Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation

By

ARCHANA K A

(2016-22-003)

THESIS

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR - 680 656

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Submitted in partial fulfillment of the requirement for the degree of

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DEPARTMENT OF VEGETABLE SCIENCE

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2021

DECLARATION

I, hereby declare that this thesis entitled "**Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,

Date: 10.05.2021

Archana K. A.

(2016 -22- 003)

<u>**CERTIFICATE**</u>

Certified that this thesis entitled "**Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation**" is a record of research work done independently by **Ms. Archana K. A.** (2016-22-003) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Date: 10.05.2021

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We, undersigned members of the advisory committee of **Ms. Archana K. A.** (2016-22-003) a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in Vegetable Science, agree that this thesis entitled **"Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation** " may be submitted by Ms. Archana K. A. (2016-22-003), in partial fulfilment of the requirement for the degree.

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"Knowledge is knowing what to do but wisdom is knowing how to do"

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(ARCHANA. K .A)

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List of abbreviations

%	: Percentage
˚C	: Degree Celsius
˚N	: Degrees North
APEDA	: Agriculture and Processed Food Products Export
CD (0.05)	: Critical difference at 5% level
Chl	: Chlorophyll
DAT	: Days after transplanting
	Development Authority
EST	: Expressed Sequence Tag
et al.	: and co-workers
ET	: Evapotranspiration
etc.	: Et cetera / and the rest
F_1	: First filial generation
GCA	: General combining ability
GCV	: Genotypic Coefficient of Variation
HB	: Heterobeltosis
IARI	: Indian Agricultural Research Institute
IIHR	: Indian Institute of Horticultural Research
KAU	: Kerala Agricultural University
MSL	: Mean Sea Level

NBPGR	: National Bureau of Plant Genetic Resources
NS	: North South
PCR	: Polymerase Chain Reaction
PCV	: Phenotypic Coefficient of Variation
QTL	: Quantitative Trait Locus
RFLP	: Restriction Fragment Length Polymorphisam
RH	: Relative Heterosis
SCA	: Specific combining Ability
SH	: Standard Heterosis
SSR	: Simple Sequence Repeats
TSS	: Total Soluble solids
viz.	: Namely
β	: Beta

Introduction

1. Introduction

Tomato (*Solanum lycopersicum* L.), 2n=2x=24, is the most important fruit vegetable grown widely all over the world. It is a member of *Solanaceae* family and is native to Central and South America. In the world, it ranks second in importance and production after potato but tops the list of processed vegetables. The world production of tomato was 184 million tonnes in 2019. The major tomato growing countries are China, India, United States, Turkey and Egypt. In India tomato is the third crop after potato and onion. The total production of tomato was 21.57 Million tonnes in the year 2019-20 (2^{nd} Advance Estimates of 2019-20 of Horticultural crops). The major tomato producing states are Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat and Odisha.

It is an excellent source of nutrients and secondary metabolites which are important for human health including minerals, vitamins C and E, *ß*-carotene, lycopene, flavonoids, organic acids, phenolics and chlorophyll. Tomato has medicinal values and being used in cooking and processing. It is a good source of income for small and marginal farmers.

Tomato is used throughout the year. During spring season there is often a glut in the market leading to spoilage and price reduction of the produce. But in off – season, weather anomalies coupled with many biotic stresses will lead to scarcity and high price of the produce in the market. So, the emphasis is given to evolve an appropriate genotype for summer season with higher production.

Protected cultivation is a unique and specialized form of agriculture in which the microclimate surrounding the plant is controlled partially or fully, as per the requirement of the plant species grown. Protected cultivation of tomato offers distinct advantages of earliness, higher productivity, quality, particularly pesticide residue free produce, and minimized yield loss. Protected cultivation warrants, high yielding F_1 hybrids, to harness the full advantage of growing environment.

At present there is an influx of hybrid seeds, but mainly from the private sector, where the seed cost is very high. Better marketing opportunities for the marginalised farmers, can be ensured through development of new hybrids from the public sector adapted for the protected cultivation. KAU has not yet developed a F_1 hybrid in tomato for protected cultivation.

The protected cultivation of tomato under Kerala condition is associated with the challenges, the unavailability of suitable indeterminate genotype with bacterial wilt resistance and hotset characters. Bacterial wilt caused by *Ralstonia solanacearum* is a major threat to Solanaceous crops in Kerala, and a yield loss up to 95 per cent is reported (Kumar *et al*., 2018). Certain bactericides and antibiotics have shown a little efficiency in controlling the disease. The best possible method of controlling disease is the use of resistant genotypes. KAU has developed bacterial wilt resistant varieties in tomato (Varghese *et al.,* 2012).

Prolonged hours of solar radiations results in the elevation of temperature and humidity inside the protected structures in the tropics. In the case of tomato heat stress can affect vegetative, flowering and reproductive stages of the crop. During the vegetative phase the heat stress may affect the photosynthetic rate, efficiency of photosystems and stomatal conductance resulting in the growth retardation. The effect of high temperature in flowering and reproductive phases may result in the changes in pollen production, pollen viability, pollen tube growth, number of flowers per plant, female fertility, style length, style protrusion, reduced pollination, abortion *etc*., resulting in reduced fruit set and yield.

The full advantage of protected cultivation could be exploited in Kerala with the use of indeterminate hotset types. The reported hotset types can be used for developing indeterminate bacterial wilt resistant genotypes. Also these are valuable resources to broaden the genetic basis of heat tolerance in tomato.

Breeding inbred lines with disease resistance and other desired traits are worthy but often a difficult goal. Selection of screening protocols, sequence of trait screening and managing the segregating population are challenging. An effective selection of the parent genotype should be efficient and cost effective which permits rapid screening of thousands of plants. Many disease resistant genes have been mapped in tomato, and molecular markers linked to these genes are available for marker assisted selection. Two major QTLs, *Bwr-12* and *Bwr-6*, have been identified in tomato associated with stable bacterial wilt resistance. Molecular markers linked with bacterial wilt resistance genes would improve the effectiveness of screening for bacterial wilt.

Hence the present study was carried out at Department of Vegetable Science, College of Agriculture, Vellanikkara, to address the above constrains and following the major objectives

- To study the performance of tomato genotypes under polyhouse and rainshelter to identify stable thermo-tolerant types
- To study the resistance reaction of genotypes to bacterial wilt
- To develop a F_1 hybrid with bacterial wilt resistance and hotset characters for cultivation in Kerala under protected environment
- To analyse the magnitude of heterosis and combining ability of the hybrids
- To assess the linkage of available molecular markers with bacterial wilt

Review of Literature

2. Review of Literature

The present study 'Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation' was aimed on evolving an appropriate genotype for protected cultivation especially suitable for Kerala. The success of the breeding programme anchors on the knowledge of the genetics of the traits that contribute to the qualitative and quantitative improvement of the crop. Also these previous works helps in the strategic planning of the research. A brief account of the available relevant literatures pertinent to this research work are reviewed in this chapter under the following heads

- Protected cultivation of tomato
- Hotset in tomato
- Genetic variability, heritability and genetic advance
- Genetic divergence
- Incidence of bacterial wilt in tomato
- Heterosis breeding for yield and its components
- Combining ability
- Marker assisted selection for resistance to bacterial wilt

2.1 PROTECTED CULTIVATION OF TOMATO

The impact of abiotic and biotic stresses under the present changing climate severely compromises the crop production and quality. The foremost constraints in horticultural crop production are the extremes of temperature, sun light,water, relative humidity, weeds, nutrient deficiency, wind velocity, carbon dioxide concentration, diseases and insect pest incidence. Protected cultivation means to grow the crop with improved quality out of season under protected structures, thereby increasing the profitability of the farmer especially in hostile climatic conditions. This technology thus, has a potential for supply of high quality vegetables, mainly in the peri-urban areas there by reducing the transportation time and delivering fresh produce.

Tomatoes are being grown in protected structures for about 100 years. The availability of information on the techniques of growing tomato inside protected structure is more than any other greenhouse crop. Even soilless cultures are practiced in tomato. Hybrids or varieties with indeterminate and semideterminate growth habit are suitable for greenhouse cultivation. The hybrids can be grown up to a height of 3 m there by utilizing the vertical space in the greenhouse and have a yield potential of 170 t/ha and more, from a crop of six month duration (Naika et al., 2005).

Many workers have suggested the feasibility of tomato cultivation inside the protected structures.

The high priced vegetable tomato is an important crop for production around metropolis and big cities during summer season or off-season. Thus, in the tropical region during summer and rainy days it may be useful to grow tomato in protected structures as the plants which are protected from heat and excess rain will manifest faster and better growth resulting in earlier fruiting than the crops grown in the open field (Singh, 1998)

Cheema *et al*. (2005) recommended net house for extending the availability of tomato from last week of January to the first week of June with less damage by fruit borer.

Harmanto *et al.* (2005) recommended greenhouse farming system for growing tomatoes than in the open-field farming system in terms of crop yield, irrigation water productivity and fruit quality.

Plastic house technology was recommended as a viable and eco-friendly alternative for quality tomato production in the high hills by Chapagain *et al*., (2010) The cultivation of tomato in net houses required comparatively less land for agriculture production system resulting in increased land productivity and year-round production (Dunage *et al.,* 2010).

Parvej *et al.* (2010) reported that mere application of conventional cultural practices and chemical fertilizers had left the tomato production lag behind the demand in our country. Phenological development determines the plant productivity, and temperature plays major role in phenological development. The higher temperature inside the polyhouse (4-9°C) higher when compared to the open filed) hastened the flowering and fruit setting and fruit maturation by 3-8 days in tomato. Thus, the polyhouse environment could provide a new scope for commercial production of tomato.

Chapagain *et al.* (2011) suggested that plastic houses could reduce the number of days taken for flowering, fruit setting and fruit maturing in tomato. Thus this system of production could ensure an early crop in the market. Also the product was free from leaf minor, fruit borer and fruit fly damage.

India being a vast country with diverse and extreme agro-climatic conditions, the protected vegetable cultivation technology could be utilized for year round and off-season production of high value, low volume vegetables like tomato and could also be used as a tool for disease resistance breeding programs (Wani *et al*., 2011).

Greenhouse, polyhouse, shade nethouse, low tunnels and rainshelters were the most commonly used protected structures by Indian farmers depending on the prevailing climate in the area (Kittas *et al*., 2012).

Tomato cultivation was extended to protected structures to ensure the availability of vegetable in the off-season. Also alterations in light intensity, temperature and relative humidity occur in protected environments and could affect production and the partitioning of photo-assimilates in the plant, consequently, the composition of the produced fruit (Rana *et al*., 2014).

Sam and Rageena (2016) opined increase in yield was to the tune of 82.24% in the case of tomato polyhouse cultivation

Ansul (2017) recommended low poly tunnel and black polythene mulch could improve the yield and quality of tomato.

Malavika *et al.* (2017) recommended rainshelter for cherry tomato cultivation.

Singh and Kumar (2017) opined that the optimum temperature accompanied by low relative humidity inside polyhouse could hasten crop development and early maturity in tomato. This could positively influence the morpho-phenological and physiological events of tomato plants and in turn gave premium crop for the growers.

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Naik *et al*. (2018) reported that tomato planted under polyhouse established good crop stand and matured early. The optimum temperature and lower levels of humidity inside the polyhouse during winter months benefited the growers to produce high quality and off-season tomato which fetch premium price in the market.

2.1.1Crop management under protected cultivation

The management practices for protected cultivation are different than for open field production. Protected cultivation technologies include drip irrigation and fertigation, mulching and pruning.

2.1.1.1Site selection, structure and orientation of the structure

In order to ensure a premium quality high value crop from a protected structure, at most care should be given right from the site selection and manufacturing of the structure. The care taken in this area is equally important in selection of crop and variety.

The first requirement of a plant to grow is the photosynthesis. Therefore the region with good light intensity year-round is best suited for greenhouse. The area should be preferably free of tall trees, building and other tall constructions as they may give a shading effect especially in the morning and evening hours. In order to avoid shading, the protected structure should be at a distance of 2-2.5 times the height of the obstruction (Suseela, 2015). Enough amount of good quality water availability is also crucial. There should be provision for adequate drainage facility.Typical grading of ½ per cent or a six inch drop over a distance of 100 feet along the gutter side and 1.25 per cent along the gable side could be adopted (FAO, 2017). The preferred soil pH is 6.0-7.5. If the area is prone to high wind velocity, sufficient wind breakers are to be provided. It is preferable that the area is not known for any diseases or pests of tomato. Sufficient skilled labour availability, market accessibility and sufficient land availability for future expansion is also preferred.

The major limitation of protected cultivation in the tropics is the high temperature inside the greenhouses caused by the heating effects of high irradiation. Obtaining a cooling effect in the growing environment is, thus, one of the key points to grow tomatoes in controlled environments during the hot season. The elevation of the structure determines the maximum and minimum temperatures in the summer and winter months. Optimum elevation of (6-8 m) reduced the heating cost in winter and cooling cost in summer months. The proper selection of the structure and its design can effectively control the microclimate inside.

Temperature reduction with fans and cooling pads might improve tomato fruit set, but high humidity increased the risk of fungal diseases (Peet *et al.*, 1997).

Naturally ventilated polyhouses with insect proof net are recommended for humid tropics (Ajwang, 2005)

Nowadays, it is common practice to cover the ventilation openings with insect-proof screens that can physically block the entry of insects, and, consequently, the virus attack to the crop. At the same time, these screens can reduce the air exchange rate and light quantity transmitted into the greenhouse. The use of 78 mesh and 52 mesh insect proof nets found to reduce the heat exchange by 50% and 40% respectively, thereby increasing the relative humidity by 200% and 50% respectively. 40 mesh insect proof screens were found to be ideal for naturally ventilated polyhouses of tropics (Harmanto, 2006).

High intensity of solar radiation and resulting high humidity in the tropics made the cooling challenging (Mutwiwa *et al.,* 2007). Among various methods, evaporative cooling, shading and natural ventilation were easy to adopt. High ambient humidity limited the efficiency of evaporative cooling systems; whilehigh ambient temperature limited the efficiency of natural ventilation in tropics.

Suhardiyanto and Romdhonah (2007) recommended both roof and side ventilation for greenhouses in the tropics. The side ventilation could be provided maximum due to heavy rains during the rainy season in the tropics. They recommended the ventilation area of 20% of the floor area could improve the inside microclimate considerably.

Santhosh *et al.* (2017) reported that in the monthly average temperature rise there was significant increase inside the polyhouse (8%) compared to shallow hall (5%) and shade nethouse (2%). The increase in the relative humidity was 3-

7% in the polyhouse, 2-6% inside shallow hall and 1-5% inside the shade nethouse. They recommended shade nethouse for humid tropical climate like Kerala condition for year round tomato production since they provide protection against heat stress, and allowed the wind run there by controlling the humidity.

Sudheer *et al*. (2018) recommended naturally ventilated saw-toothed type of polyhouses with roll up side ventilation for high value vegetable cultivation in Kerala.

