different shade levels for the number of primary branches. A reduction in primary branch production due to increase in shade level was noticed. There was less incident radiation available per branch and this may be partially responsible for the decrease in primary branch production under shade (Attridge, 1990).

At high shade levels an increase in plant height was seen and this may have resulted in the diversification of energy for that rather than to increase the number of branches. Thus the reduced photosynthate availability under shade may be suppressing the growth and development of primary branches.

Increased synthesis of auxin in the apex under shade may induce the formation of abscisic acid in the axillary buds which inhibit the growth of axillary buds or side shoots (Tucker, 1976). The reduced number of primary branches under shade may be due to the strong apical dominance which prevented side shoot sprouting and further development (Rylski and Spigelman, 1986b).

5.2 Leaf characters

Leaf length, leaf width and petiole length showed significant increase with increase in shade levels. This can be attributed to the influence of light intensity on cell enlargement and differentiation which thus influenced the growth and leaf size of plants (Thompson and Miller, 1963).

The larger leaves and longer petioles obtained in the shade occupied more of the available area, leading to greater light interception. The increased leaf width and leaf length and petiole length lead to an increase in the leaf area and improved the light harvesting efficiency of the plant. Attridge (1990) reported that under shade, plants produced more leaves and leaf area as an adaptation to expose larger photosynthetic surface under limited illumination. Under shade, plants tend to adjust to the specific environment by increasing the area of light interception so that the available light energy is utilized more efficiently. This finding is in line with that of Smith *et al.* (1984), El-Abd *et al.* (1994) and Heuvelink and Marcelis (1996) in tomato and Yinhua and Jianzhen (1998) in *Capsicum*.

5.3 Flowering characters

Commencement of flowering with minimum number of days is a desirable character since it denotes the earliness. There was significant delay in flowering due to shade in all genotypes. The number of days taken from transplanting to flowering was 31.74 in open, 33.89 under 25

per cent shade and 41.58 under 50 per cent shade. But the number of days taken from flowering to fruit set did not show any significant difference among the shade levels although there was significant difference among the genotypes under all the shade levels suggesting that this character is unaltered by changes in external growth conditions.

Delay in flowering due to shade in tomato was also reported by El-Gizawy *et al.* (1993a) and Thangam (1998). In chilli also there were reports of prolonged vegetative phase resulting in delayed flowering under shade (Jeon and Chung, 1982; Sreelathakumary, 2000).

A plant has two phases in its life cycle *viz.* vegetative phase and reproductive phase. Under shading there is a prolonged vegetative phase. Shading might have reduced the net photosynthesis or interfered with the light controlled plant morphogenesis favouring vegetative development (Logendra *et al.*, 1990). More over, under shade there is reduced rate of transpiration and respiration compared to open, which favours vegetative growth (Schoch, 1972). It is also assumed that the physiological shifting of the vegetative growth to reproductive phase may be weak in shade due to the low solar radiation (Voican and Voican, 1982). In other words, in open where there is sufficient amount of light and temperature, the plant after putting forth its vegetative growth readily enter into the reproductive phase. Shading interfere with this normal cycle of plant growth and make

it slow. Hence it may be concluded that shading results in diversification of assimilates produced for excessive vegetative growth to make the plant more adaptable to the adverse situation. This results in delay in the transformation from vegetative phase to the reproductive phase.

Eventhough there was no significant difference between open and 25 per cent shade for flowers per cluster and percentage fruit set, under dense shade of 50 per cent it was reduced significantly in the present study.

Carbohydrate shortage under conditions of low light intensity might have resulted in reduced flower production under shade. Wien and Turner (1989) opined that shading reduces the sugar concentration in the flower buds with an increase in ethylene production. This leads to flower bud abscission under shade. This also may be a reason for reduced number of flowers under shade.

The reduced fruitset under shade may be due to low photosynthetic activity resulting in shortage of carbohydrates for production of fruits.

Pollen viability is one of the essential requirements for good fruitset. Low light intensity results in stylar exsertion, non-viable pollen production and poor fertilization (Kalloo, 1986). Rylski (1986) also reported that pollen viability reduces with shading in tomato.

Low light intensity causes flower abscission in tomato (Cooper, 1964). Increased flower drop under heavy shade may have resulted in reduced percentage fruitset.

5.4 Fruit and Yield characters

The fruit characters like fruit length, fruit diameter and fruit weight did not differ significantly between shade levels although there was significant difference among genotypes indicating that fruit size is governed by the genetic architecture and is not altered by the environment. Similar findings were given by Sreelathakumary (2000) in chilli.

There was significant variation in the number of fruits per plant among genotypes under all the shade levels. Mild shade of 25 per cent did not reduce the number of fruits per plant, while 50 per cent shade reduced it considerably. High flower drop and reduced fruitset might be resulted to less number of fruits under shade as reported by Picken (1984) and Thangam (1998) in tomato.

The present study revealed that number of flowers per cluster reduced considerably with shading. Dense shade adversely affected flower production in tomato. Hence it may be concluded that reduction in number of fruits per plant under heavy shade may be attributed to the reduction in flower production, high flower drop and low fruitset.

Shading results in reduction in number of flowers per cluster, increased flower drop, poor fruitset and reduced number of fruits per plant. Flowering and fruiting is an exhaustive process which requires more energy. Under stress of shade, due to low light availability, net photosynthesis is low resulting in shortage of photosynthates for plant growth and

productivity. Here, plants managed to adjust with the deficiency of photosynthates by the efficient utilization of its limited resources for the more essential and inevitable aspects of its growth and development. As a part of this, it reduced its crop load which would otherwise exhaust the plant. Here the plant sustained itself with minimum number of flowers and fruits which is sufficient to carry it through the next generation.

Significant variation in yield was noticed among genotypes under all shade levels. LE 45 recorded the maximum yield under all shade levels. LE 34 and LE 22 were also found to be performing well under shade. There was significant variation in the ability to tolerate shade among the genotypes.

The differential shade responses of different genotypes is due to the inherent variability that exists among tomato genotypes. In any environment the successful plant populations are those which have evolved the most appropriate physiological mechanisms (Bjorkman and Holmgren, 1963). The rate of photosynthesis depends upon the efficiency of light absorption and utilization by the leaves. Some genotypes are more efficient in the utilization of light and such genotypes perform better even under low light conditions (Nilwik *et al.*, 1982).

For better utilization of light and temperature, the compensation point between photosynthesis and respiration in relation to light intensity and temperature is important. The light intensity and temperature at which

photosynthesis and respiration are exactly balanced are important to make a better use of light and temperature under poor light and temperature conditions. A genotype exhibiting a compensation point at low light intensity and temperature may have a high photosynthetic efficiency (Kalloo, 1986) and such genotypes perform better under shade.