Tomato requires a relatively cool and dry climate for optimum growth and yield. The crop is sensitive to frost. So it is a considered as an annual warm season crop. However, the crop can be adapted a wide range of climatic conditions from temperate to hot humid tropics. The orientation of the structure largely determines the microclimate inside the structure.The optimum orientation of the greenhouse cad reduce the heat load on the installed system, thereby reducing the cost.

At 24ºN latitude the best suited orientation was East-West direction as it received less solar radiation in the summer months with small differences in received solar radiation in the winter months. At 34ºN latitude North-South orientation received more sunlight in the summer months than in the EW direction. At 44ºN and 54ºN latitudes received less solar radiation in the winter months and more in the summer months (Dragicevic, 2011).

However Suseela (2015) recommend North-South orientation for Kerala conditions, since the East-West orientation resulted in more heat build - up inside the structure. She also reported that the greenhouses connected to one another might be oriented in the NS, as this orientation would allow passing the shadow through the floor during the day.

2.1.1.2 Irrigation

The greenhouse farming combined with drip irrigation saved about 20-25% of water requirement compared to the open field farming system (Holmer and Schnitzler, 1997).

The irrigation water for tomato crop in tropical greenhouse environment was found to be 0.3-0.4 L / plant / day using drip irrigation (Tiwari *et al.,* 2000).

Chaibi (2003) observed that the main driving forces of crop water requirements in protected cultivation were diurnal and seasonal fluctuation of the varying solar irradiation.

For tomato crops cultivated in Indian greenhouses, it was recommended that daily water requirement depends on the cultural system and prevailing weather data. It might vary widely from 0.89 to 2.31 L/ plant / day (Tiwari, 2003).

Sharma *et al.* (2015) observed that the net water requirement for tomato crop in drip irrigation varied from 1.614 mm per day to 4.582 mm per day inside the shade net house, whereas in the open field it was from 2.52 mm to 7.62 mm per day.

2.1.1.3 Fertigation

Sam and Regeena (2016) opined that drip irrigation with fertigation and fogging could help in saving water and fertilizers and at the same time increased the quantity and quality of produce. Fogging was practised only during the peak hours of the day. Otherwise natural ventilation system could provide a good degree of environmental control.

Yeptho *et al*. (2012) opined that the optimum yield of tomato under polyhouse could be obtained with integrated application of *50% NPK + 50% Poultry manure + Bio-fertilizers.*

Ughade *et al*.(2016) studied an effective fertigation level and schedule for polyhouse cultivation of tomato. The results indicated that fertigation of 80 per cent RD of NPK (240:120:120 N, P_2O_5, K_2O kg/ha) in 12 equal splits at every 9 days interval up to 120 DAT was found to beneficial for higher growth and fruit yield of tomato under polyhouse condition during summer season.

2.1.1.4 Mulching

Black or silver polythene mulch film of 100 micron thickness was commonly used. They were of 1.2 m width and secured by burying into the soil on both the sides. 5 cm diameter holes were made with a sharp knife according to the plant spacing (Singh *et al*., 2015).

2.1.1.5 Training and pruning

Season-long crop maintenance is necessary for indeterminate greenhouse tomatoes to ensure good yields. Training can be started at one month after transplanting. Trellising vines, support the weight of the plants and fruits, balance vegetative and reproductive growth, and maintain overall good hygiene inside the structure. Keeping the fruit off touching the soil maintains the quality of the fruit and helps in the easy harvesting.

The hanging string method was the most common used approach for trellising indeterminate greenhouse tomato varieties. It involved vertically training the vines onto strings suspended above the plants and limiting the plant to a small number of main vines, also known as leaders. The vines were clipped to the strings. Clips were provided at every 12″. The GI trellis structure was provided at 3 m above the ground level. The plants were lowered to maintain at a workable height. This was done 20-30 days interval from 80-90 DAT (Singh *et al*., 2015).

Pruning is practised for inderteminate and semidetermnate tomato inside greenhouse. Pruning is the removal of excessive shoots, leaves and branches to maximize the number and quality of fruit and easiness of harvest. In tomato vegetative growth has direct relationship with leaf dry matter, stem thickness and leaf area, however it has negative correlation with fruit yield.

The pruning in tomato under protected structure allowed better light penetration and thereby improved the fruit qualities and quantities (Ara *et al.,* 2007).

Mabiko *et al*. (2011) reported that two stem pruning with zero fruit pruning was effective for tomato under shade nethouse for increasing the yield and qualities of the fruit.

Mazed *et al*. (2015) observed that three stem pruning inside greenhouse has given the highest yield (66.81t / ha). The same treatment also produced the highest potassium use efficiency inside the green house.

2.1.1.6 Pollination

Even though tomato is considered as a self pollinating crop, mechanical shaking of plants could improve the fruit setunder protected structures in tomato.The blowers are also available to increase the movement of pollen inside the structure. The bumblebee hives are also available from insect companies to keep inside the structure (Singh *et al.,* 2015).

Vandre (2017) reported that the structure with aided pollination could improve the fruit setting from 30.2% to 100%.

2.1.2 Varieties recommended for protected cultivation

One hybrid ‘Pant Polyhouse Hybrid Tomato-1’ and one pureline ‘Pant Polyhouse Tomato-2’ were developed, and has been released for commercial cultivation at farmer’s polyhouse (Singh, 2013).

Jindal *et al*. (2015) observed that HS-18 (8.51) was promising for yield and quality characters thus, can be recommended for polyhouse cultivation.

Lekshmi and Celin (2015) opined superior performance of INDAM 9802 and Tomato F_1 T 30 inside polyhouse under Kerala conditions for vegetative, yield and quality parameters, and recommended for commercial cultivation.

Jaffin (2016) recommended LE 20 × LE 1 and LE 2 × LE 20 with promising yield and yield attributes for cultivation in naturally ventilated polyhouse.

Malavika *et al.* (2017) recommended the cherry tomato genotype Slc-10 and SLc-9 for cultivation inside rainshelter

Singh and Kumar (2017) recommended San Marzano (cv. UG-8122) for polyhouse cultivation.

Murkute *et al.* (2018) recommended Pusa Hybrid -2 for cultivation inside naturally ventilated polyhouse.

Naik *et al*. (2018) recommended the variety Shakthiman for early flowering and high average fruit weight under polyhouse cultivation.

Prakash *et al*. (2019) on the basis of performance in fruit quality and biochemical traits recommended the hybrids Punjab Sartaj × EC163605 and Punjab Sartaj × IIVR BT-10 for cultivation under polyhouse condition.

More reviews on this aspect are depicted in Table 1.

Table 1: Variety / hybrid suitable for protected cultivation with salient feature

Sl. No.	Variety /hybrid	Characters	References
1	Puhong 909 and Naveen	Highest average marketable yield	Zhu-wei Min *et al.,* (2003) and Singh (2011)
2	Avinash-2, Naveen and CLN 2026D		Cheema *et al.*,(2005)
3	ET 35	Highest fruit weight	Shah *et al.*, 2011
4	All rounder and Srijana	Minimum days to flowering from transplanting, highest average fruit weight and highest average marketable yield	Chapagain *et al*., (2011)
5	Himshikar, Himsona, Sartaj and Shreshtha	Indeterminate growth habit	Singh *et al*., (2015)
6	Money maker and Marglobe	Highest number of fruits per cluster	Yeshiwas *et al*., 2016
7	Monica and Tesha	Extended shelf life and low unmarketable yield	Binalfew *et al*., 2016
8	Pusa Ruby, ArkaVikas and Rakshitha	Indeterminate growth habit	Fentik (2017)
9	DPTH-60	Better yield with good TSS and lycopene	IARI Annual report, 2018-19

2.1.3 Yield and quality comparison of tomato in the protected cultivation with open field

Semideterminate tomato varieties 'Akshaya' and 'Anagha' when grown under rainshelter showed significant superiority over open field crops with respect to number of fruits and total yield per plant (Indira *et al.,* 2005; Varghese *et al.,* 2012)

Kittas *et al.* (2012) concluded that the shade nethouses can reduce the number of cracked fruits. The number of fruits per plant was high for shade nethouse plants and total yield per plant was 50% more than the open field plants.

Plant growth and total biomass production was higher inside the greenhouse. Fruit cracking was found only outside (Sringarm *et al*., 2013).

Cheema *et al*., (2014) opined that there was a reduction of 65% in number of flowers per cluster, 71.0% in the average fruit weight, 54.0% in the number of fruits per plant, 46.8% in the yield per plant, 70% in the TSS and 97.4% in the acidity of tomato when grown in the open field compared to protected cultivation.

Rana *et al*.(2014) reported taller plants with higher yield from the polyhouse with shade nets during the summer season.

Sam and Rageena (2016) recorded that per plant yield of tomato under polyhouse was 2.1 kg whereas, it was only 0.7 kg in the open field. Earlier flowering and better shelf life was also observed for polyhouse crop.

An advantage of improved fruit appearance of uniform red colour was noticed under the polyhouse compared to open field (Lekshmi and Celin, 2015).

Inside polyhouse and 35% shade nethouses vigorously growing healthy thick stemmed tomato plants with significantly more chlorophyll were observed.

The fruits obtained were lighter, red coloured and early, compared to open field. Significantly high fruit weight and yield were observed for polyhouse and 35% shade nethouse as compared to open field (Singh *et al*., 2015).

In the greenhouse evaluation of Moneymaker, the number of fruits per plant was reported to be 46.4 with average fruit weight of 123.6 g. The number of picking was also high inside the green house as it was 12-13 when compared to 5-6 rounds picking in the open filed (Yeshiwas *et al*., 2016).

Pooja and Hakkim (2017) reported more plant height at polyhose compared to rainshelter in Kerala. Early flower initiation, early harvesting and more yield per plant were possible inside rainshelter than in polyhouse.

Chouhan *et al*. (2018) reported that under shade net the crop yield was increase by 75.32% over open field cultivation.

Murkute *et al.* (2018) recorded maximum fruit weight (38.24 g) and acidity (0.43%) in protected cultivation.

2.1.4 Pest infestation

Cheema *et al.* (2005) observed that incidence of *Helicoverpa armigera* and *Aphis gossypii* were nil in the net house tomato cultivation which otherwise were serious pests of tomato crop in open conditions.

Sringarm *et al*. (2013) made observations that the infestation with leaf miners (*Liriomyza brassicae* Riley), aphids (*Myzus persicae* Sulzer), spider mites (*Tetranychus* sp.) and whiteflies (*Bemisia tabaci* Gennadius) was very high outside and low inside the structure. Consequently, the pesticide use in the greenhouses was substantially lower than outside thus ensuring the quality of the final produce.

Singh *et al.* (2015) reported no aphids and white flies under polyhouse, and less infestation under shade net houses compared to open field. Hence, they opined that shade nethouses allow a passage for insect pest not compromising the quality and yield. Also they reported that coloured shade nets decrease the insect transmitted viral diseases.

Sam and Rageena (2016) observed sucking pest like thrips only in the open filed cultivation of tomato, but not under the polyhouse cultivation.

2.2 HOTSET IN TOMATO

Heat stress is a major abiotic factor limiting crop productivity worldwide. A temporary increase in temperature 10°C to 15°C above normalcan lead to heatstress or shock (Wahid *et al.,* 2007). Heat resistanceis the capability of the crop to develop andcreate economic production in high temperatures.Tomato is particularly sensitive to heat stress. Tomato growth, fruit set, and yield are optimalunder average day and night temperature ranges of 21°C to 29.5°C. Hazra *et al.* (2007) clarified that, in tomato, the signals which cause fruit set failure at high temperatures involves bud drop, abnormal flower growth, poor pollen germination and viability, abortion of ovule and reduced carbohydrate assimilation.The heat stress may viably affect the reproductive organs, especially pollen viability and female fertility, resulting in drastic decreases oreven total failure of fruit setting. Hence, there is a dare need to develop heat tolerant cultivars (Silva *et al*., 2017).

Since, the present study was aimed in developing a hotset genotype for off-season protected cultivation. The recent literatures available in this aspect are reviewed below.

2.2.1 Breeding heat tolerant lines

Dominant gene action was reported for different characters influencing heat tolerance *viz.*, flowers / truss, fruit set / truss, flower drop / truss, pollen viability, pollen germination, fruits / plant and fruit weight (Dhankhar and Dhankhar, 2002).

Hanson *et al.* (2002) observed complete dominance with the involvement of some epistatic component for heat tolerance.

Grilli *et al.* (2003) crossed ‘Caribe’, a heat susceptible cultivar and ‘Jab-95’, a line that possesses high tolerance to heat. The result suggested that the gene action involved in fruit setting of tomato was predominantly additive, hence it was easy in the selective process in terms of identifying genotypes with a greater concentration of favourable alleles

‘*Solar Fire*’ has been reported as a heat-tolerant F_1 hybrid of two heat tolerant parents having superior fruit-setting ability under high temperatures (>32°C day / >21°C night) (Scott *et al.*, 2006).

Saeed *et al*. (2007) opinedincreased value for membrane thermal stability is an indicator of heat tolerance, and revealed Cchaus and 2413L genotypes with high membrane thermal stability value with good retention of flowers and mature fruits.

Three consecutive field evaluation of 38 genotypes revealed three lines *viz*., CLN 2413R, CLN 2116B and COML CR-7 as heat tolerant genotypes considering pollen viability, pollen germinability, fruit set, fruit yield / plant. These three lines along with highly heat susceptible lines Patharkuchi and Ratan were crossed in all possible combinations. They concluded the non-additive genetic system for the expression of the characters influencing heat tolerance. (Hazra *et al*., 2009).

Aslam *et al.* (2010) reported C-7 with high fruit setting ability and yield under hot humid conditions.

Golam *et al.* (2012) suggested deeper planting (1.50 cm), irrigation during early morning hours and white surfaced plastic mulch or combinations of these three can increase the yield of heat tolerant tomato. They also reported that the cultural modification must be done simultaneously with genetic improvement for consistent yield rise.

Ethylene responsive genes are expressed in tomato pollen under high heat stress. Pre-treatment of tomato plants with an ethylene releaser could increase number of germinating pollen grains to over 5-fold and pollen quality under heat stress (Firon *et al*., 2012).

Nankishore and Farrell (2016) screened a range of physiological methods to detect the individual and combined effects of heat and drought stress on three contrasting varieties of tomato: Hybrid 61, Moskvich, and Nagcarlang. They observed Hybrid 61 was considerably tolerant to heat and drought stress compared to the other varieties.

Xu *et al*. (2017) observed serious impairment of reproductive traits in long term moderate heat shocks. Only cultivars Nagcarlang, Saladette and Malintka 101 could produce higher percentage of viable pollen underlong term heat shock. Fruit set could be obtained only with the pollen grains of Nagcarlang. Correlation studies revealed that under heat stress fruit set is positively correlated with pollen viability and number of flowers per cluster. The study suggested the suitability of Nagcarlang for high temperature field conditions.

Ayenan *et al.* (2019) reported heat tolerant wild relatives *Solanum habrochaites, Solanum pennellii,* and *Solanum pimpinellifolium*. But their potential to improve the cultivars are limited due to the negative correlation between fruit weight and heat tolerance particulars like pollen tube length, pollen viability, length of the style and stigma exertion. The overall improvement of yield under heat stress could be based on fruit number and fruit size.

2.3 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any breeding programme depends on the magnitude and nature of variability present among the available germplasm. And the effectiveness of the breeding material selection depends on the heritability and genetic advance of the traits involved. So an insight into these factors is important for success of breeding.

The geneticvariance of any quantitative trait is composed of additive variance (heritable) and non-additive variance therefore, it essential to partition the estimated phenotypic variability into its heritable and non-heritable components with suitable parameters such as genetic variance, phenotypic variance, genotypic coefficientof variation, phenotypic coefficient of variation, genetic advance, and heritability. The relevant literature pertinent to these aspects are summarised in Table 2.

2.4 GENETIC DIVERGENCE

Genetic divergence studies have helped in designing the hybridization programmes in crop plants effectively to generate noble variants having adaptation and yielding potential far better than parental types. In vegetable crops like tomato, estimates of genetic divergence have been proposed to provide diverse parents for getting high yielding hybrids. An improvement in the yield and quality of self-pollinated crops like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization.

Dar *et al.* (2015) grouped 60 tomato genotypes into 20 clusters. The contribution of each character towards the genetic divergence was maximum for beta carotene (49.49%), followed by ascorbic acid (16.44%), total soluble solids (7.57%), alcohol insoluble solids (7.12%), pericarp thickness (5.82%), lycopene content (4.80%) and polygalacturonase activity (3.73%). They also reported that fruit weight (2.15%), fruit pH (1.64%), number of fruits per plant (0.85%) and yield per plant (0.40%) contributed minimally towards total divergence.

Table 2: Summary of genotypic and phenotypic coefficient of variation, genetic advance as per cent mean and heritability for yield and quality and its contributing traits in tomato

Components	Status	Traits	References
GCV	High	Number of fruits per plant, fruit yield per plant, number of flowers per cluster, ridges on fruit and branches per plant	Ligade *et al*., (2017), Meena *et al.,* (2018)
	Moderate	Number of fruits per cluster, number of locules per fruit, number of flowers per cluster, fruit set per cluster, fruit weight, number of fruits per plant and TSS	Meena *et al.,* (2018), Prakash *et al.,* (2019)
	Low	TSS, pericarp thickness, fruit length, fruit width and number of flowers per plant	Buckseth *et al*.(2012), Rai *et al* ., 2016, Meena *et al.,* (2018), Prakash *et al.,* (2019)
PCV	High	Plant height , fruit yield per plant, average fruit weight, TSS, number of fruits per plant, fruit set per cluster and number of flowers per cluster	Rai *et al* ., 2016, Meena *et al.,* (2018), Prakash *et al.,* (2019)
	Moderate	TSS, thousand seed weight, number of fruits per cluster, number of flowers per cluster, number of locules per fruit and ascorbic acid	Chadha and Bhusan (2013), Rai *et al* ., 2016, Meena *et al.,* (2018), Prakash *et al.,* (2019)
	Low	Number of fruits per plant, pericarp thickness, fruit length and days to 50% flowering	Meena *et al.,* (2018), Prakash *et al.,* (2019)

Table 2: Continued

Components	Status	Traits	References
GCV and PCV	High	Number of fruits per plant, number of locules per fruit, average fruit weight, fruit yield per plot, fruit yield perplant, plant height at 120 DAT, number of fruit per cluster, TSS(^{0}Brix), acidity and lycopene	Lal *et al.,* (1991), Pradeepkumar *et al.* (2001)Bharti *et al.,* (2002), Brar *et al.*, (2000), Mohanty (2002), Kaushik *et al.,* (2011), Islam *et al.,* (2012). Rahaman *et al.,* (2012), Kumar *et al.,* (2013), Dar and Sharma (2011), Rani and Anitha (2011), Golani *et al.,* (2007), Rai *et al* ., 2016, Ligade *et al*., (2017) and Prakash *et al.,* (2019)
	Moderate	Intermodal length, pericarp thickness, number of flowers per cluster, number of fruits per cluster, number of locules per fruit, TSS, ascorbic acid and harvest duration	Manna and Paul (2012), Shwetha *et al.,* (2015), Kumar *et al.,* (2015), Rai *et al* ., (2016) and Ligade *et al*., (2017)
	Low	Days to first flowering, lycopene content , days to first flowering, days to 50% flowering, days to first picking and ascorbic acid	Islam *et al.* (2012), Rai *et al.* (2016), Ligade *et al.* (2017) and Prakash *et al.* (2019)
Genetic Advance as a percent mean	High	Plant height, number of fruits per plant, number of Flowers/cluster, number of fruit /cluster, average fruit weight, fruit yield/plant, TSS, ascorbic acid, pericarp thickness, number of locules/fruit and lycopene	Haydar *et al.* (2007),Tasisa *et al.,* (2011), Ahmed *et al.* (2006), Bharti *et al.,* (2002), Manna and Paul (2012), Rai *et al* . 2016, Ligade *et al*. (2017), Meena *et al.,* (2018), Prakash *et al.* (2019)

Table 2: Continued

Components	**Status**	**Traits**	**References**
	Moderate	Days to first flowering, branches per plant Number of fruits per cluster, number of fruits per plant, harvest duration, plant height, ridges on the fruits, average fruit weight (g), pericarp thickness, number of locules per fruit and lycopene.	Rai *et al* ., 2016, Ligade *et al*., (2017), Meena *et al.,* (2018), Prakash *et al.,* (2019)
	Low	Days to first flowering, days to 50% flowering, number of flowers per cluster, number of fruits per cluster, yield per plant, days to first picking, TSS, ascorbic acid, tirable acidity and thousand seed weight	Rai *et al* ., 2016, Ligade *et al*., (2017), Meena *et al.,* (2018), Prakash *et al.,* (2019)
Heritability	High	Plant height, Days to first flowering, Days to 50 % flowering, number of flowers per cluster, number of fruit per cluster, fruit weight, number of fruits per Plant, fruit yield per Plant (g), fruit yield per Plot, TSS (^{0}Brix), ascorbic acid (mg/100g), lycopene (mg/100g), pericarp thickness (mm) and number of locules per fruit.	Phookan *et al.*(1998), Ahmed *et al.* (2006), Mahesha *et al.* (2006),Joshi and Singh (2003), Bharti *et al.* (2002), Dar and Sharma (2011), Kumar *et al.* (2004), Rai *et al* ., (2016), Ligade *et al*., (2017), Meena *et al.,* (2018)
	Moderate	Days to first picking, days to 50% flowering, number of fruits per cluster, inter nodal length, average fruit weight, pericarp thickness, number of locules per fruit, fruit yield per plant, TSS and crop duration	Rai *et al*. (2016); Prakash *et al.* (2019)
	Low	Number of fruits per cluster, ascorbic acid, titrable acidity, TSS (^{0}Brix), number of fruits per plant, number of flowers per cluster and days to first flowering	Prakash *et al.*(2019

Lekshmi and Celin(2016) assessed genetic divergence depending on Mahalanobis D^2 statistics and grouped forty tomato genotypes into eight clusters indicating the presence of wide range of genetic diversity among the genotypes. The genotypes were grouped into clusters irrespective of their geographical origin indicating that there was no parallelism between genetic diversity and geographical divergence. The intra-cluster distances were observed to be lower than inter-cluster distances. A close relationship was observed between clusters V and VII being the inter-cluster value minimum (19.64). From the study they concluded that cluster VII was superior as far as yield under protected conditions was considered whereas cluster VI, VII and VIII were promising for quality attributes.

2.5 INCIDENCE OF BACTERIAL WILT IN TOMATO

Bacterial wilt caused by the soil-borne plant pathogen *Ralstonia solanacearum* is one of the most devastating bacterial plant diseases in the tropical and subtropical regions of the world. *Ralstonia solanacearum* gained its importance in the world due to its destructive nature, wide host rangeand geographical distribution. In India the destruction is reported to be from 10 to 100 per cent. It affects a wide range of economically important crops such as tomato,potato, eggplant, chilli and non-solanaceous crops like banana and groundnut in India. The bacterialwilt symptoms in tomato are characterised by initial wilting of upper leaves, and within a few dayscomplete wilting of the plants. Some strains are reported with resistance to even cold (Jones *et al*., 2014).

Ralstonia solanacearum, is a Gram-negative, rod-shaped, strictly aerobic bacterium that is 0.5-0.7 × 1.5-2.0 μm in size. It is very sensitive to desiccation and is inhibited in culture by low concentrations (2%) of sodium chloride (NaCl). For most strains, the optimal growth temperature is 28°C to 32°C; however some strains have a lower optimal growth temperature of 27°C (Mansfield *et al*., 2012). The pathogen can remain in the plant debris as long as 40 years.The first report of the disease was from China in 1954 (Jiang *et al.,* 2017). Now the disease is a serious threat in tropical, subtropical and hot temperate regions.

The first visible symptoms of bacterial wilt are usually seen on the foliage of plants. These symptoms consist of wilting of the youngest leaves at the ends of the branches during the hottest part of the day. At this stage, only one or half a leaflet may wilt, and plants may appear to recover at night, when the temperatures are cooler. As the disease develops under favourable conditions, the entire plant may wilt quickly and desiccate although dried leaves remain green, leading to general wilting and yellowing of foliage and eventually plant death. Another common symptom associated with bacterial wilt in the field is stunting of plants. These symptoms may appear at any stage ofplant growth, although in the field it is common for healthy appearing plants to suddenly wilt when fruits are rapidly expanding. In young tomato stems, infected vascular bundles may become visible as long, narrow, dark brown streaks. In young, succulent plants of highly susceptible varieties, collapse of the stem can also be observed. In well-established infections, cross-sections of stems may reveal brown discoloration of infected tissues. Symptom expression is favoured by high temperatures (29-35°C) and symptoms of the disease may progress rapidly after infection. After infection the pathogen may survive in and be spread from the infected plant (Singh *et al*., 2015).

A common sign of bacterial wilt of tomato observed at the surface of freshly-cut sections is the release of sticky, milky white exudates, which indicates the presence of dense masses of bacterial cells in infected vascular bundles, particularly in the xylem. Another common sign of the disease can be observed when the cut stem sections are placed in clear water a viscous white-creamy spontaneous slime will be streaming from the cut end of the stem. This streaming represents the bacterial ooze exuding from the cut ends of colonized vascular bundles.

The pathogen has a vast genetic variation according to climate, cropping practices, soil types, and geographic locations. Species of *R. solanacearum* can be subdivided into five races based on the host range. The *R. solanacearum* strains attacking tomato belong to races 1 and 3. Race 1 is dominant, while race 3 is rare. Three biovars II, III, and IV have been identified from tomato, of which biovars III and IV are dominant (Jiang *et al.,* 2017).

Numerous sources for resistance to bacterial wilt have been found in *S. pimpinellifolium* , *S. lycopersicum* var. *cerasiforme* and cultivated tomato , since the first discovery of the resistant accession PI127805A (*S. pimpinellifolium*) in 1964 (Yuqing, *et al.,* 2018). Most of the resistance in current resistant cultivars is derivedfrom three major sources, PI127805A (*S. pimpinellifolium*), CRA66 (*S. lycopersicum* var. *cerasiforme*) and PI129080 (*S. pimpinellifolium*). The resistance can be dominant, partially dominant or recessivedepending on the resistant sources and bacterial strains used.

The genetics of resistance are complex and controlled mostly by polygenes. At least seven QTLs on six chromosomes (3, 4, 6, 8, 10, and 12) from the resistant line Hawaii7996 (resistance derived from PI127805A) and three QTLs on three chromosomes (6, 7, and 10) from a *S. lycopersicum* var. *cerasiforme* accession L285 have been reported (Kim *et al.,* 2018). The QTLs on chromosome 6 are located inthe same region, which could be a resistance gene cluster with different loci conferring resistance to different strains, or could be one locus conferring resistance to all three tested strains. This QTL shows a stable field performance of resistance and may be used for developing cultivars with resistance to bacterial wilt.

Single nucleotide polymorphism (SNP) markers tightly linked to two QTLs *Bwr-6* (chromosome 6) and *Bwr-12*(chromosome 12) have been identified recently (Kim *et al.,* 2018).These markers will facilitate the process of developing resistant cultivars using MAS

Even though some commercial bactericides are available, they have only limited application. The best possible way is to use resistant varieties. But the stability of bacterial wilt resistance is highly affected by pathogen density, pathogen strains, temperature, soil moisture and presence of root-knot nematodes. However, the recent breeding attempts done conferring resistance to the disease are reviewed below.

2.5.1 Breeding for bacterial wilt resistance

Sadhankumar (1995) reported consistent resistance of 'Sakthi' and 'Mukthi' to bacterial wilt. He also obtained 4 additional sources (LE 214, CAV-5, LE 415 and LE 382-1) for wilt resistance. Recessive genes governed resistance to bacterial wilt in these lines.

Hanson *et al.* (1996) reported suitability of CRA 66 derivatives, such as CRA 84-58-1, in improving bacterial wilt resistance which are relatively large-fruited but require improvement for high temperature fruit set. L 285 can be considered as a potential source for bacterial wilt resistance.

Smitha (2002) reported LE 45, LE 34 and LE 22 as superior genotypes with tolerance to bacterial wilt and shade. Yield in open and 25% shade were on par indicating that tomato plant is tolerant to mild shade.

Sharma *et al.* (2006) recommended parents, CHDT-4 (EC-339074) and CH-180 (BT-17), as the resistant parents for breeding. The best cross with resistance was CHDT-4 × CHDT-1 (EC-339074 × EC-386021) which has been released in the name Swarna Sampada. The cross had six times more yield than the susceptible check Pusa Ruby.

Jayaprakash (2007) recommended FL7514 and BHN 466 as resistant varieties to bacterial wilt. But they are producing only small fruits which are not acceptable to consumers. Also the resistance varies with location and temperature.

Vanitha *et al*. (2009) suggested the effective control of the disease by the seed treatment using *Pseudomonas fluorescens* under polyhouse cultivation. It could also improvethe seed germination per cent

Yadav (2011) observed that the crosses Mukthi × H-7998, Mukthi × LE-474, Mukthi × LE-640, LE-1-2 × LE 474 and LE -626 × LE 474 were resistant to bacterial wilt and opined that crossing two bacterial wilt resistant parents gives bacterial wilt resistant progenies.

Resistance to bacterial wilt is believed to be monogenic or oligogenic. All the F_1s were found to be resistant by Jyothi (2011).

Peters *et al.* (2013) recommended 32*Bw-1* and 32*Bw-2* as resistance sources for bacterial wilt.