In the present study, the yield of tomato under mild shade (25 per cent) is on par with that of open condition. However, under dense shade of 50 per cent, yield was reduced considerably. There are even reports of increased yield under mild shade (10-30 %) in tomato (Smith *et al.*, 1984; El-Aidy, 1986 and El-Gizawy *et al.*, 1993b) and in pepper (Rylski and Spigelman, 1986b; Hou *et al.*, 1987 and Yinghua and Jianzhen, 1998).

C_3 plants are more efficient in dim to intermediate light intensities, whereas C_4 plants are more efficient in bright light than in dim light (Lawler, 1987). This explains the tolerance nature of C_3 plants like tomato and chilli towards mild shade.

Low yield was recorded under 50 per cent shade in the present study. Similar results of reduced yield under stress of shade was reported in tomato by Yamashiti and Hayashi (1994). Results of the studies undertaken by Nair (1991) on various tropical vegetables and by Sreelathakumary (2000) in chilli are also in line with the present finding.

The genetic make up of the plant decides its yield potential. But the expression of yield is influenced by the environmental factors in which the

plant grows. In adverse environment, the plant fails to express its normal production potential.

Photosynthesis, the process of providing the sources of chemical energy and the substrates for all subsequent biosynthesis in the plant is a physiological process that is most sensitive to variation in external light conditions. Under heavy shade light acts as the major limiting factor for photosynthesis. Only small amount of light is reaching the leaf surface, which impairs the photosynthetic activity. Similar finding of reduced photosynthetic rate due to shade was also made by Noggle and Fritz (1979) and Logendra *et al.* (1990).

Increased stem length, petiole length, leaf length and leaf width was noticed in the present study in the shaded plants. Eventhough there is less photosynthate accumulation under dense shade, the shaded plants had to diversify or spend more energy (photosynthates) for making them adaptable to the adverse environmental conditions compared to sun plants, and consequently only less energy is available for reproductive growth. There were only less number of flowers per cluster, low fruit set and reduced number of fruits per plant ultimately resulting in poor yields under heavy shade.

It may be concluded that under heavy shade, plants were adjusted to survive with the limited food materials available due to reduced photosynthesis rather than to produce good yields.

5.5 Reaction towards diseases, pests and physiological disorders

Pest and disease incidence play a vital role in tomato production. In the present investigation, bacterial wilt resistant genotypes were evaluated under different shade levels along with a susceptible check. It was observed that none of the resistant genotypes were affected by the bacterial wilt under all shade levels, whereas the susceptible check completely succumbed to the disease irrespective of shade levels. It indicated that bacterial wilt resistance is genetically controlled and environment has little role in modifying the resistance.

There was no incidence of fusarium wilt in the experimental plots. Hence could not compare the disease incidence in open and shade.

Spotted wilt is one of the important viral diseases of tomato in Kerala. Natural transmission of the virus is through vectors *viz. Thrips tabaci*, *Frankliniella schultzei*, *Frankliniella occidentalis* and *Frankliniella fusca.*

Significant variability was observed among the genotypes and shade levels for incidence of the disease. Among the genotypes LE 34, LE 44 and LE 45 were found least affected. Significant reduction in disease incidence was noticed under shade, the least incidence being under 50 per cent shade. The reduction in spotted wilt incidence with shade is probably due to reduced insect activity (vector) under shade.

Leaf miner incidence showed significant variation among the genotypes under all shade levels. Among the genotypes LE 2, LE 42 and LE 22 were found least affected. There was significant reduction in leaf miner incidence with increase in shade level. Pest incidence was found considerably reduced under 50 per cent shade.

Fruit borer (*Helicoverpa armigera*) incidence also showed a decreasing trend with increase in shade levels. The lowest score of 0.33 was recorded under 50 per cent shade level compared to 1.12 in open.

All the genotypes were found affected by fruit borer. However, there were significant variability among the genotypes for incidence of the pest under all the shade levels. Fruit borer attack was minimum in the genotypes LE 42 and LE 2. LE 22 was found affected maximum by the pest.

Reduction in leaf miner and fruit borer infestation may also be attributed to the reduced insect activity under low light conditions.

Juvik and Stevens (1982) reported that in tomato, the fruit skin, particularly the toughness of the pericarp is the principal source of resistance to fruit borer. In the present investigation also the tough skinned varieties *viz.* LE 42 and LE 2 had shown remarkable resistance to this pest. Variability among the genotypes to the pest attack may also be due to the

difference in the degree of palatability of fruits and leaves of various genotypes as reported by Cosenza and Green (1979).

Fruit cracking and sunscald were not noticed in any of the genotypes under study in the present experiment. Hence, observations on shade effects on the occurrence of these physiological disorders could not made in the present study.

5.6 Anatomical characters

5.6.1 Stomatal percentage

Stomata play an important role in gas transfer and water loss by transpiration. In the present study, the effect of shade on stomatal percentage was found to be increased significant by with a decrease in shade. Maximum stomatal percentage was found in open.

Schoch (1972) reported reduction in number of stomata per mm^2 under shade in *Capsicum annuum*. Similar results of reduced stomatal frequency under shade were also made by Buisson and Lee (1993) in papaya and Sreekala (1999) in ginger.

According in Thompson and Miller (1963), shading stimulates cell division and cell differentiation in the leaves. It is inferred that this results in a wider distribution of stomata on the leaves under shade resulting in reduced stomatal percentage on the enlarged leaves.

5.6.2 Vascular bundle

The number of vascular bundles was reduced under heavy shade of 50 per cent, although there was no significant reduction under 25 per cent shade compared to open. This indicates that low light intensities not only interfere with photosynthetic assimilation but also reduce the translocation of assimilates, water and nutrients in the plant.

5.7 Biochemical characters

5.7.1 Chlorophyll a, chlorophyll b and total chlorophyll

There was significant variation in the contents of chlorophyll a, chlorophyll b and total chlorophyll among the genotypes and between different shade levels. Chlorophyll a, chlorophyll b and total chlorophyll contents increased with increase in shade level which is in agreement with the findings of El-Gizawy *et al.* (1993a) in tomato, Singh (1994) in okra, Yinghua and Jianzhen (1998) in pepper and Sreelathakumary (2000) in chilli.

Chloroplast pigments are the principal light harvesting pigments in plants. Increase in chlorophyll content under shaded condition is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency (Attridge, 1990). However heavier shade limited the efficient utilization of increased chlorophyll. The lower chlorophyll content in sun leaves may be attributed to the decomposition of chlorophyll under intense light conditions (Kochhar, 1978).