A number of rootstocks have been identified with resistance to bacterial wilt *viz;* TA04, TA06, TA08, TA10, TA18, TA034 and TA103. These rootstocks are useful in grafting of tomato (Mondal *et al.,* 2014).

Sharma and Sharma (2015) crossed bacterial wilt resistant stable lines (Hawaii-7998, BT-18 and TBL-4) as one of the parents with commercial but susceptible cultivar 'Solan Gola' as the other parent. They suggested that resistance to the disease was dominant over susceptibility since all the F_1 plants were observed to be resistant.

Kim *et al*. (2016) reported four accessions IT 201664, IT 201669, IT 201659 and IT 173773 were resistant to bacterial wilt and could be used as parents for breeding.

Ambresh *et al*. (2017) crossed bacterial wilt resistant variety Anagha with susceptible one Vaibhav. The F_1 was found to be resistant. Again they screened 300 recombinant inbred lines in a sick field condition. Among 300 populations RILs 61 were resistant, 170 were moderately resistant and 69 were susceptible.

Acharya *et al*. (2018) crossed one tolerant, Utkal Kumari and two susceptible, CLN-2498D and CLN-2777F lines. They reported that tolerance to bacterial wilt disease was predominantly by single dominant gene in two tolerant × susceptible crosses. However, significance of scaling test revealed involvement of duplicate epistasis. In this situation they recommend modified bulk method of selection and at least one tolerant parent in the breeding programme.

2.5.2 Genetics of bacterial wilt resistance in tomato

Huet (2014) reported the polygenic resistance to bacterial wilt in the resistant cultivar Hawaii 7996. Also the resistance was strain specific and the QTLs in Hawaii 7996 may deploy a phylotype specific resistance. This suggested the difficulty in obtaining a worldwide resistance to bacterial wilt.

Kunwar *et al.* (2019) observed high resistance to phylotype 1 in the genotypes F7-80-pink, F7-80-465-1-pink, LS 89, H7998S, H7997, TmL114-42-N-H.T.P., TML114 and LE 415. These entries had better survival per cent than H7996 and significantly better than the susceptible check L390 and Pant Bahar. *Bwr -12* contributed to resistance to phyllotype I strain and *Bwr - 6* contributed to phylotype II. Entry 94T765-24-79 lacked both the QTLs, but carry high resistance against the phylotype II indicating that the strain may carry a new QTL.

2.6 HETEROSIS BREEDING FOR YIELD AND ITS COMPONENTS

In Tomato heterosis was first observed by Hedrick and Booth (1907) for the traits greater yield and more number of fruits perplant. It manifests in tomato in the form of greater vigour, fastergrowth and development, earliness in maturity, increasedproductivity, improved quality and higher levels of resistanceto biotic and abiotic stresses. The unusual high heterosis in a self-pollinated crop tomato attributedto the fact that originally tomato was a highly cross pollinatedgenus which has later evolved into a self-pollinated one (Rick1965).

Use of F_1 hybrids is the quickest way of combiningthe traits into one, besides the added advantages of heterotic yield (Choudhury *et al.*, 1965). Released varieties are given in Table 3. Tomato genotype varied not only in the morphological features but also in the quality (Abhusita *et al.,* 1997). Most of the quality traits in tomato exhibited continuous variation and is strongly influenced by environmental conditions (Lecomte *et al.,* 2004).

Heterosis for Yield and its components, like fruit number, fruit size and fruit yield and quality traits, like TSS, lycopene and ascorbic acid were studied extensively in tomato.

Ahmad *et al*. (2011) estimated significant heterosis for early flowering (P2 × P3, P3 × P4, P3 × P5) and individual fruit weight (P1 × P2 and P1 × P7). Six cross combinations P4 × P7 (62.31%), P2 × P6 (37.44%), P4 × P6 (34.77%), P2 × P7 (33.67%), P3 × P7 (32.09%), and P3 × P4 (29.82%) manifested higher heterosis over better parent for the trait yield per plant.

Hybrid combination, PT-09-06 × PT-3 revealed as most promising with respect to heterosis for fruit yield per plant and total fruit yield per hectare. PT-20 × Roma with negative heterosis was most promising for number of locules. The promising hybrids with respect to heterosis were PT-2009-02 × PT-3 for average fruit weight, PT-09-06 × Punjab Chhuhara for number of fruits per plant, PT-20 × Punjab Chhuhara for pericarp thickness and fruit width (Sharma, 2014)

Five cross combinations *viz*; Arka Saurabh × Arka Meghali, Arka Saurabh × Punjab Chhuhara, Arka Saurabh × Best of All, Arka Abha × Best of All and Punjab Chhuhara × Best of All resulted in significant positive heterosis over better parent for yield. Arka Saurabh × Arka Meghali with positive and significant heterosis for both mid and better parent for lycopene content and total soluble solids. Arka Saurabh × Arka Abha, Arka Meghali × Punjab Chhuhara and Arka Saurabh × Punjab Chhuhara expressed significant heterosis for pericarp thickness. Significant improvement in the shelf life was observed for the crosses Punjab Chhuhara × Sioux and Best of All × Sioux (Kumar and Paliwal, 2016).

The cross LE 20 × LE 1 showed highest standard heterosis over the hybrid (Naveen) and the variety (Akshaya) for fruit length (5.36% ; 38.74%), fruit girth (21.09% ; 32.79%), fruit weight (38.62% ; 114.53%), yield per plant (157.52% ; 90.41%) and yield per plot (231.48% ; 90.58%) (Jaffin, 2016).

Kumar *et al*. (2016) reported fruit yield per plant of the cross Punjab Chhuhara × Best of All exhibited maximum heterosis over midparent (34.73%) and better parent (31.28%), and the cross Arka Abha × Punjab Chhuhara exhibited heterosis over commercial check hybrid HYBRoop-666 (19.03%) and commercial check variety TS-15 (34.44%).

Bharathkumar *et al*. (2017) reported IIHR 1816 × IIHR 2852, IIHR 1816 × IIHR 2853,IIHR 1816 × IIHR 2890, IIHR 2850 × IIHR 2852, IIHR 2891 × IIHR 2853, IIHR 2892 ×IIHR 2852 and IIHR 2892 × IIHR 2890 with significant heterosis for vitamin C, lycopene, pericarpthickness, average fruit weight and yield / plant.

Kumar *et al.* (2017) estimated maximum standard heterosis for total yield per plant for Azad T-5 × DT-2 (62.46%). Highest heterotic effects for yield traits were observed for number of fruits per cluster and number of fruits per plant.

Table 3: IIHR and IARI have released varieties through heterosis breeding

Sl. No.	Varieties	Parental lines	Institute
1	Arka Vishal	IHR-837 × IHR-932	IIHR, Banglore
2	ArkaVardan	IHR-550-3 × IHR-932	IIHR, Banglore
3	Arka Shreshta	15-SBSB × IHR-1614	IIHR, Banglore
4	Arka Abhijit	15- SBSB × IHR-1334	IIHR, Banglore
5	Arka Samrat	IIHR-2835 × IIHR-2832	IIHR, Banglore
6	Arka Rakshak	TLBR-12-21-43-1 SB × IIHR-2833	IIHR, Banglore
7	Arka Ananya	Resistance to TOLCV and Bacterial wilt	IIHR, Banglore
8	Pusa Divya	Long style × Roma (Developed using male sterile line, anther less mutant.)	IARI, New Delhi
9	Pusa Hybrid-1	Pusa Sheetal × Chikoo (Fruit set at high night temperature)	IARI, New Delhi
10	Pusa Hybrid-2	Highly tolerant to root knot nematode	IARI, New Delhi
11	Pusa Hybrid-4	Pusa-120 × Chikoo (Highly tolerant to root knot nematode)	IARI, New Delhi
12	Pusa Hybrid-8		IARI, New Delhi

Sharme *et al*. (2019)

Savale *et al*. (2017) observed maximum standard heterosis for the cross AVTO-5 × GT-2 followed by AVTO-7 × GT-2, AVTO-5 × JT-3, JTL-12-12 × GT-2 and JTL-12-12 × JT-3 for fruit yield and its component traits.

Singh (2017) reported significant better parent heterosis and standard heterosis for total fruit yield in Arka Alok × CLNB (38.45% and 22.94%, respectively), whereas Pusa Rohini × Sel-12 possessed significant standard heterosis for total soluble solid, ascorbic acid, and lycopene.

Gautham *et al*. (2018) reported the heterosis over better parent to the extent of -14.64%, -7.70%, 15.84%, 21.29%, 15.30% and 38.91% for days to first flowering, average fruit weight, number of fruits per plant, and plant height , respectively. Three crosses *viz*., UHFT-9 × Solan Lalima, UHFT-10 × Solan Lalima, and UHFT-22 × Solan Lalima were identified with desirable horticultural traits.

More review on the extend of heterosis in tomato for various traits are depicted in Table 4.

2.7 COMBINING ABILITY AND GENE ACTION

The concept of combining ability is a major landmark in understanding the genetic architecture of populations and in planning breeding programmes. Combining ability is one of the most effective devices for selection of superior parents for hybridization programme and provides valuable information regarding successful crosse combinations to be exploited commercially.

On GCA basis H-86, Sel-12 and Pusa Rohini were found to be better for fruit yield, earliness and biochemical traits, respectively. The crosses *viz*., Pusa Rohini × CLNB, Arka Alok × CLNB, Pusa Rohini × Sel-12 and Pusa Rohini× CLNR were better performing hybrids for yield and quality contributing traits (Singh, 2007).

In a line × tester analysis involving six lines and four testers, Yadav *et al*. (2013) reported non-additive gene action in preponderance for majority of growth, yield and quality traits and thus, the hybrid vigour could be exploited.

Table 4: Review on the extent of Heterosisfor different traits in tomato

Trait studied	Heterosis (%)			Reference
	RH	HB	SH	
Plant height	-23.80 – 6.81	-	-14.44 – 26.46	Sajjan (2002)
	2.61 – 129.67			Joshiand Thakur (2003)
	31.46 – 69.13	-45.30 – 62.32		Ashwini (2005)
	-22. 52 – 44.19	-35.99 – 26.02	-40.99 – 4.73	Yashavanthkumar *et al.* (2009)
		-29.13 -33.26	-32.50 – 16.36	Kumari and Sharma (2011)
		11.58 – 25.23	9.04 – 22.65	Angadi (2011)
		58.74 – 70.06		Singh and Asati (2011)
Internodal length		-52.80 – 21.70		Gul *et al*. (2010)
Days to 50% flowering		-8.41 – 16.31	-3.03 -15.15	Kumari and Sharma (2011)
Number of flowers per cluster	14.22 – 43.97	8.93 – 37.22	-4.56 – 20.43	Sajjan (2002)
	-49.7 – 53.10	37.20 -52.30		Gul *et al*. (2010)
Number of fruits per cluster	-31.56 – 51.64			Joshiand Thakur (2003)
	-49.37 – 94.93		68.04	Ashwini (2005)
		-34.61 – 46.25	-36.05 – 45.35	Angadi (2011)
			-15.28 – 24.73	Ahmad *et al.* (2011)
Fruit set per cent	-49.97 – 83.30	-62.45 – 68.56	-63.35	Ashwini (2005)
Number of fruits per plant	-34.41 – 4.05		26.95 – 78.88	Sharma *et al.* (2001)
	-27.69 – 49.37			Joshi and Thakur (2003)
	14.80 – 32.70	-35.70 – 15.50		Gul *et al*. (2010)
Average fruit weight	-15.10 – 25.40		-47.41 – 0.74	Sharma *et al.* (2001)
	3.43 – 41.31	3.41 – 40.31		Premalakshme *et al.* (2006)
	-45.00 - 12.44			Ahmad *et al.* (2011)

Table 4: Continued

Trait studied	Heterosis (%)			Reference
	RH	HB	SH	
Average fruit weight	-15.10 – 25.40		-47.41 – 0.71	Sharma *et al.* (2001)
	-31.16 - 46.13			Joshi and Thakur (2003)
	-38.95 – 90.69			Ashwini (2005)
	40.31	40.31		Premalakshme *et al.* (2006)
	-45.0 – 12.44			Ahmad *et al.* (2011)
		-35.12 - 15.75	-27.61 – 30.05	Angadi (2011)
Yield per plant	15.44 – 58.59		-18.49 – 31.21	Sharma *et al.* (2001)
	-78.09 – 82.11		55.38	Ashwini (2005)
	19.30 - 30.90	14.60		Gul *et al.* (2010)
	40.31	40.31		Premalakshme *et al.* (2006)
		-35.12 – 15.75	-27.61 – 30.05	Angadi (2011)
TSS	-27.0 – 35.09	-36.46 – 33.80		Ashwini (2005)
	-41.87 – 31.89			Ahmad *et al.* (2011)
	-20.30 – 86.40	-31.50 – 73.90		Gul *et al.* (2010)
Lycopene	78.82	26.33	53.49	Bhatt *et al.* (2004)
		-4.34 – 35.22	-35.03 – 41.67	Angadi (2011)
Ascorbic acid		-20.71 – 23.49	-20.18 – 29.47	Kumari and Sharma (2011)
			-48.21 – 8.04	Bhatt *et al.* (2004)

Sharma (2014) reported PT-2009-02 as a promising general combiner for fruit yield per hectare, fruit yield per plant, average fruit weight, number of locules per fruit and pericarp thickness, S-816 for plant height, number of locules per fruit and PT-1 for days to first harvest. Most promising hybrids exhibiting significant SCA effects were PT-19 × Punjab Chhuhara for fruit yield per hectare, fruit yield per plant and average fruit weight, PT-19 × PT-3 and PT-11 × PT-3 for earliness, PT-41 × Roma for number of fruit per plant and tallness and PT-09-06 × Punjab Chhuhara for pericarp thickness. He suggested both additive and non-additive gene action for different growth, yield and fruit quality characters.

Baban *et al.* (2015) observed the exotic parents EC 17737 and EC 490130, producing firm fruits, were expressing constant GCA effect over generations segregated thus, regarded as best general combiners. It was reported that the cross combinations P1 × P4 and P4 × P8 in F_1 and P1 × P7 and P3 × P4 in F_2 were showing desirable SCA effects for fruit firmness.

Kumar *et al.* (2015) reported lines LBR-12, LBR-13 and LBR-19 were good general combiners for fruit yield, pericarp thickness, lycopene and titrable acidity. The testers 8-2-1-2-5 and EC-119197 were good general combiners for locule number and average fruit weight. In the analysis of SCA the cross LBR-7 × 8-21-2-5 was a good specific combiner for average fruit weight and lycopene, LBR-15 × EC-119197 for total fruit yield and locules per fruit and LBR-13 × EC-119197 for average fruit weight, number of locules per fruit, pericarp thickness and titrable acidity

Zengin *et al.* (2015) reported high and positive GCA for the lines BH-28, BH-102, BH-135 and G-8 for early yield. The same lines recorded negative GCA for number of days taken for 50% flowering and number of days taken for fruit maturation. Line G-8 (30.52%) recorded highest GCA for fruit weight. They recommended BH-4, BH-28, BH-37, BH-135, BH-53, BH-102 and line G-8, as promising parents for further breeding programmes for better yield.

Battarai *et al*. (2016) suggested Nagcarlan to be the best combiners for heat tolerance from a 5 × 5 diallel cross in tomato. The hotset traits like pollen viability and chlorophyll stability index governed by both additive and dominant gene action.

Jaffin (2016) observed high SCA for fruit yield per plant, average fruit weight, pollen viability and fruitset per cent for the cross LE 20 × LE 1.

Rajkumar *et al*. (2018) reported the GCA effects of parents proved the lines IIHR 2042, Punjab Sartaj and EC 160885, and the tester EC 163605 were the best general combiners for yield and attributing traits. The crosses Punjab Sartaj × EC 163605, IIHR 2042 × IIVR BT-10, Punjab Rakthak × EC 163611 and EC 160885 × EC 163611 were proved to be good specific combiners for the growth, yield and quality attributing traits.

The overall appraisal of GCA effects revealed that the parent Hawaii 7998 to be the best parent as it gave consistently high GCA in all the environments for maximum number of traits including yield per plant and total number of fruits per plant. In the pooled analysis of SCA effects the cross combinations Palam Pride x BER-5, 12-1 × BWR-5, Palam Pride × 12-1, Hawaii 7998 × 12-1 and CLN2123 A-1 red ×Arka Abha proved to be good combiners for marketable yield per plant (Thakur *et al*., 2019).

More reviews on combining ability are given in Table 5

Table 5: Review on combining ability and gene action for various traits in tomato

Trait	Mating design	Combining ability		Gene action		Reference
		GCA	SCA	Additive	Non- additive	
Plant height	10 x 2 (L x T)	Significant	Significant	-	+	Sharma *et al.* (2001)
	10 x 2 (L x T)	Significant	Significant	-	+	Joshiand Thakur (2003)
	14 x 14 (HD)	Significant	Significant	+	+	Bhatt *et al.* (2004)
	5 x 8 (L x T)	Significant	Significant	-	+	Ashwini (2005)
	10 x 2 (L x T)	Significant	Significant	-	+	Sharma *et al.* (2006)
	6 x 6 (HD)	Significant	Significant	-	+	Premalakshme *et al.* (2006)
Days to 50 % flowering	8 x 8 (HD)	Significant	Significant	+	+	Sekhar *et al.* (2010)
	10 x 3 (L x T)	Significant	Significant	-	+	Kumari and Sharma (2011)
Number of flowers per cluster	8 x 8 (HD)	Significant	Significant	+	+	Sekhar *et al.* (2010)
Number of fruits per cluster	5 x 10 (L x T)	Significant	Significant	-	+	Dharmatti *et al.* (2001)
	5 x 10 (L x T)	Significant	Significant	-	+	Kulkarni *et al.*(2003)
	5 x 9 (L x T)	Significant	Significant	-	+	Prashant (2004)
	14 x 14 (HD)	Significant	Significant	+	+	Bhatt *et al.* (2004)
	5 x 8 (L x T)	Significant	Significant	+	-	Ashwini (2005)
Fruit set per cent	10 x 5 (L x T)	Significant	Significant	+	-	Dharmatti *et al.* (1997)
	5 x 8 (L x T)	Significant	Significant	-	+	Ashwini (2005)
Number of fruits per plant	5 x 10 (L x T)	Significant	Significant	-	+	Kulkarni *et al.*(2003)
	5 x 9 (L x T)	Significant	Significant	+	-	Prashant (2004)
	5 x 8 (L x T)	Significant	Significant	+	-	Ashwini (2005)
	10 x 2 (L x T)	Significant	Significant	-	+	Sharma *et al.* (2006)
	6 x 6 (HD)	Significant	Significant	+	-	Premalakshme *et al.* (2006)
	10 x 10 (HD)	Significant	Significant	+	-	Farzane *et al.* (2012)
	10 x 3 (L x T)	Significant	Significant	+	+	Kumari and Sharma (2011)

Table 5: Continued

Trait	Mating design	Combining ability		Gene action		Reference
		GCA	**SCA**	**Additive**	**Non- additive**	
Average fruit weight	6 x 6 (HD)	Significant	Significant	+	+	Padma *et al.* (2002)
	5 x 9 (L x T)	Significant	Significant	+	-	Prashant (2004)
	5 x 8 (L x T)	Significant	Significant	-	+	Ashwini (2005)
	10 x 2 (L x T)	Significant	Significant	+	-	Sharma *et al.* (2006)
	6 x 6 (HD)	Significant	Significant	-	+	Premalakshme *et al.* (2006)
	7 x 7 (HD)	Significant	Significant	+	+	Mondal *et al.* (2010)
	8 x 8 (HD)	Significant	Significant	+	+	Sekhar *et al.* (2010)
	10 x 3 (L x T)	Significant	Significant	+	+	Kumari and Sharma (2011)
Yield per plant	6 x 6 (HD)	Significant	Significant	-	+	Padma *et al.* (2002)
	14 x 14 (HD)	Significant	Significant	-	+	Bhatt *et al.* (2004)
	10 x 2 (L x T)	Significant	Significant	+	-	Sharma *et al.* (2006)
	10 x 3 (L x T)	Significant	Significant	+	-	Pandey *et al.* (2006)
	6 x 6 (HD)	Significant	Significant	-	+	Premalakshme *et al.* (2006)
	8 x 8 (HD)	Significant	Significant	+	+	Sekhar *et al.* (2010)
	8 x 8 (HD)	Significant	Significant	+	+	Agarwal *et al.* (2014)
TSS	5 x 10 (L x T)	Significant	Significant	+	-	Kulkarni *et al.*(2003)
	5 x 9 (L x T)	Significant	Significant	+	-	Prashant (2004)
	5 x 8 (L x T)	Significant	Significant	+	-	Ashwini (2005)
Lycopene	7 x 7 (HD)	Significant	Significant	-	+	Mondal *et al.* (2010)
	10 x 3 (L x T)	Significant	Significant	+	+	Kumari and Sharma (2011)
Ascorbic acid	14 x 14 (HD)	Significant	Significant	-	+	Bhatt *et al.* (2004)
	7 x 7 (HD)	Significant	Significant	-	-	Mondal *et al.* (2010)
	10 x 3 (L x T)	Significant	Significant	-	-	Kumari and Sharma (2011)

2.8MARKER ASSISTED SELECTION FOR BACTERIAL WILT RESISTANCE

The traditional methodology of plant genetics based on morphological, biochemical and anatomical marker for assessing the genetic diversity have proven been effective in crop screening and improvement from ancient decades. This lengthy process may not allow the time sensitive need to increase the crop productivity in the future. An alternative approach for assessing the diversity among the cultivated genotypes is the use of molecular marker.

Tomato is very rich in the number of available molecular markers. Currently there are >1000RFLP markers and approximately 214000 EST sequences. The whole process can be again simplified by the use of user – friendly, PCR-based markers such as SSR markers. SSR markers are multiallelic, highly polymorphic, co-dominant, and easily assayed in a basic laboratory set-up. Sarvanan *et al.* (2014) had already reported the feasibility of SSR markers for analysis of genetic variability in tomato, the number of alleles detected varied from 1.00-2.00 alleles per locuswith average PIC value 0.3623.

The present study attempted to find out an effective SSR marker for bacterial wilt disease in tomato. In this context the available recent literatures in this aspect are briefed below.

In Hawai 7996 the QTL *Bwr*-12 was the major contributor (17.6-56.1%) of stable resistance to bacterial wilt. The presence of two QTLs *Bwr*-12 and *Bwr*-6 could confer 45.5-70.4% reduction in the incidence of the disease. Under high disease pressure environment *Bwr*-12 was the only detected QTL (Wang *et al*., 2013).

Belge *et al*. (2012) screened eight SCAR markers for bacterial wilt in the F_3 population of a cross between Sakthi and IIHR2196. Out of the eight SCAR markers evaluated, $TSCAR_{AAG/CAT}$ and $TSCAR_{AAT/CAT}$ were specific to bacterial wilt.

Marker-assisted selection for *Bwr-12* could facilitate early elimination of susceptible plants, reduce the number of bacterial wilt confirmation screening trials during generation advance, and has enabled characterization of lines for the presence of specific resistance genes. SSR markers SLM12-2 and SLM1210 were found to effective and inexpensive for conferring resistance (Hanson *et al*., 2013).

Hanson *et al*. (2016) used two SSR markers for *Bwr*-12 and *Bwr*-6. In five F_7 testlines (CLN3241 prefixes) and parent CLN2777G, the per cent mean of wilted plants ranged from 15% to 35% (95% for susceptible plant). In the marker analysis these five lines tested positive for *Bwr*-12.

Ho *et al.* (2016) reported that *Bwr*-12 contributes resistant to phylotype I only, whereas *Bwr*-6 contributes to phylotype I and II. So the pyramiding of gene could contribute stable resistance to different strains with different virulence level. They suggested SLM12-2 and SLM 12-10 for *Bwr*-12 and SLM 6-124, SLM6-118, SLM 6-119, SLM 6-136 and SLM6-17 for *Bwr*-6.

Dheemant *et al*. (2018) reported SSR20 for effective utilization in marker assisted selection for bacterial wilt in tomato.

One SNP marker, including a functional SNP in a gene i*Solyc12g009690.1*, was found to be effective in identifying resistant lines from a group even containing susceptible ones(Kim *et al*., 2018).

The SSR markers SLM6-110 and SLM6-107 were found to be effective for QTL *Bwr*-12. SLM12-65 SSR marker could be effectively used for *Bwr-12.2* (Shin *et al.,* 2019).

Materials and Methods

3. Materials and Methods

The experiment entitled "Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation" was carried out in the Department of Vegetable Science, College of Agriculture, Vellanikkara, during January 2018 – January 2020. The objectives of the experiment were to identify superior hotset genotypes suitable for protected cultivation under Kerala condition, to develop indeterminate hotset F_1 hybrids with bacterial wilt resistance for protected cultivation in Kerala and to suggest a SSR marker linked to bacterial wilt resistance in tomato.

The study was conducted in the following five experiments

3.1 EXPERIMENT I

Screening of tomato accessions under polyhouse and inside rainshelter for two seasons, summer evaluation from January 2018 to May 2018 and rainy season evaluation from July 2018 to December 2018.

3.1.1 Experimental site

The site is located at an altitude of 22.25 m above mean sea level, between 10°31'N latitude, and 76°13'E longitude. This area enjoys a tropical warm humid climate and receives an average rainfall of 2663 mm per year. The weather parameters during the experimental period depicted in Appendix I and Appendix II. The soil of the experimental plot comes under sandy loam texture, order Ultisol, with acidic reaction (pH 5.7).

The experiment was conducted in both polyhouse and rainshelter. The polyhouse was saw toothed type naturally ventilated polyhouse of gutter height 4.5 m, gutter slope 2 per cent eve height 1.5 m and floor area 384 m^2 (24 m x 16 m) oriented in the N-S direction located at the Department of Vegetable Science, College of Agriculture, Vellanikkara. The frame work is made up of GI pipes of 76 mm ID and 3 mm thickness. The roof is made up of 200 micron UV stabilized polyethylene sheet and the sides are made up of 25 per cent shade net. The rainshelter with floor area 384 m^2 (24 m x 16 m)and height 3.048 m was used. The frames of the rainshelter was constructed using GI pipes and it was cladded with UV stabilized polythene sheet of 200 micron thickness and the sides are made with 64 mesh in one square feet.

3.1.2 Experimental materials

The experimental materials consisted of 35 tomato genotypes, 29 tomato accessions were collected from NBPGR, New Delhi, Pusa Ruby, three IIHR released varieties (Arka Abha, Arka Saurabh and Arka Alok) and two KAU released varieties (Akshaya and Anagha). The details of tomato genotypes used for the study are given in Table 6.

3.1.3 Method

3.1.3.1 Design and layout

Design	: RBD
Replication	: Two
Treatments	: 35
Spacing	: 1 m X 0.5 m
Plants / plot	: 6
Plot size	: 3 m^2

3.1.3.2 Seedlings production

Tomato seedlings were raised in protrays (Plate1). The seeds of each genotype were sown separately in protrays and kept inside a rainshelter with insect proof wire mesh on all sides. The plastic protrays helped in proper germination, reduced mortality rate. Uniform and healthy seedlings with good root growth were produced. Twenty one days old seedlings were transplanted to the polyhouse and rainshelter.

Table 6: List of tomato accessions used for study

Sl. No.	Accession name / number	Sources
1	EC-145057	NBPGR, New Delhi
2	EC-151568	NBPGR, New Delhi
3	EC-157568	NBPGR, New Delhi
4	EC-160885	NBPGR, New Delhi
5	EC-163605	NBPGR, New Delhi
6	EC-164263	NBPGR, New Delhi
7	EC-164563	NBPGR, New Delhi
8	EC-164670	NBPGR, New Delhi
9	EC-165395	NBPGR, New Delhi
10	EC-165690	NBPGR, New Delhi
11	EC-165700	NBPGR, New Delhi
12	EC-249514	NBPGR, New Delhi
13	EC-521067 B	NBPGR, New Delhi
14	EC-528368	NBPGR, New Delhi
15	EC-538153	NBPGR, New Delhi
16	EC-620376	NBPGR, New Delhi
17	EC-620378	NBPGR, New Delhi
18	EC-620382	NBPGR, New Delhi
19	EC-620387	NBPGR, New Delhi
20	EC-620389	NBPGR, New Delhi
21	EC-620395	NBPGR, New Delhi
22	EC-620401	NBPGR, New Delhi
23	EC-620406	NBPGR, New Delhi
24	EC-620410	NBPGR, New Delhi
25	EC-620417	NBPGR, New Delhi
26	EC-620427	NBPGR, New Delhi
27	EC-620429	NBPGR, New Delhi

Table 6. Continued

Sl. No.	Accession name / name	Source
28	EC-631369	NBPGR, New Delhi
29	EC-631379	NBPGR, New Delhi
30	Pusa Ruby	NBPGR, New Delhi
31	Arka Abha	ICAR-IIHR, Bengaluru
32	Arka Saurabh	ICAR-IIHR, Bengaluru
33	Arka Alok	ICAR-IIHR, Bengaluru
34	Akshaya	KAU, Thrissur
35	Anagha	KAU, Thrissur

3.1.3.3 Field preparation

The experimental plot was ploughed thoroughly using mini hoe and incorporated with lime at the rate of 500 kg per hectare. Weeds and stubbles were removed and brought to a fine tilth. Raised beds of 22 m length and 1m width were prepared. The beds were incorporated with cow dung and vermicompost, each of 100 kg, and 2½ kg Rock Phosphate. Then the beds were levelled and covered with black and white double shaded polythene mulch of 30 micron thickness. Pits were cut on the mulch sheet as per the spacing (Plate 2).The seedlings were transplanted on prepared beds in one row at spacing of 50 cm. Six plants per genotype were maintained in each plot (Plate 2).