It was also observed in the present study that among genotypes higher contents of chlorophyll a, chlorophyll b and total chlorophyll were noticed in shade tolerant genotypes *viz*., LE 45, LE 34 and LE 22 suggesting that high chlorophyll content is an adaptive mechanism for shade tolerance.

5.7.2 Proline

The genotypes varied significantly for proline content under all the shade levels. Maximum proline content was reported in plants grown in open. Least value for proline content was recorded under 50 per cent shade.

Proline content of the crop has been reported as a determinant of drought tolerance by many workers. In open the rates of evaporation and respiration were higher compared to shade, leading to loss of more water from sun plants. This resulted in moisture deficit in those plants and as a drought tolerance mechanism they might have produced more proline to combat the adverse effect of moisture stress. Hervieu *et al*. (1994) in ginger, Sreelathakumary (2000) in chilli and Sunilkumar (2000) in rice also reported similar findings.

5.7.3 Vitamin C

Significant variation in vitamin C content of fruits was observed both among genotypes and between different shade levels. In the present

study, the highest vitamin C content was recorded under 25 per cent shade. Increased vitamin C content under shading was also reported by El-Gizawy *et al.* (1993b) and Sharma and Tiwari (1993a) in tomato. The lowest value was recorded under 50 per cent shade. Similar findings were also made by Nasiruddin *et al.* (1995) and Yanagi *et al.* (1995) in tomato.

5.7.4 Vitamin A

Tomato is a rich source of vitamin A. Wider variability was observed among the genotypes for vitamin A content in the fruits under all the shade levels. Among the genotypes LE 42 and LE 34 recorded higher values of vitamin A.

Although vitamin A content did not change under the mild shade of 25 per cent, a marked reduction was noticed under heavy shade of 50 per cent. Vitamin A content under 50 per cent shade was as low as 246.41 IU compared to 261.56 IU in open condition indicating that heavy shade interferes with vitamin A synthesis in the fruits.

An additional advantage of improved fruit appearance was noticed in shaded plants. Fruits under shade were found uniformly coloured with very good appearance (Plate 16). Similar report of improved colouration under shade was given by Nasiruddin *et al.* (1995) in tomato.

Present study revealed that tomato tolerates mild shade. LE 45, LE 34 and LE 22 are identified as shade and bacterial wilt tolerant genotypes.

These accessions can be recommended for large scale cultivation in the homesteads after proper multilocational trials.

Comparison of fruit appearance in open and under shade

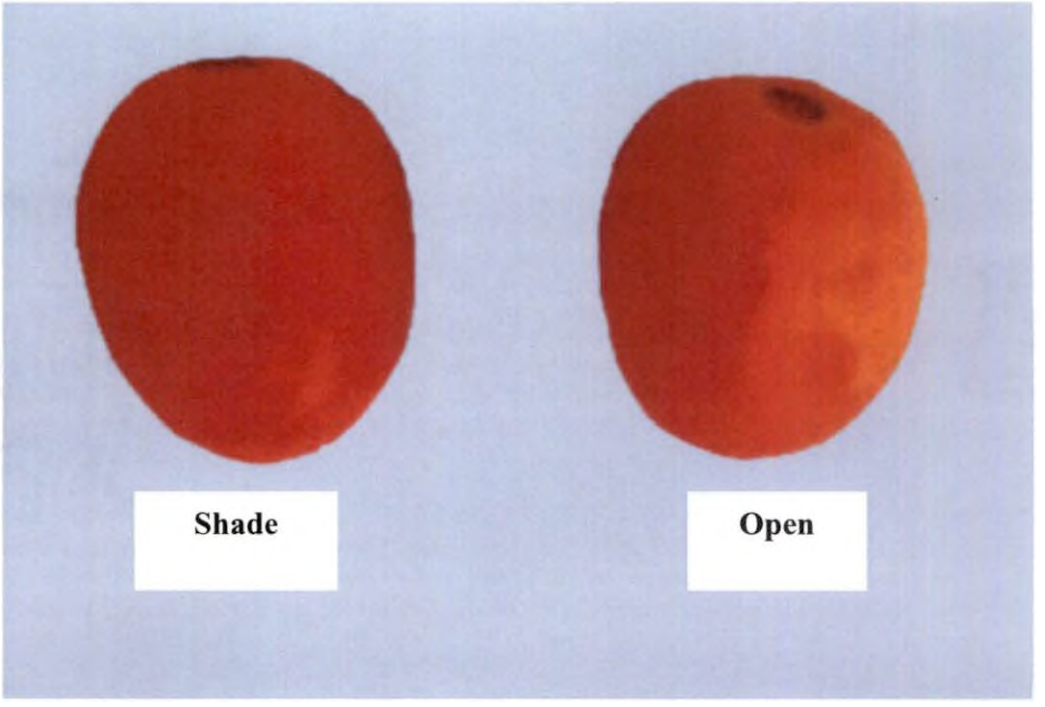


Plate 16

SUMMARY

SUMMARY

The study entitled "Performance of bacterial wilt tolerant tomato (*Lycopersicon esculentum* Mill.) genotypes under shade" was conducted at the Department of Olericulture, College of Agriculture, Vellayani during the period 2000 – 2001. The main objective of the study was to identify shade and bacterial wilt tolerant superior tomato genotypes for the homesteads of Kerala. The investigation also aimed at studying the morphological, anatomical and biochemical characters and the reaction towards pests and diseases under shade.

Ten promising tomato genotypes were utilized for the study. Three separate experiments were carried out in 25 and 50 per cent shade levels along with open condition adopting randomised block design with three replications. Pooled analysis was done to analyse the data statistically.

The salient findings of the investigation are summarised below.

The height and internodal length of plants increased with increase in shade levels.

The number of primary branches decreased with increase in shade level indicating that shading reduces the production of primary branches. Highest number of primary branches was in the high yielding genotype LE 45 under all shade levels.

Leaf characters *viz.*, leaf length, leaf width and leaf petiole length were found to increase with increase in levels of shade.

There was significant variation both among the genotypes and between shade levels for number of days to flowering. It was found that shading delayed flowering. The genotype LE 1 was the earliest in flowering in open and 25 per cent shade. But under 50 per cent shade, LE 44 took least time for flowering.

There was significant variation for days to fruit set among the genotypes under all shade levels. However, between shade levels no significant difference was noticed. Flowers per cluster and percentage fruit set varied significantly among genotypes. The high yielding genotype, LE 45 was superior with respect to both these characters under all shade levels. All though a mild shade of 25 per cent did not affect the flowers per cluster and percentage fruit set, heavy shade of 50 per cent markedly reduced both these traits.