3.1.4 Crop management

Plant protection and fertilizers were administered as per the ad-hoc package of practices recommendations for precision farming for tomato (KAU, 2016).

3.1.4.2 Irrigation

Drip irrigation system was followed in both polyhouse and rainshelter.

3.1.4.3 Training and pruning

Since the genotypes screened were indeterminate in growth habit regular training and pruning were carried out. A single stem was retained in at early stages (Plate 3) by removing the side and lower shoots and water suckers. Staking of the plants with the help of clips were done to support the plants and to permit easier training. The plants were supported on the floriculture nets provided all along the entire length of the rows inside the polyhouse. Inside the rainshelter the plants were supported by poles which were connected to one another by wires. The individual plants were clipped to wires. Field view of the experiment is given in Plates 4 and 5.

3.1.5 Main items of observation

Five plants were randomly selected per genotype per replication for recording observations and the mean was worked out. For recording observations on fruit characters, five fruits were selected randomly from each genotype in each replication. Observations on the following characters were recorded.

3.1.5.1 Quantitative parameters

3.1.5.1.1 Vegetative Characters

3.1.5.1.1.1 Plant height at flowering (cm)

Height of the plants from the ground level to the top most leaf bud on the day of first flower opening was recorded.

3.1.5.1.1.2 Plant height at harvest (cm)

Height of the plants from the ground level to the top most leaf bud at the time of first fruit harvest was recorded.

3.1.5.1.1.3 Internodal length(cm)

The distance between two adjacent nodes below the 5^{th} leaf from the top was recorded.

3.1.5.1.1.4 Leaf area (mm^2)

Fifth leaf from top was plucked and area was measured using a leaf area meter.

3.1.5.1.1.5 Crop duration (number of days)

Recorded as number of days from transplanting to the date of last harvest.

3.1.5.1.2 Flowering Characters

3.1.5.1.2.1 Days to 50% flowering (number of days)

Number of days from sowing until 50% plants show opened flowers in each genotype

3.1.5.1.2.2 Intercluster distance (cm)

The distance of two adjacent fully open clusters were measured below 5^{th} leaf from the top.

3.1.5.1.2.3 Flowers with exerted stigma (%)

Number of flowers with stigma exertion were counted per inflorescence. The observations were taken in three distinct stages of flowering *viz;* (i) Early (First flower opening to first fruits), (ii) Mid (First fruit set to first fruit ripening) and (iii) Late (After first harvest).

3.1.5.1.2.4 Number of flowers per cluster (No.)

The number of flowers in the tagged clusters from five random clusters were recorded in three distinct stages of flowering

3.1.5.1.2.5 Pollen viability (%)

Pollen viability was estimated using acetocarmine dye method in three stages of flowering.

Plate 1: Field preparation

Plate 2: Seedlings, planting and planted seedlings

Plate 3: Training seedlings on floriculture nets

Plate 4: Field view of rainshelter

Plate 5: Field view of polyhouse

3.1.5.1.2.6 Length of the style (cm)

The length of the style from the top of the ovary to the top of the stigma of an emasculated flower was measured with the help of a scale. Length of the style was observed in three stages of flowering.

3.1.5.1.2.7 Anther length (cm)

The anther cone was removed from the flower was length measured with the help of a scale. The anther length was observed in three stages of flowering.

3.1.5.1.2.8 Days to first fruit set (No.)

Recorded as the number of days taken from transplanting to the first fruit set.

3.1.5.1.3 Fruit Characters and Yield

3.1.5.1.3.1 Days from anthesis to fruit maturity (No.)

Recorded as the number of days taken from the day of flower opening to the date of attaining physical maturity (turning stage).

3.1.5.1.3.2 Days to first fruit harvest (No.)

Recorded as the number of days from transplanting to the date of first fruit harvest at breaker stage.

3.1.5.1.3.3 Number of fruits per cluster (No.)

The number of fruits per cluster was recorded at marketable stage. The observations taken in three distinct stages of flowering.

3.1.5.1.3.4Fruit set per cent (%)

Recorded as the ratio of number of fruits per cluster to the number of flowers per cluster. The observations taken in three distinct stages of flowering.

3.1.5.1.3.5 Number of fruits per plant (No.)

Total number of fruits harvested from observational plants

3.1.5.1.3.6 Locule number (Number)

The number of locules per fruit in the equatorial section of the fruit at fully ripe stage was recorded.

3.1.5.1.3.7 Pericarp thickness (cm)

Recorded as the pericarp thickness in the equatorial section of the fruit at full ripe stage.

3.1.5.1.3.8 Average fruit weight (g)

Recorded as the mean of the weight of five random fruits from each replication at full ripe stage in an electronic weighing balance.

3.1.5.1.3.9 Fruit yield per plant (g)

Recorded as the average of cumulative yield of observational plants.

3.1.5.1.3.10 Fruit yield per plot (kg)

Recorded as the average of cumulative yield from each plot (3 m^2)

3.1.5.1.4 Biochemical / Quality Characters

3.1.5.1.4.1 Total soluble solids (^{0}Brix)

TSS was measured using a hand refractometer at fully ripe stage.

3.1.5.1.4.2 Lycopene (mg/ 100g fresh weight)

Lycopene content of the fruits was estimated at the full ripe stage by following the method of Srivastava and Kumar (1949).

Reagents

Acetone, petroleum ether, anhydrous sodium sulphate and five per cent sodium sulphate.

Procedure

Tomato fruits were crushed with the help of pestle and mortar and pulped well to a smooth consistency in a blender. Five to ten gram of this pulp was weighed and the pulp was extracted repeatedly with acetone using pestle and mortar or a blender until the residue was colourless. The acetone extracts were pooled and transferred to a separating funnel containing 20 ml petroleum ether and gently mixed. 20 ml of five per cent sodium sulphate solution was added to the separating funnel, and shaken gently. Volume of the petroleum ether might be reduced during the process because of its evaporation and so additional 20 ml petroleum ether was added to the separating funnel for the clear separation of two layers. Most of the colour was noticed in the upper petroleum ether layer. The two phases were separated and the lower aqueous phase was re-extracted with additional 20 ml petroleum ether until the aqueous phase was colourless. The petroleum ether extracts were pooled and washed once with a little distilled water. The washed petroleum ether extract containing carotenoids was poured into a brown bottle containing about ten gram anhydrous sodium sulphate and kept it aside for 30 minute or longer. The petroleum ether extract was decanted into a 100 ml volumetric flask through a funnel containing cotton wool. Sodium sulphate slurry was washed with petroleum ether until it was colourless and the washings were transferred to the volumetric flask. The volume was made up and the absorbance was measured in a spectrophotometer at 503 nm using petroleum ether as blank.

$$Lycopene\ (mg/100g\ ) \ = {}^{31.206 \times absorbance}\!/_{weight\ of\ the\ sample}$$

3.1.5.1.4.3 Ascorbic acid (mg/100gfresh weight)

Ascorbic acid content of the fruit was estimated by 2, 6-dichlorophenol indophenole dye method (Sadasivam and Manickam, 1992).

Reagents

1. Oxalic acid (four per cent)
2. Ascorbic acid (standard)

Stock solution was prepared by dissolving 100 mg of ascorbic acid in 100 ml of 4 per cent oxalic acid. Ten ml of this stock solution was diluted to 100 ml with 4 per cent oxalic acid to get working standard solution.

3. 2, 6-dichlorophenol indophenole dye

42 mg sodium bicarbonate was dissolved in a small volume of distilled water. 52 mg of 2, 6-dichlorophenol indophenole was added into this and made up to 200 ml with distilled water.

4. Working standard

Ten ml of stock solution was diluted to 100 ml with 4 per cent oxalic acid. The concentration of working standard is 100 mg per ml.

Procedure

Five ml of the working standard solution was pippeted out into a 100 ml conical flask and 10 ml of 4 per cent oxalic acid was added. This was titrated against the dye (V1). End point is the appearance of pink colour which persisted for at least 5 seconds.

Five gram of fresh fruit was extracted in four per cent oxalic acid medium, the extract was filtered and volume was made up to 100 ml using oxalic acid. From this five ml of aliquot was taken, 10 ml of 4 per cent oxalic acid was added and titrated as above against the dye and the endpoint (V2) was determined.

Ascorbic acid content of the sample was calculated using the formula

$$Amount\ of\ the\ ascorbic\ acid\ (mg\ per\ 100\ g)$$
$$= (0.5 \times V2 \times 100 | V1 \times 5 \times weight\ of\ the\ sample) \times 100$$

3.1.5.1.4.4 Acidity (%)

Acidity of fruits estimated as titrable acidity (Sadasivam and Manickam, 1992)

Reagents

1. Phenophthalein
2. 0.1N sodium hydroxide

Procedure

Weigh 10 g of fruit pulp. Mix it with 100 ml distilled water and heat in a water bath at 65^0C to dissolve the pulp completely for 30 minutes. Cool it and filter to a 250 ml standard flask and make up the volume. Pipette out 30 ml of the sample to a conical flask and dilute with equal amount of distilled water. Add one or two drops of phenolphthalein indicator and titrate against 0.1N sodium hydroxide. Light pink colour is the end point.

Calculations

Weight of the sample =10 g

Volume made up to =250 ml

Volume pipette out =30 ml

Volume of 0.1N sodium hydroxide = titre value

1ml of 0.1N sodium hydroxide =0.064 g citric acid

=0.0775g tartaric acid

=0.067 g malic acid

=0.090 g lactic acid

=0.045 g oxalic acid

Acidity is expressed in terms of anhydrous citric acid in 100 g fruit

$Acidity = (titre\ value \times 0.1 \times 0.064 \times 250 | 10 \times 30) \times 100$

3.1.5.1.4.5 Cholorophyll content

One gram of finely cut fresh leaves were taken and ground with 20 – 40 ml of 80% acetone. It was then centrifuged at 5000 –10000 rpm for 5 minutes. The supernatant was transferred and the procedure was repeated till the residue becomes colourless. The absorbance was read at 645 nm and 663 nm against the solvent (acetone) blank.

Calculation of Chlorophyll content

The concentrations of chlorophyll were calculated as:

Total Chlorophyll: $20.2(A_{645}) + 8.02\ (A_{663})$

Chlorophyll a: $12.7(A_{663}) – 2.69\ (A_{645})$

Chlorophyll b: $22.9(A_{645}) – 4.68(A_{663})$

3.1.5.1.5 Incidence of pest and diseases

3.1.5.1.5.1 Bacterial wilt incidence (%)

Recorded as the number of plants wilted in each genotype in each replication and the genotypes were scored

$$Per\ cent\ disease\ incidence = (no.\ of\ plants\ wilted | total\ no.\ of\ plants) \times 100$$

Scoring was done as follows (Aslam *et al.*, 2017)

R (Resistant)	<10 wilting
MR (Moderately resistant)	>10-20 wilting
MS (Moderately Susceptible)	>20-30 wilting
S (Susceptible)	>30-70 wilting
HS (Highly susceptible)	>70-100 wilting

3.1.5.1.5.2 Fruit cracking (%)

Recorded as the cumulative number of fruits with cracked symptoms for each genotype.

$$Per\ cent\ infestation = (no.\ of\ fruits\ infested\ per\ plant | total\ no.\ of\ fruits\ per\ plant) \times 100$$

Scoring was done as follows (Wahyun *et al.*, 2014)

0 - No infestation

1 – up to 15% infestation

2 – 15-25% infestation

3 – 25-50% infestation

4 – 50-75% infestation

5 - > 75 % infestation

3.1.5.1.5.3 Blossom end rot (%)

Recorded as the cumulative number of fruits with blossom end rot for each genotype.

$$Per\ cent\ infestation = (no.of\ infested\ fruits\ per\ plant | total\ no\ of\ fruits\ per\ plant) \times 100$$

Scoring was done as follows (Henareh *et al.,* 2015)

0 - No infestation

1 – Up to 15% infestation

2 – 15-25% infestation

3 – 25-50% infestation

4 – 50-75% infestation

5 - > 75 % infestation

3.1.5.1.5.4 Incidence of other pest and diseases

3.1.5.1.5.4.1 Leaf miner (%)

Recorded as ratio of the number of leaves mined to the total number of leaves for each genotype.

$$Per\ cent\ infestation = (no.of\ leaves\ mined | total\ no.of\ leaves) \times 100$$

The scoring was done as follows (Oliveira *et al.,* 2017).

1 - No mines on leaves

2 – Traces up to 25 %

3 – 25-50% infestation

4 – 50-75% infestation

5– 75-100% infestation

3.1.5.1.5.4.2 Fruit borer (%)

Recorded as the ratio of infested fruits to the total number of fruits per plant in each genotype.

$$The\ per\ cent\ disease\ infestation = (no.of\ infested\ fruits|plant)/(total\ no.of\ fruits\ |plant) \times 100$$

Scoring was done as follows (Oliveira *et al.*, 2017).

0 - No infestation

1 – Up to 15% infestation

2 – 15-25% infestation

3 – 25-50% infestation

4 – 50-75% infestation

5 - > 75 % infestation

3.1.5.1.6 Shelf life (No.)

Recorded as the number of days from breaker stage to visible symptoms of decaying.

3.1.5.2 Qualitative observations

Qualitative parameters were observed according to the minimal descriptor for agri-horti crops part 2 vegetables (Srivasthava *et al*., 2001)

3.1.5.2.1 Fruit size

Recorded at near maturity stage. Scores given according to the descriptor

Specification	**Score**
Very small (≤ 20 g)	1
Small (> 20 – 30 g)	2
Medium (>30-80 g)	3
Medium large (>80-100 g)	4
Large (>100-175g)	5
Very large (> 175 g)	6
Others	99

3.1.5.2.2 Fruit shape

Recorded at near maturity stage. Scores given according to the descriptor

Specification	Score
Flat round	1
Slightly flattened	2
Round	3
Oval	4
Heart shaped	5
Lengthened cylindrical (banana type)	6
pyriform	7
Plum shaped	8
Others	99

3.1.5.2.3 Immature fruit colour

Recorded at fully developed fruit. Scores given according to the descriptor

Colour	Score
Greenish white	1
Light green	2
Green	3
Dark green	4
Very dark green	5
Others	99

3.1.5.2.4 Presence of green shoulders

Recorded on fully ripened fruits. Scores given according to the descriptor

Specification	Score
Absent (uniform ripening)	0
Present (upper part of the fruit around the calyx green, while pistil area of the fruit red)	1

3.1.5.2.5 Mature fruit colour

Recorded on fully ripened fruits. Scores given according to the descriptor

Colour	Score
Yellow	1
Green	2
Orange	3
Red	4
Crimson	5
Pink	6
Tangerine	7
Yellow and red	8
Tangerine and red	9
Yellow, tangerine and red	10
Others	99

3.1.5.2.6 Fruit surface

Recorded at near maturity stage. Scores given according to the descriptor.

Specification	Score
Smooth	1
Corrugated	2
Others	99

3.1.5.2.7 Blossom end fruit shape

To be recorded at near maturity stage. Scores given according to the descriptor.

Specification	Score
Indented	1
Flat	2
Pointed / nippled	3
Others	99

3.1.6 Meteorological observations

Air temperature, soil temperature, relative humidity and light were recorded during the entire period of experiment. Air temperature, soil temperature and relative humidity were recorded at 9.00 am and at 2.00 pm. Light measured at 12.00 noon.

3.1.6.1 Air temperature (˚C)

Air temperature was recorded with the help of two dry bulb thermometers fixed at foliage height in each structure.

3.1.6.2 Soil temperature (˚C)

Soil temperature was recorded with the help two soil thermometers fixed in each structure at a depth of 10-20 cm.

3.1.6.3 Relative humidity (%)

Relative humidity was recorded using whirling psychrometer. From the observations RH was calculated using the agromet table provided from the Department of Agricultural Meteorology, COA, KAU, Vellanikkara.

3.1.6.4 Light (μ mol / m^2 /sec)

The light intensity was measured using quantum sensor.

3.1.7 Statistical Analysis

3.1.7.1Analysis of Variance

Data recorded from experimental plants were statistically analyzed. Analysis of variance and covariance were done:

a) To test significant difference among the genotypes and

b) To estimate variance components and other genetic parameters like variance, heritability, genetic advance etc.

Table 7. Analysis of variance / covariance

Source	DF	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Block	(r-1)	B xx		B xy		B yy	
Genotype	(v-1)	G xx	$\sigma^2_{ex+}\sigma^2_{gx}$	G xy	σ^2_{exy} + r σ^2_{gxy}	G yy	Σ^2_{ex}+r σ^2_{gx}
Error	(v-1) (r-1)	E xx	σ^2_{ex}	E xy		E_{xy}	σ^2_{xy}
Total	T xx		T xx			T yy	

From the above table other genetic parameters were estimated as follows:

3.1.7.2 Variance

The variance and covariance components were calculated as per the formula

X **Y**

Environmental variance (σ^2_e) σ^2_{ex} - E xx σ^2_{ey} =E yy

Genotypic variance (σ^2_g)(σ^2gx) $= (G_{xx} = E_{xx})/r(\sigma^2 gy) = (G_{xx} = E_{xx})/r$

Phenotypic variance (σ^2_p) $= \sigma^2_{px} - \sigma^2_{gx} + \sigma^2_{ex}\ \sigma^2_{py} - \sigma^2_{gy} + \sigma^2_{ey}$

3.1.7.3 Pooled analysis

Pooled analysis was done using the data of the evaluation of 35 tomato genotypes for two seasons (Table 8).

Table 8: ANOVA for pooled analysis

Source	DF	Mean squares	Expectation of mean squares
Replication	r-1	M_r	$\sigma^2_{ea} + g\ \sigma^2_r$
Genotype	g-1	M_g	$\sigma^2_{ea} + r\ \sigma^2_g$
Error a	(r-1) (g-1)	M_{ea}	
Season	s-1	M_s	
Genotype Vs. season	(s-1) (g-1)	M_s Vs. M_g	
Error b		M_{eb}	σ^2_e

Where,

r = number of replications

g = number of genotypes

s = number of seasons

Significance of the treatments was tested at 5 and 1 per cent level of probability.

3.1.7.4 Genetic Parameters

Genetic parameters of the first experiment was analysed using the pooled data of the two seasons

3.1.7.4.1 Coefficient of Variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as

$$Genotypic\ coefficient\ of\ variability\ (GCV) = \frac{\sigma_{gx}}{\bar{y}}$$

$$Phenotypic\ coefficient\ of\ variation\ (PCV) = \frac{\sigma_{px}}{\bar{y}}$$

where, σ_{gx} -Genotypic standard deviation

σ_{px} - Phenotypic standard deviation

$\bar{y}$ - mean of the characters under study

GCV and PCV values were categorized as low, moderate and high values as suggested by Sivasubramanian and Menon (1973) which is as follows.

0-10 per cent : Low

10-20 per cent : Moderate

20 per cent and above: High

3.1.7.4.2 Heritability

$$H^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}} \times 100$$

Where H^2 is the heritability (Jain, 1982) expressed in percent.

The range of heritability was categorized as suggested by Robinson *et al*. (1949) as follows:

0 – 30 per cent	Low
31 – 60 per cent	Medium
61 per cent and above	High

3.1.7.4.3 Genetic Advance as Percent Mean

Genetic advance as percentage over mean was calculated as per the formula given by Lush (1949) and Johnson *et al*. (1955).

$$GA = \frac{kH^2\ \sigma^2_{px}}{\bar{y}} \times 100$$

Where, k is the standard selection differential.

k = 2.06 at 5% selection intensity (Miller *et al*., 1958)

The range of genetic advance as per cent of mean was classified according to Johnson *et al.,* (1955).

0- 10 per cent	Low
11- 20 per cent	Moderate
> 20 per cent	High

3.1.7.5 Mahanolobis D^2 Analysis

Genetic divergence was studied using D^2 statistic. The genotypes were clustered by Tocher's method as described by Rao (1952).

3.1.7.6 Selection index

The selection index developed by Smith (1937) using discriminate function of Fisher (1936) was used to discriminate the genotypes based on selected traits.

The selection index is described by the function, $I = b_{1x1} + b_{2x2} + ... b_{kxk}$ and the merit of a plant is described by the function $H = a_1G_1+a_2G_2+............a_kG_k$ where $x_1,x_2,.....x_k$ are the phenotypic values and $G_1, G_2,.......G_k$ are genotypic values of the plant for the character $x_1, x_2,....x_k$ and H is the genetic worth of the plant. It is assumed that the economic weight assigned to each character is equal to unity i.e., $a_1,a_2,.....a_k = 1$

The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b= p^{-1}Ga$ where, P is the phenotypic variance - covariance matrix and G is the genotypic variance - covariance matrix. Based on the 'b' estimates and the mean values for the ten characters with respect to each genotype, scores were calculated and the genotypes were ranked.

3.2 EXPERIMENT II: SCREENING FOR BACTERIAL WILT

3.2.1 Methodology

The experiment was conducted during November 2018. The seeds were sown in the 98 well protrays. The protrays were filled with sterilised soil media. Another set of 98 well protrays were drenched with bacterial suspension.The inoculation concentration in the bacterial suspension was adjusted to 0.8 – 1.3 by taking OD at 600 nm. This set of protrays was used as sick protrays. Seedlings starved for 24 hrs prior to inoculation.

No of genotypes - 37

Inoculation methods - root dip

No of replications - 3

3.2.1.1 Root dip method

Seedlings uprooted and the root system was washed. Root tips were trimmed with sterile scissors in order to make a wound in the root system and then immediately dipped in the 150 ml of bacterial suspension for 30 minutes. Then planted in the sick protrays.

3.2.2 Main item of observation

The per cent disease incidence was calculated as given in 3.1.3.1.5.1. Disease index was calculated according reaction observed on the seventh day of inoculation

Table 9: Disease rating scale for disease index calculation (Winstead and Kelman, 1952)

Rating	Reaction observed
0	No wilting
1	1 leaf partially wilted
2	2 or 3 leaves wilted
3	All leaves wilted except top three leaves
4	All leaves wilted
5	Plant dead

Table 10: Disease index scale for categorization of genotypes (Aslam *et al.*, 2017)

Disease index	Reaction
0.00 - 0.2	Highly resistant
0.21 - 0.3	Resistant
0.31 - 0.4	Moderately resistant
0.41 - 0.5	Moderately susceptible
0.51 - 0.6	Susceptible
0.61 - 0.9	Highly susceptible
0.91 - 1.0	Extremely susceptible

3.3 EXPERIMENT III: PRODUCTION OF F_1 HYBRID SEEDS

3.3.1 Selection of parents

The experiment was conducted in line x tester fashion. Three hotset high yielding genotypes selected from experiment I, namely EC-620401, EC-620406 and EC-620410, were taken as lines. Four bacterial wilt resistant genotypes were selected from experiment II, namely EC-620382, EC-620427, EC-620429 and Arka Abha, were taken as testers. Details of parents are given in Table 11.

Table 11: Details of the parental genotypes

Lines (Hotset)			
Sl. No.	**Accession Number**	**Code number**	**Source**
1	EC-620401	1	NBPGR, New Delhi
2	EC-620406	2	NBPGR, New Delhi
3	EC-620410	3	NBPGR, New Delhi
Testers (Bacterial wilt resistant)			
Sl. No.	**Accession Number**	**Code number**	**Sources**
1	EC-620382	4	NBPGR, New Delhi
2	EC-620427	5	NBPGR, New Delhi
3	EC-620429	6	NBPGR, New Delhi
4	Arka Abha	7	ICAR-IIHR, Bengaluru

They were planted in the crossing block and crossed in line x tester fashion during November 2018 - February 2019. Twelve hybrids were produced. The details of crosses are given in table 12.

3.3.2 Crossing technique

In tomato anthesis occurs between 7 00 am and 8 00 am. The well developed flower which are expected to open next day morning were emasculated on the previous day evening and bagged using butter paper covers. On the next day morning (between 7 00 am and 8 00 am) the emasculated flowers were pollinated with the pollen from the male parent (testers). The pollinated flowers were again bagged and labelled. The mature crossed fruits were harvested and seeds collected separately from each cross.

3.4 EXPERIMENT IV: EVALUATION OF F_1 HYBRIDS

Experiment done from March 2019 to August 2019 under both polyhouse and rainshelter.

Table 12: Details of hybrid combinations

Sl No.	Parents	Cross combinations
1	1 x 4	EC-620401 x EC-620382
2	1 x 5	EC-620401 x EC-620427
3	1 x 6	EC-620401 x EC-620429
4	1 x 7	EC-620401 x Arka Abha
5	2 x 4	EC-620406 x EC-620382
6	2 x 5	EC-620406 x EC-620427
7	2 x 6	EC-620406 x EC-620429
8	2 x 7	EC-620406 x Arka Abha
9	3 x 4	EC-620410 x EC-620382
10	3 x 5	EC-620410 x EC-620427
11	3 x 6	EC-620410 x EC-620429
12	3 x 7	EC-620410 x Arka Abha

3.4.1 Experimental site

Same as that in experiment I (3.1.1)

3.4.2 Experimental material

The twelve hybrids combinations and their seven parents along with one check variety Akshaya (KAU, Thrissur) and one check hybrid Abhilah (Seminis Vegetable Seeds, Inc., Andheri)

3.4.3 Method and crop management

Same as that in part I of experiment 1 (3.1.3 and 3.1.4)

3.4.4 Main items of observation

Same as that in experiment I (3.1.5 and 3.1.6)

3.4.5 Statistical Analysis

The statistical analysis used in this study were presented under the following sub heads

- Analysis of variance for line x tester design
- Estimation of heterosis
- Estimation of combining ability
- Average degree of dominance
- Gene action

3.4.5.1 Analysis of variance for line x tester design

In order to find difference among parents, hybrids and parents Vs hybrids the data obtained for each character is analysed by Randomized Block Design (RBD) which was based on the following mathematical model

$$y_{ik} = \mu + g_i + r_k + e_{ik}$$

Where, $Y_{ik}$is the phenotype of the ith genotype grown in the kth replication

μ is the general mean

g_i is the effect of ith genotype

r_k is the effect of kth replication

e_{ik} is the error component associated with ith genotype of kthreplication.

The effect in the above model were assumed to be fixed and unknown parameters except e_{ik} assumed to be normally and independently distributed with mean zero and common variance (σ^2). The analysis of variance based upon this model is given below:

The mean sum of squares is calculated by dividing the sum of squares by their respective degree of freedom and were tested against the error variance by F test at 5 per cent and 1 per cent level of significance.

The standard error of difference (SF_d) between the genotypic means and critical difference (CD) were calculated by using the formula :

$SE_d = \pm (2MSE/r)^{0.5}$

Where, MSE = error mean of squares

r = number of replication

C. D. = t $_{(g-1)\ (r-1)}$ x SE_dWhere, t $_{(g-1)\ (r-1)}$is the t value at (g-1) (r-1) degrees of freedom

If the difference among the hybrids were found significant, only then combining ability analysis was done.

Table 13: Analysis of variance for line x tester design

Source of variance	**d. f.**	**Sum of square**
Replication	r-1	$\sum_{k=1}^{r} \frac{y^2k}{g} - \frac{(yk)^2}{g.r.}$
Genotype	g-1	$\sum_{i=1}^{g} \frac{G^2i}{g} - \frac{(Gi)^2}{g.r.}$
Parents	p-1	$\sum_{r=1}^{p} \frac{p^2i}{r} - \frac{(pi)^2}{P.r.}$
Female (lines)	f-1	$\sum_{r=1}^{f} \frac{F^2i}{r} - \frac{(Fi)^2}{f.r.}$
Males (testers)	m-1	$\sum_{r=1}^{m} \frac{M^2i}{r} - \frac{(Mi)^2}{m.r.}$
Line Vs tester	1	(3) – (4) – (6)
Hybrids	mf-1	$\sum_{r=1}^{m} \frac{fC^2i}{r} - \frac{(Ci)^2}{m.f.r.}$
Parents Vs hybrids	1	(2) – (3) – (6)
Error	(r-1) (g-1)	Total SS – (1) –(2)

Where, r - the number of replications

g - the total number of genotypes (hybrids + lines + testers)

p – number of parents (lines + testers)

f - number of female parents

m - number of male parents

Yk - total of k^{th} replication over genotypes

Gi - total of i^{th} genotype over replication

Pi - total of i^{th} parent over replication

Fi - total of i^{th} female parent over replication

Mi - total of i^{th} male parents over replication

Ci - total of i^{th} hybrid over replication

3.4.5.2 Estimation of heterosis

The mean of all replications of each parent, hybrids and check for all characters was computed and used in the estimation of heterosis. Heterosis was calculated as the per centage increase or decrease of mean F1 performance over the means of mid parent (MP), better parent (BP) and the standard check (SC)

$$Mid\ parent\ value(MP) = {P1 + P2}/{2}$$

$$Heterosis\ over\ mid\ parent\ (RH) = ({F_1 - MP}/{MP}) \times 100$$

Where, MP is the mean performance of parent 1 and 2

F_1 is the mean performance of the hybrids

$$Heterosis\ over\ better\ parent\ (HB) = ({F_1 - BP}/{BP}) \times 100$$

Where, BP is the mean performance of better parent

F_1 is the mean performance of the hybrid

$$Heterosis\ over\ standard\ check\ (SC) = {F_1 - SC}/{SC} \times 100$$

Where, SC is the mean performance of the standard check

F_1 is the mean performance of the hybrid

3.4.5.3 Test of significance

Test of significance was done by comparing the mean deviation with values of critical difference (CD) obtained separately for MP, BP and SC by using the formula

$$tMP = {F_1 - MP}/{SE\ of\ heterosis\ over\ mid\ parent}$$

$$tBP = {F_1 - BP}/{SE\ of\ heterosis\ over\ better\ parent}$$

$$tSC = {F_1 - SC}/{SE\ of\ heterosis\ over\ standard\ check}$$

Where,SE of heterosis over mid-parent = $[3Me/2r]^{1/2}$

SE of heterosis over better parent = $[2Me/2r]^{1/2}$

SE of heterosis over check hybrid = $[2Me/2r]^{1/2}$

(Me= error mean square; r= replication)

3.4.5.4 Analysis of variance for combining ability

The combining ability analysis for different characters was done as per the model suggested by Kempthorne (1957).