It was found that length, diameter and weight of fruit remained unaltered under all shade levels. Among the genotypes LE 2 had the largest fruits while, LE 22 had the smallest.

Fruits per plant varied significantly among genotypes under all shade levels. Among genotypes, the high yielding LE 45 recorded maximum fruits per plant under all shade levels which was on par with LE 22 under 25 and

50 per cent shade. Lowest number of fruits per plant was recorded in LE 2 under all shade levels.

In the present study, the yield of tomato genotypes under mild shade of 25 per cent was on par with that in open condition. However under heavy shade of 50 per cent, yield was reduced considerably. It indicates that tomato tolerates mild shade without any reduction in yield although dense shade affects its performance. LE 45, LE 34 and LE 22 were identified as superior genotypes both in open and under shade. They yield substantially even under dense shade of 50 per cent and are identified as shade tolerant.

Incidence of spotted wilt disease was reduced due to shade. As the level of shade increased, there was less incidence of the disease probably due to the reduced insect activity under higher levels of shade. Among the genotypes, LE 34 and LE 44 were found least affected under all shade levels while, LE 22 showed high incidence of the disease.

Shading has a marked positive effect on the infestation of serpentine leaf miner also. Among the genotypes, LE 2 and LE 42 were least affected whereas, the high yielding genotypes LE 45 and LE 44 recorded the highest infestation.

Fruit borer (*Helicoverpa armigera*) damage was reduced with increase in shade level. LE 1, LE 2 and LE 42 recorded the lowest score for fruit borer under all shade levels, while, the high yielding LE 22 was found affected maximum.

Shading influenced the anatomical characters of the plant. Density of stomata and vascular bundles were found reducing with increase in level of shade.

Chlorophyll a, chlorophyll b and total chlorophyll were found affected by changing levels of shade. There was an increase in chlorophyll content with increase in the shade level. Shade tolerant genotypes, LE 45, LE 34 and LE 22 recorded higher values of chlorophyll a, chlorophyll b and total chlorophyll under all shade levels compared to other genotypes. Significant variation in proline content was recorded both among genotypes and between the shade levels. Maximum accumulation of proline was recorded in open.

It was observed that mild shade of 25 per cent increased the vitamin C content of tomato fruits compared to open. But under 50 per cent shade, vitamin C content reduced significantly. The genotype, LE 22 was superior to all other genotypes for vitamin C content.

Vitamin A content of fruits did not change between open and 25 per cent shade but it was reduced significantly under 50 per cent shade. Among genotypes, LE 34 and LE 42 recorded the highest values for vitamin A.

REFERENCES

REFERENCES

Abdul – Baki, A. A. 1991. Tolerance of tomato cultivars and selected germplasm to heat stress. *J. Amer. Soc. Hort. Sci.* **116**: 1113 –1116

Abdul – Baki, A. A. and Stommel, J. R. 1995. Pollen viability and fruit set of tomato genotypes under optimum and high temperature regimes. *J. Amer. Soc. Hort. Sci.* **120**: 115 – 117

Abou-Hadid, A. F., El-Beltagy, A. S. and El-Saeid, H. M. 1988a. Potential evapotranspiration for different regions and water consumptive use patterns under plastic house conditions in Egypt. *Egyptian J. Hort.* **15**: 1 – 12

Abou-Hadid, A. F., El-Saeid, H. M. and El-Beltagy, A. S. 1988b. Factors affecting transpiration of protected vegetables in North Nile Delta Region. *Egyptian J. Hort.* **15**: 13 – 21

Achhireddy, N. R., Fletcher, J. S. and Beevers, L. 1982. The influence of shade on the growth and nitrogen assimilation of developing fruits on bell pepper. *HortScience* **17**: 635 – 637

Anand, N., Tikoo, S. K. and Ramachander, P. R. 1986. Genotypic variations in tomato for moisture stress conditions. *Veg. Sci.* **13**: 153 – 159

Anderson, R. A., Karperbaner, M. J. and Burton, H. R. 1985. Shade during growth; effects on chemical composition and leaf colour of air cured barley tobacco. *Agron. J.* 77: 543 – 546

A. O. A. C. 1975. *Official and Tentative Method of Analysis*. Association of Official Agricultural Chemists, Washington D. C, p. 343

Arora, S. K. and Pandita, M. L. 1982. Studies on performance of tomato varieties under high temperature conditions. *Haryana agric. Univ. J. Res.* **12**: 376 – 379

Arora, S. K., Pandita, M. L. and Singh, K. I. 1983. Effect of shading and methods of planting on performance of tomato varieties during summer season. *Haryana agric. Univ. J. Res.* **13**: 464 – 467

Attridge, T. H. 1990. *Light and Plant Responses*. Edward Arnold, A Division of Hodder and Stoughtton Ltd., London, p. 82 – 101

Banerjee, M. K., Kalloo, G. and Jalali, I. 1990. Studies on fusarium wilt resistance in *Lycopersicon* : screening and method of assessment. *Veg. Sci.* **17** : 222 –226

Balasimha, D. 1982. Leaf growth and associated physiological changes in six cocoa accessions under water stress. *Proc. PLACROSYM V.* Indian Society for Plantation Crops, Kasargode, Kerala, India, p. 224 – 230

Bell, A. A. 1981. Biochemical mechanisms of disease resistance. *Annu. Rev. Plant Physiol.* **32**: 21 – 81

Bhat, J. G. and Ramanujam, T. 1975. Response of the cotton plant to variations in the instensities of natural light. *Turrialba* **25** : 440 – 444

Bjorkman, O. and Holmgren, P. 1963. Adaptability of the photosynthetic apparatus to light intensity in ecotypes from exposed and shaded habitats. *Physiol. Plant.* **16** : 889 – 913

Bose, S. C. S. and Rajan, S. 2000. Peroxidase isozyme as marker for bacterial wilt resistance in tomato (*Lycopersicon esculentum* Mill.). *Veg. Sci.* **27** : 136 - 141

Buisson, D. and Lee, D. W. 1993. The development responses of papaya leaves to stimulated canopy shade. *Amer. J. Bot.* **80**: 947 – 952

*Buitatar, K. and Janse, J. 1983. Light interception with tomatoes. *Groentern en fruit* **39** : 38 – 39

Calvert, A. 1966. Temperature requirement of the young tomato plant. *Acta Hort.* **230**: 459 – 470

Calvert, A. and Slack, C. I. 1980. Effect of light dependent control of day temperature on the yields of early sown tomato. *J. hort. Sci.* **55**: 7 – 13

Celine, V. A. 1981. Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 69

Chaudhuri, N., Deb, D. C. and Senapati, S. K. 2000. Evaluation of commonly grown tomato varieties and hybrids in Terai region of West Bengal. *Environ. Ecol.* **18**: 933 – 939

Chen, Y., Zhao, J. W. and Fan, Q. H. 1999. Effects of temperature on development, survival and reproduction of *Liriomyza sativae*. *Chinese J. appl. Ecol.* **10**: 110 – 112

Cockshull, K. E., Graves, C. J. and Cave, C. R. J. 1992. The influence of shading on yield of glass house tomatoes. *J. hort. Sci.* **67**: 11 – 24

Cockshull, K. E. and Ho, L. C. 1995. Regulation of tomato fruit size by plant density and truss thinning. *J. hort. Sci.* **70**: 395 –407

Cooper, A. J. 1964. The seasonal pattern of flowering of glass house tomatoes. *J. hort. Sci.* **39**: 111 – 119

Cosenza, G. W. and Green, H. B. 1979. Behaviour of the tomato fruit worm (*Heliothis zea*) on susceptible and resistant lines of processing tomatoes. *HortScience* **14**: 171 – 173

Dalletregulu, M. 1997. Export potential of fruits, vegetables and flowers from India. National Bank for Agriculture and Rural Development, Mumbai, p. 78

Deepa, B. P. and Anbu, S. 1996. Performance of tomato cultivars during summer season under Jorhat condition. *Haryana J. hort. Sci.* **25**: 153 – 155

Deli, Y. and Tiessen, H. 1969. Interaction of temperature and light intensity on flowering of *Capsicum frutescens* var. *grossum* cv. California Wonder. *J. Amer. Soc. Hort. Sci.* **94**: 349 – 351

Dhopte, A. M., Jamdar, S. L., Rahangdale, S. L. and Potkile, N. N. 1991. Influence of light intensity during pre-flowering on leaf physiology and anatomy in cotton genotypes. *Ann. Pl. Physiol.* **5**: 10 – 17

El-Abd, M. T. G., Shanan, S. A., Abou-Hadid, A. F. and Saleh, M. M. 1994. Effect of different shading densities on growth and yield of tomato and cucumber plants. *Egyptian J. Hort.* **21** : 68 – 80

El-Aidy, F. 1986. Tomato production under simple protective tunnels in Egypt. *Acta Hort.* **190**: 511 – 514

El-Gizawy, A. M., Gomaa, H. M., El-Habbasha, K. M., Mohamed, S. S., Abou-Hadid, A. F. and Smith, A. R. 1993a. Effect of different shading levels on tomato plants 1. Growth, flowering and chemical composition. *Acta Hort.* **323** : 341 – 347

El-Gizawy, A. M., Abdullah, M. M. F., Gomaa, H. M. and Mohamed, S. S. 1993b. Effect of different shading levels on tomato plants. 2. Yield and fruit quality. *Acta Hort.* **323**: 349 – 354

Fahl, J. L., Carelli, M. L., Vega, J. and Magalhaes, A. C. 1994. Nitrogen and irradiance level affecting net photosynthesis and growth of young coffee plants (*Coffea arabica* L.). *J. hort. Sci.* **69**: 161 – 169

Fery, R. L. and Cuthbert, F. P. 1974. Resistance of tomato cultivars to the fruit worm, *Heliothis zea*. *HortScience* **9**: 457 – 470

Gent, M. P. N. 1988. Effect of diurnal temperature variation on early yield and fruit size of green house tomato. *Appl. agric. Res.* **3**: 257 – 263

*Gogoi, S. 1980. Improvement of fruit set and productivity of tomato under plastic tunnels. *J. Amer. Soc. Hort. Sci.* **105**: 280 – 289

Hazarika, M. H. and Das, P. K. 1998. Genetic variability and correlation in fruit characters of tomato (*Lycopersicon esculentum* Mill.). *Ann. agric. Res.* **19**: 77 – 80

Hedge, M. R., Yusuf, M. and Gopalasundaram, P. 1993. Intercropping of vegetables in coconut gardens. In: *Advances in Coconut Research and Development*. Nair, M. K., Khan, H. H., Gopalasundram, P. and Bhaskara Rao, E. V. V.(Eds.). Oxford and IBH publishing Co., Ltd, New Delhi, p.407

Hervieu, F., Dily, F. L., Billard, J. P. and Huault, C. 1994. Effects of water stress on proline content and ornithine aminotransferase activity of radish cotyledons. *Phytochemistry.* **37**: 1227 – 1231

Heuvelink, E. and Marcelis, L. F. M. 1996. Influence of assimilate supply of leaf formation in sweet pepper and tomato. *J. hort. Sci.* **71**: 405 – 414

Ho, B. L. 1988. Bacterial wilt control in tomato using house hold disinfectants. *MARDI Res. J.* **16**: 73 – 76

Ho, L. C. and Hewitt, J. D. 1986. Fruit development. In: *The Tomato Crop – A Scientific Basis for Improvement*. Atherton, J. G. and Rudich, J. (Eds.). Chapman and Hall, London, p. 201 – 239

Hou, G. Q., Chen, D. S. and Liu, B. Z. 1987. The microclimate and ecophysiological effects of shading and pinching on capsicums. *Acta Hort.* **14**: 251 –256

IIHR. 1998. *Final report of ICAR Ad-hoc scheme on bio-ecology and management of serpentine leaf miner, Liriomyza trifolii (Burgess) on vegetable crops.* Indian Institute of Horticulture Research, Bangalore, p. 1 – 57

Jalali, I., Banerjee, M. K. and Kalloo, G. 1989. Screening for resistance to fusarium wilt in *Lycopersicon* – tests of agrochemicals and cultivars. *Ann. Appl. Biol.* **114**: 160 – 161

Janardhan, K. V. and Murty, K. S. 1980. Effect of low light during vegetative stages on photosynthesis and growth attributes in rice. *Indian J. Pl. Physiol.* **23** : 156 – 162

Jeon, H. J. and Chung, H. D. 1982. Chilli and capsicum. *J. Korean Soc. hort. Sci.* **23**: 3 – 6

Joonkook, K., Youngcheol, U. M., Dougkum, P., Jachan, L. and Kwangwoon, K. 1998. Effect of automatic shading during summer season on growth and yield of fruit vegetables in plastic film houses. *J. hort. Sci.* **40**: 1 – 7

Jung, H. B., Ito, T. and Maruo, T. 1994. Effects of shading and NO_3:NH_4 ratios in the nutrient solution on the growth and yield of pepper plants in nutrient film technique culture. *J. Jap. Soc. hort. Sci.* **63**: 371 – 377

Juvik, J. A. and Stevens, M. A. 1982. Physiological mechanisms of host plant resistance in the genus *Lycopersicon* to *Heliothis zea* and *Spodoptera exigua*, two insect pests of the cultivated tomato. *J. Amer. Soc. Hort. Sci.* **107**: 1065 – 1069

Kadam, D. D., Deore, B. P., Wattamvar, M. J. and Pawar, B. B. 1991. The influence of environment on drymatter accumulation and yield in tomato (*Lycopersicon esculentum* Mill.) Pusa Ruby. *Maharashtra J. Hort.* **2**: 60 – 63

Kalloo, G. 1986. *Tomato (Lycopersicon esculentum* Miller*)*. Allied publishers Pvt. Ltd., New Delhi, p. 172 – 180

Kalloo, G. 1989. Tomato (*Lycopersicon esculentum* Mill.). *Indian Hort.* **33** & **34**: 12 – 15

Kashyap. R. K., Bhutani, R. N. and Kalloo, G. 1982. Relative susceptibility and variability studies against fruit borer in tomato. *Punjab hort. J.* **22**: 190 – 195

Kashyap, R. K. and Verma, A. N. 1986. Screening of tomato germplasm for susceptibility to fruit borer, *Heliothis armigera* (Hubner). *Indian J. Entomol.* **48**: 46 – 53

Kamaruddin, S. W. 1983. The effect of shade on growth of tomato caused by fruit borer. *Indian J. agric. Sci.* **54** : 341 – 343

Kanthasamy, V. and Balakrishnan, R. 1989. Studies on hybrid vigour in F_1 generation of tomato (*Lycopersicon esculentum* Mill.). *South Indian Hort.* **37** :77 – 83

KAU, 1996. *Package of Practices Recommendations – Crops 96.* Directorate of Extension. Kerala Agricultural University, Thrissur, p. 166

KAU, 1997. *Research Report 1996 – 1997*, Kerala Agricultural University, Thrissur, p. 20

Kishun, R. 1982. *Annual Report.* Indian Institute of Horticulture Research, Bangalore, p. 72

Kishun, R. 1985. Effect of bacterial wilt on yield of tomato. *Indian phytopath.* **38**: 606

Kishun. R. 1987. Loss in yield of tomato due to bacterial wilt caused by *Pseudomonas solanacearum*. *Indian Phytopath.* **40**: 152 – 155

Kochhar, P. L. 1978. *A Text Book of Plant Physiology.* Atma Ram and Sons, New Delhi, p. 218

Kutty, C. N. and Peter, K. V. 1986. Evaluation of segregating and non-segregating population of tomato for bacterial wilt resistance and assessment of their performance. *Veg. Sci.* **13**: 169 – 173

Lal, S. D., Singh, S. S., Srivastava, P. M., Phogat, K. P. S. 1999. Screening of tomato hybrids for resistance against fruit borer, *Heliothis armigera* (Hubner) in Kumaon Hills (U.P.). *Indian J. Entomol.* **61**: 48 – 50

Lawler, D. W. 1987. *Photosynthesis : Metabolism, Control and Physiology.* Longman scientific and technical, England, p. 243 – 245

Logendra, S., Putnana, J. D. and Janos, H. W. 1990. The influence of light period on carbon partitioning, translocation and growth on tomato. *Scient. Hort.* **42** : 75 - 83

Lohar, D. P. and Peat, W. E. 1998. Floral characteristics of heat tolerant and heat sensitive tomato (*Lycopersicon esculentum* Mill.) cultivars at high temperature. *Scient. Hort.* **73**: 53 – 60

Magalhaes, J. R. and Wilcox, G. E. 1983. Tomato growth and mineral composition as influenced by nitrogen forms and light intensity. *J. Pl. Nutr.* 6: 847 – 862

Meyer, B. S. and Anderson, D. B. 1952. *Plant Physiology*, D Von Nostrand Company, London, p. 624 – 627

Meyer,B. S., Anderson, D. B., Bohning, H. R. and Fratianne, D. G. 1973. *Introduction to Plant Physiology*. D Von Nostrand Company, London, p. 48 – 54

Muthuvel, I. 1999. Evaluation of certain genotypes of tomato (*Lycopersicon esculentum* Mill.) to heat tolerance. Ph. D thesis. Tamil Nadu Agricultural University, Coimbatore, p. 126 – 127

Nair, M. C. and Menon, M. R. 1983. *Diseases of Crop Plants of Kerala*. Kerala Agricultural University, Thrissur, p. 252 – 253

Nair, R. V. 1991. Shade response of few tropical vegetable crops. In: *Recent Advances in Tropical Vegetable Production*. Peter, K. V., Joseph, S. and Indira, P. (Eds.). Kerala Agricultural University, Thrissur, Kerala, p. 762

Naniwal, N. C., Jaiswal, R. C. and Sanjeevkumar, A. 1992. Suitability of tomato (*Lycopersicon esculentum* Mill.) cultivars for juice, ketchup and chutney making. *Prog. Hort.* **24**: 70 – 73

Nasiruddin, K. M., Sharfuddin, A. F. M. and Begum, R. 1995. Effect of different shading treatments on growth, yield and quality of tomato cv. Roma VF and Marglobe. *Punjab Vegetable Grower* **30**: 35 – 44

Nilwik, H. J. M., Gosiewski, W. and Bierlurizen, J. F. 1982. The influence of irradiance and external carbon dioxide concentration on

photosynthesis of different tomato genotypes. *Scient. Hort.* **16** : 117 – 123

Noggle, G. R. and Fritz, G. J. 1979. *Introductory Plant Physiology*. Prentice Hall of India Pvt. Ltd., New Delhi, p. 688

Panse, V. G. and Sukhatme, P. V. 1978. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, p. 68 – 75

Papadopoulos, A. P. and Tissen, H. 1983. Root and air temperature effects on the flowering and yield of tomato. *J. Amer. Soc. Hort. Sci.* **108**: 805 – 809

Peet, M. M., Willitis, D. H. and Gardner, R. 1996. Response on post pollen production process in male sterile tomatoes to chronic, sub-acute high temperature stress. *J. Expt. Bot.* **48** : 101 – 111

Picken, A. J. F. 1984. A review of pollination and fruit set in the tomato. *J. hort. Sci.* **89**: 1 – 13

Prameela, R. 1990. Screening of different morphotypes of colocasia for shade tolerance. M.Sc. (Ag.) thesis. Kerala Agricultural University, Thrissur, p. 135

Rajasekhar, R., Cox, S. and Sathyanarayana, N. 1988. Evaluation of certain morphological factors in tea cultivars under water stress. *Proc. PLACROSYM VIII*. Indian Society for Plantation Crops, Kasargode, Kerala, India, p.204 – 210

Rao, D. V. R. and Sreevijayapadma, S. 1991. Effect of induced moisture stress at different phenological stages on growth and yield of tomato cultivars. *South Indian Hort.* **39**: 281 – 287

Rath, P. V. and Nach, P. 1997. Screening of some tomato genotypes for susceptibility to the fruit borer, *Heliothis armigera* (Hubner) at Varanasi. *Veg. Sci.* **24**: 153 – 156

Reddy, S. M. and Rao, G. P. 1999. Weed flora and yield of tomato as influenced by herbicides, their combinations and integrated measures. *The Andhra agric. J.* **46** : 63 - 66

*Roberts, F. 1987. Yield quantity and quality of tomato F_1 hybrids under greenhouse conditions. *Turrialba* **34**: 472 – 480

Romano, D. and Leonardi, C. 1994. The response of tomato and egg plant to different minimum air temperatures. *Acta Hort.* **366**: 57 – 63

Rosaiah, B. 2000. Effect of different plant products against serpentine leaf miner (*Liriomyza trifolii*) or ridge gourd (*Luffa acutangula*). *Pestology* **25** : 7 – 8

Rylski, I. 1986. Improvement of pepper fruit quality and timing of harvest by shading under high solar radiation conditions. *Acta Hort.* **191**: 221 – 228

Ryslki, I. and Spigelman, M. 1986a. Use of shading to control the time of harvest of red ripe pepper fruits during the winter season in a high radiation desert climate. *Scient. Hort.* **29**: 37 – 45

Rylski, I. and Spigelman, M. 1986b. Effect of shading on plant development, yield and fruit quality of sweet pepper grown under

conditions of high temperature and radiation. *Scient. Hort.* **29**: 31 – 35

Rylski, I. and Aloni, B. 1994. Flowering, fruit set, fruit development and fruit quality under different environmental conditions in tomato and pepper crops. *Acta Hort.* **366**: 45 – 55

Sadasivam, S. and Manikam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Ltd, Madras, p. 246

Saito, T. and Ito, H. 1967. Studies on the growth and fruiting in tomato. *J. Jap. Soc. hort. Sci.* **36**: 195 – 205

Sakimura, K.1963. *Frankliniella fusca* an additional vector of tomato spotted wilt with notes on *Thrips tabaci* and other vectors. *Phytopathology:* **53**: 412 – 415

Schoch, P. G. 1972. Effect of shading on structural characteristics of the leaf and yield of fruit in *Capsicum annuum* L. *J. Amer. Soc. Hort. Sci.* **97**: 461 – 464

Sharma, N. K. and Tiwari, R. S. 1993a. Effect of shade on soil temperature, light intensity, number and quality of tomato fruits cv. Pusa Ruby. *Prog. Hort.* **25**: 56 – 59

Sharma, N. K. and Tiwari, R. S. 1993b. Effect of shade on growth contributing characters and factors in relation to yield of tomato cv. Pusa Ruby. *Prog. Hort.* **25**: 180 – 184

Shoba, N. and Arumugam, R. 1991. Evaluation of quality attributes in inter-varietal crosses of tomato. *South Indian Hort.* **39**: 350 – 352

Shukla, N., Tiwari, D. N., Kashyap, R. L. and Sharma, R. N. 1997. Effect of subabul canopy on vegetable yield over the year. *Adv. Pl. Sci.* **10**: 41 – 44

Singh, H. and Singh, G. 1975. Biological studies on *Heliothis armigera* (Hubner) in Punjab. *Indian J. Entomol.* **37**: 154 – 164

Singh, L. 1988. Adaptation and yield of potato under low light intensity. *Indian J. Pl. Physiol.* **31**: 114 –116

Singh, R. S. 1975. Effect of environments on pathogenesis. *Principles of Plant Pathology*. 3rd edn. Oxford and IBH publishing Co. Ltd., New Delhi, p. 260 – 264

Singh, S. 1994. Physiological response of different crop species to low light stress. *Indian J. Pl. Physiol.* **37**: 147 – 151

Smith, I. E., Savage, M. L. and Mills, P. 1984. Shading effects on green house tomatoes and cucumbers. *Acta Hort.* **148**: 491 – 500

Soohyun, K., Younghyun, K., Zeewon, L. and Kwonso, H. 1998. Analysis of chemical constituents of fruits of red pepper (*C. annuum* L.) cv. Burgary. *J. Korean Soc. hort. Sci.* **186**: 49 – 53

Sorenson, E. J. 1984. The effect of phosphorus and light intensity on the growth of winged bean (*Psophocarpus tetragonalobus*) *Diss. Abstr. Int. (S &E)* **45**: 735 – 737

Sreekala, G. S. 1999. Biomass production and partitioning of photosynthates in ginger (*Zingiber officinale* R.) under different shade levels. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 57

Sreelathakumary, I. 2000. Genetic analysis of shade tolerance in chilli (*Capsicum* spp.). Ph. D. thesis. Kerala Agricultural University, Thrissur, p. 45 – 147

Srivastava, R. P. and Kumar, S. 1994. *Fruit and Vegetable Preservation.* International Book Distributing Co, Lucknow, p. 236

Srinivasan, P. M. 1958. Control of fruit borer *Heliothis armigera* (Hubner) on tomato. *Indian J. Hort.***16**: 187 – 188

Stevens, M. A. and Ruchid, J. 1978. Genetic potential for overcoming physiological limitations on adaptability, yield and quality of tomato. *HortScience* **13**: 673 – 678

Sunilkumar, B. 2000. Suitability of upland rice cultivars (*Oryza sativa* L.) for shaded situations. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p. 30 – 98

Tewari, G. C. and Moorthy, K. P. N. 1984. Yield loss in tomato caused by fruit borer. *Indian J. agric. Sci.* **54**: 341 – 343

Thangam, M. 1998. Effect of shade on growth, yield and quality of certain tomato (*Lycopersicon esculentum* Mill.) genotypes. M.Sc. thesis, Tamil Nadu Agricultural University, Coimbatore, p. 144

Thompson, B. F. and Miller, P. M. 1963. The role of light in histogenesis and differentiation in the shoot of pisum. *Amer.J. Bot.* **50** : 219 – 227

Tiwari, R. N. and Choudhury, B. 1994. Solanaceous crops. In: *Vegetable Crops*, Bose, T. K., Som, M. G. and Kabir, J. (Eds.). Naya Prokash, Culcutta, p. 262

Todd, J. M., Panniah, S. and Subramanyan, C. P. 1975. First record of tomato spotted wilt virus from the Nilgris in India. *Madras agric. J.* **62**: 162 – 163

Tucker, D. J. 1976. Effect of far-red light on the hormonal control of side shoot growth in the tomato. *Ann. Bot.* **40** :1033 – 1042

Turner, A. P. and Wien, H. C. 1994. Photosynthesis, dark respiration and bud sugar concentrations in pepper cultivars differing in susceptibility to stress induced bud abscission. *Ann. Bot.* **73**: 623 – 628

Varghese, S. 1998. Genetic make up of yield and yield attributes in a six parental diallel cross of tomato (*Lycopersicon esculentum* Mill.). M.Sc. (Ag.) thesis, Kerela Agricultural University, Thrissur, p. 120

*Vasudeva, N., Venkataraman, D., Raju, K. I. and Rategeri, M. C. 1981. Preliminary studies on the pattern of accumulation of proline in coffee cultivars during drought. *Turrialba* **31**: 388 - 390

Viraktamath, C. A., Tewari, G. C., Srinivasan, K. and Gupta, M. 1993. American serpentine leaf miner is a new threat to crops. *Indian Fmg.* **43**: 10 –12

*Voican, V. and Voican, A. V. 1982. The effect of light conditions on the growth and development of green house tomatoes. *Horticultura* **25** : 5 – 17

Voleti, S. R., Kasturibai, K. V., Rajagopal, V. and Sivashankar, S. 1990. Relative water content and proline accumulation in coconut genotypes under moisture stress. *J. Plantn. Crops* **18**: 88 – 95

Wallace, D. H and Enriquez, G. A. 1980. Day length and late maturing beans. *J. Amer. Soc. Hort. Sci.* **105**: 583 –591

Warren R. B. and Anderson, J. A. 1994. Canopy shade and soil mulch affect yield and solar injury of bell pepper. *HortScience*. **29**: 258 – 260

Wien, H. C. and Turner, A. D. 1989. Hormonal basis for low light intensity induced flower bud abscission of pepper. *J. Amer. Soc. Hort . Sci.* **114**: 981 – 985

Wolf, S., Rudich, J., Marani, A. and Rakh, Y. 1986. Predicting harvesting dates of processing tomatoes by a stimulation model. *J. Amer. Soc. Hort. Sci.* **111**: 11 – 16

*Yamashiti, F. and Hayashi, G. 1994. Studies on year round production of tomato in water culture methods for prevention of fruit cracking during high temperature periods. *Res. Bull. Aichi Ken Agri. Res. Center* **26**: 157 – 162

Yanagi, T., Ueda, Y., Sato, H., Hirai, H. and Oda, Y. 1995. Effect of shading and fruit set order on fruit quality in shade truss tomato. *J. Jap. Soc. hort. Sci.* **64**: 291 – 297

*Yao, Y. G., Shi, X. H., Yang, J. G., Wang, S. Y. and Liu, Y. 1998. Study on physiological and biochemical indices of heat tolerance of pepper leaves. *J. Hunan agrl. Univ.* **24**: 119 – 122

*Yinghua, C. and Jianzhen, J. 1998. The effects of light intensity on photosynthetic characteristics, growth and development in pepper (*Capsicum annuum*). *Acta Agri. Shanghai*. **14**: 46 – 50

Zhong, L. F. and Kato, T. 1988. The effect of sunlight intensity on growth, yield and chemical composition of system exudates on solaneceous fruits. *Agric. Sci*. **37**: 39 – 40

*Zuieli, Y., Gamliel, B., Golan, R., Zabari, Y., Teitel, M., Shikarji, A., Chen, R. and Mezarfi, E. 1993. Growing pepper in screen house. *Hassadeh* 74: 35 –40

*Originals not seen

PERFORMANCE OF BACTERIAL WILT TOLERANT TOMATO (*Lycopersicon esculentum* Mill.) GENOTYPES UNDER SHADE

BY

SMITHA. K

ABSTRACT OF THE THESIS
Submitted in partial fulfilment of the requirement for the degree
MASTER OF SCIENCE IN HORTICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF AGRICULTURE
Vellayani
Thiruvananthapuram
2002

ABSTRACT

An experiment on the "Performance of Bacterial wilt tolerant tomato (*Lycopersicon esculentum* Mill.) genotypes under shade" was conducted at the College of Agriculture, Vellayani, during 2000 – 2001.

The experiment was laid out in randomised block design with three shade levels, open, 25 and 50 per cent and replicated thrice. Artificial shade was provided using high density polyethylene shade nets. Ten bacterial wilt tolerant genotypes of tomato collected from various sources along with a susceptible check were used.

The results indicated that plant height at flowering, height at harvest, internodal length, leaf length, leaf width and petiole length showed an increasing trend with increase in level of shade, while number of primary branches reduced with shade.

Shading prolonged vegetative phase and delayed flowering. Flowers per cluster, percentage fruit set and number of fruits per plant were found unaffected by mild shade of 25 per cent, but under dense shade of 50 per cent, there was marked reduction in all these characters. Fruit characters like fruit length, diameter and fruit weight were found unaffected by shade.

Yield in open and 25 per cent shade were on par indicating that tomato plant was tolerant to mild shade. There were significant variation for yield among the genotypes. LE 45, LE 34 and LE 22 were identified as superior

with tolerance to bacterial wilt and shade. These genotypes are recommended for large scale cultivation in the homesteads after proper multilocational trials.

There was significant reduction in the incidence of tomato spotted wilt disease under shade. LE 34 and LE 44 were found least affected while LE 22 showed the highest level of incidence. Fruit borer and serpentine leaf miner infestation were also reduced under shade. LE 1, LE 2 and LE 42 recorded the lowest score against fruit borer infestation. Leaf miner infestation was least in LE 2 and LE 42 while the high yielding genotype LE 45 was affected more.

Anatomical characters like stomatal density and number of vascular bundles showed a decreasing trend with increase in level of shade.

Chlorophyll a, chlorophyll b and total chlorophyll contents increased with increase in level of shade. The shade tolerant genotypes showed higher content of chlorophyll under all shade levels. On the contrary, open condition showed maximum accumulation of proline compared to both the shade levels.

Mild shade proved favourable for improving the fruit quality in tomato. There was an increase in the content of vitamin C under 25 per cent shade level. Vitamin A content of fruits were found unaffected by mild shade of 25 per cent. But 50 per cent shade reduced both vitamin C and A contents considerably. The external appearance of the fruits was also superior under 25 per cent shade. Genotype LE 22 was superior for vitamin C content while LE 34 and LE 42 recorded the highest vitamin A content.