Mathematical model

$$\boldsymbol{Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}}$$

Where, Y_{ijk} is the performance of (i x j)th hybrid in kth replication

μ is the general population mean

g_i is the general combining ability (GCA) effect of ith line

g_j is the general combining ability (GCA) effect of jth tester

s_{ij} is the specific combining ability (SCA) effect of the (i x j)th hybrid

r_k is the effect of kth replication

e_{ijk} is the experimental error associated with ijkth observation

The effect in the above model were assumed to be fixed unknown parameters except e_{ijk} which is assumed to be normally and independently distributed with mean zero and common variance (σ^2). The analysis of the variance based upon this model is given in table 14.

The different sum of squares were divided by their respective d.f. to obtain mean sum of squares. First of all, fmhMS was tested against eMS. If it is significant both mhMS and fhMS were tested against fmhMS. On the contrary if fmhMS is found to be non significant,then both mhMS and fhMS were tested against eMS.

The different sum of squares were calculated using the formula

CF = $(Y...)^2/mfr$

TSS = $\Sigma_i \Sigma_j \Sigma_k (Y_{ijk})^2$ – C. F.

fhSS = $[\Sigma_i (Y_i)^2/mr]$ – C. F.

mhSS = $[\Sigma_j (Y_j)^2/fr]$ – C. F

fmhSS = $[\Sigma_i\Sigma_j(Y_{ij})^2/r]$ – C.F.-fhSS-mhSS

eSS = TSS- $[\Sigma_k (Y_{...k})^2/fm$ – C.F.] – $[\Sigma_i\Sigma_j(Y_{ij})^2/r$ – C.F.]

where, Y..... = total of all hybrids over all replication

Y_i = i^{th} female total

Y_j = j^{th} male total

Y_{ij} = $(i \times j)^{th}$ hybrid total

$Y_{...k}$ = k^{th} replication total

Table 14: Analysis of variance for combining ability

Source of variation	d. f.	M. S. S.	Expectations of mean square
Testers in hybrids	(m-1)	mhMS	σ^2+r[Cov.(FS)-2Cov.(HS)] + [fr.Cov.(HS)]
Lines in hybrids	(f-1)	fhMS	σ^2+r[Cov.(FS)-2Cov.(HS)] + [fr.Cov. (HS)]
(line x tester) in hybrids	(m-1)(f-1)	fmhMS	σ^2+ r[Cov.(FS)-2Cov.(HS)]
Error	(r-1)(mf-1)	eMS	σ^2
Total	Mfr-1		

Cov. (HS) = mhMS + fhMS – 2fmhMS/ r (m+f)

Cov. (FS) = [mhMS + fhMS + fmhMS – 3eMS + 6r Cov. (HS) – r (m+f).Cov (HS)]/3r

The variance due to the combining ability (σ^2_{gca}) and specific combining ability (σ^2_{sca}) were calculated as under

σ^2_{gca} = Cov. (HS)

σ^2_{sca} = Cov. (FS)- 2 Cov. (HS)

Additive variance σ^2_A and dominance variance σ^2_D at F=1 (tomato being a self pollinated crop) and degrees of dominance were calculated as follows

$\sigma^2_A = \sigma^2_{gca} / [(1+F)/4] = \sigma^2_{gca}$

$\sigma^2_D = \sigma^2_{sca} / [(1+F)/2] = \sigma^2_{sca}$

Degree of dominance = $(\sigma^2_A/\sigma^2_D)^{0.5}$

The proportional contribution of lines, testers and their interaction to hybrid variance were calculated as (Sharma, 1998):

Line contribution % = [fhSS/cSS] x 100

Tester contribution % = [mhSS/cSS] x 100

Line x Tester contribution % = [fmhSS/cSS] x 100

Where, cSS is the sum of square due to hybrids

3.4.5.5Estimation of combining ability effects

The model adopted to estimate gca and sca effects of ijk observations was as follows

$X_{ijk} = m + g_i + g_j + S_{ij} + e_{ijk}$

Where, μ is the population mean

g_i is the gca effect of i^{th} line

g_j is the gca effect of j^{th} tester

S_{ij} is the sca of i x j cross and

e_{ijk} is the error associated with observation ijk

The gca effect of the parents and the sca effect of the crosses (hybrids) were estimated as given below

3.4.5.5.1 General combining ability effects

$$a)Line\ g_i \ = \frac{X_i}{t \times r} - \frac{X \ldots..}{1 \times t \times r}$$

$$b)Tester g_j \ = \frac{X_j}{1 \times r} - \frac{X \ldots.}{1 \times t \times r}$$

3.4.5.5.2 Specific combining ability effects

$$S_{ij} \ = \frac{X_{ij}}{r} - \frac{X_i}{t \times r} - \frac{X_{.j}}{1 \times r} - \frac{X_{.....}}{1 \times t \times r}$$

Where, l is the number of lines

t is the number of testers

g_i is the gca of i[th] line

x_i is the total of i[th] line over all the testers

x.... is the total of all crosses

g_j is the gca of j[th] tester

x_j is the total of j[th] tester over all lines and replication

S_j is the sca effects of i x j cross

$x_{.j.}$ is the total of cross i x j over all replications

Standard error of gca and sca effects

$$SE\ (GCA) for\ line\ = \sqrt{\frac{error\ variance}{l \times r}}$$

$$SE\ (GCA) for\ teters = \sqrt{\frac{error\ variance}{t \times r}}$$

$$SE\ (SCA)\ = \sqrt{\frac{error\ variance}{r}}$$

$$SE\ for\ BP\ and\ check\ = \sqrt{\frac{2error\ variance}{r}}$$

Critical difference (CD) were calculated by multiplying the SE with table ‘t’ value at 5 per cent probabilities for error degrees of freedom.

3.4.5.6 Gene action

Gene action has been studied under two heads, *viz*: average degree of dominance and genetic parameters.

3.4.5.6.1 Average degree of dominance

The average degree of dominance was calculated for all the characters by the formula given by Comstock and Robinson (1952).

Degree of dominance = $\sqrt{(\frac{\sigma^2 D}{\sigma^2 A})}$

Where, σ^2 D = Variance due to dominance gene action

σ^2 A = Variance due to additive gene action

The estimates of additive genetic variance and dominance genetic variance were calculated from the variance due to lines and testers utilizing the following relationship

$$\sigma^2 m = \frac{1}{4}\sigma^2 A \quad \text{or} \quad \sigma^2 A = 4\sigma^2 m$$

$$\sigma^2 f = \frac{1}{4}\sigma^2 A + \frac{1}{4}\sigma^2 D \text{ or } \sigma^2 D = 4\,(\sigma^2 f - \sigma^2 m)$$

In this experiment m ≠ f, hence : $\sigma^2 A = 4(M1 + M2 - 2M3$/r (m + f))

3.4.5.6.2 Test of significance of estimates of additive and dominance variance

Variance test was utilized to test the significance of estimates of additive genetic variance ($\sigma^2 A$) and dominance genetic variance ($\sigma^2 D$). The S. E. of the estimates was calculated as follows:

i) S. E. of $\sigma^2 A = \sqrt{(\frac{16}{r^2(f+m)}.2\,[\frac{M1^2}{(f-1)+2} + \frac{M2^2}{(m-1)+2} + \frac{M3^2}{(f-1)(m-2)+2}])}$

ii) S. E. of $\sigma^2 D = \sqrt{(\frac{16}{r^2}.2\,[\frac{M3^2}{(f-1)(m-1)+2} + \frac{M4^2}{(r-1)(fm-1)+2}])}$

Where, r = number of replications

f = number of females

m = number of males

(f-1) = degree of freedom associated with M1

(m-1) = degree of freedom associated with M2

(f-1) (m-1) = degree of freedom associated with M3

(r-1) (fm-1) = degree of freedom associated with M4

M1, M2, M3 and M4 are mean squares due to females, males, females x males and error respectively.

3.5 EXPERIMENT V: GENOMIC DNA EXTRACTION AND PCR ASSAY

3.5.1 Equipment and machinery

The equipments were available in the High-Tech Seed Testing Laboratory, Department of Vegetable Science, College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur. The centrifugation was done in high speed refrigerated floor model centrifuge (Eppendorf refrigerated centrifuge 5430 R). For the quantification of Eppendorf BioSpectrometer was used. PCR was done in Eppendorf Mastercycler (nexus gradient). PCR mixture composition and running protocol were depicted in Table 15 and Table 16.

For agarose gel electrophoresis, horizontal gel electrophoresis system (Bio-Rad) was used and analysed by using imagelab software (Boi-Rad Gel Documentation System).

3.5.2 Methodology

Tender emerging leaves, since they yield good quality DNA, were collected in the early morning from individual plants. They were surface sterilised. DNA was isolated following the CTAB method developed by Doyle and Doyle (1987).

Table 15: Materials used for the preparation of PCR mixture

Sl. No	Item	Quantity
1	Taq Buffer B	2 µl
2	$MgCl_2$	1.5 µl
3	Dntp	1.5 µl
4	H_2O (Distilled)	9.1 µl
5	TAQ polymerase	0.4 µl
6	Primer	Forward and reverse primers 2 µleach
7	DNA	2 µl
8	Toal	20 µl

Table 16: Running protocol for PCR

Sl. No.	Step name	Temperature (^0C)	Time allotted
1	Hot start	94	4 minutes
2	Denaturation	94	45 seconds
3	Annealing	Vary according to the primer	1 minute
4	Elongation	72	2 minutes
5	Repeat step 2 - 4 for 36 times		
6	Final elongation	72	8 minutes
7	Storage	4	Infinite

3.5.3 Assessing the quantity of the DNA using spectrophotometer (Nanodrop ND-1000)

The quantity of the DNA in the pure sample was calculated using the relation

IOD at 260nm = 50 µg DNA / ml

Therefore OD_{260} X 50 gives the quantity of DNA in µg / ml

3.5.4 Genotypes selected for the study

Ten genotypes were selected from the experimental material of Experiment I, *viz;*EC-165700, EC-620382, EC-620387, EC-620401, EC-620406, EC-620410, EC-620427, EC-620429, EC-631369and Arka Abha.The genotypes EC-620387, EC-620401, EC-620406, EC-620410, and EC-631369 were susceptible to bacterial wilt whereas, the genotypes EC-165700, EC-620382, EC-620427, EC-620429 and Arka Abha were resistant to bacterial wilt.

3.5.5 SSR (Simple Sequence repeats) analysis

Only SSR markers were used in the study. SSR primers (make- Sigma Aldrich) were used for amplification of DNA. These SSR primers were selected from the previous studies based on their suitability in the screening for bacterial wilt. The list of SSR primers used in the study detailed in Table 17.

Table 17: List of SSR primers used in the study

Sl. No.	Oligo name	Forward 5' sequence 3'	Reverse 5' sequence 3'	Annealing temperature (^0C)
1	SLM 12-2	ATCTCATTCAACGCACACCA	AACGGTGGAAACTATTGAAAGG	55
2	SLM12-10	ACCGCCCTAGCCATAAAGAC	TGCGTCGAAAATAGTTGCAT	54
3	SLM6124	CATGGGTTAGCAGATGATTCAA	GCTAGGTTATTGGGCCAGAA	56
4	SLM6118	CATGGGTTAGCAGATGATTCAA	GCTAGGTTATTGGGCCAGAA	56
5	SLM6119	GCCTGCCCTACAACAACATT	CGACATCAAACCTATGACTGGA	57
6	SLM6136	CCAGGCCACATAGAACTCAAG	ACAGGTCTCCATACGGCATC	58
7	SLM6-17	TCCTTCAAATCTCCCATCAA	ACGAGCAATTGCAAGGAAAA	51
8	SLM6-94	CTAAATTTAAATGGACAAGTAATAGCC	CACGATAGGTTGGTATTTTCTGG	63
9	SLM6-110	AGAATGCGGAGGTCTGAGAA	ATCCCACTGTCTTTCCACCA	55
10	KHU-1-F	TCAAGGTCCACTACCTTCATCC	GTTGCATGGGAAGTATGGCT	58
11	SSR 20	ACA TGA GCC CAA TGA ACC TC	AAC CAT TCC GCA CGT ACA TA	58

(Dheemanth *et al*., 2018, Kim *et al.,* 2018, Hanson *et al.,* 2016, Hanson *et al*., 2013)

Results

4. Results

The study entitled 'Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation' was carried out in the Department of Vegetable Science, College of Agriculture, Vellanikkara, Thrissur during January 2018 to January 2020. Experimental data has been recorded during the course of investigation, analyzed and the results are presented in this chapter under the proper heads.

4.1 SCREENING OF THE TOMATO GENOTYPES

Screening of tomato genotypes was carried out under polyhouse and rainshelter for two seasons, summer evaluation from January to May 2018 and rainy season evaluation from July to December 2018.

4.1.1 Mean performance of genotypes for quantitative characters

Analysis of variance revealed significant differences among the 35 tomato genotypes.

4.1.1.1Vegetative characters

4.1.1.1.1 Plant height at flowering (cm)

There was significant difference among the genotypes under both the growing conditions in two seasons (Table 18). During summer under polyhouse the highest plant height was recorded for EC-165395 (88.9 cm), followed by EC-165690 (88.6 cm). The lowest value was recorded for EC-165700 (60.0 cm). Inside rainshelter, the highest was recorded for EC-620389 (72.1 cm), followed by EC-165395 (67.9 cm). The lowest value was reported for EC-631369 (47.9 cm).

In the rainy season under polyhouse the highest plant height at flowering was recorded for EC-151568 (136.9 cm), followed by EC-528368 (135.3 cm). The lowest was recorded for EC-249514 (85.1 cm). Inside rainshelter the highest plant height at flowering was recorded for EC-620395 (95.5 cm), followed by

Table 18: Mean performance of tomato genotypes for plant height at flowering

Genotypes	Plant height at flowering (cm)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	82.3	50.7	121.2	75.9	101.7	63.3
EC-151568	86.8	63.0	136.9	71.5	111.9	67.3
EC-157568	78.2	62.9	118.3	81.3	98.3	72.1
EC-160885	74.9	62.4	126.2	79.3	100.6	70.9
EC-163605	77.8	60.6	126.3	85.3	102.1	73.0
EC-164263	77.2	51.2	93.7	80.1	85.5	65.7
EC-164563	78.1	60.2	120.7	89.2	99.4	74.7
EC-164670	78.8	51.7	111.9	89.5	95.4	70.6
EC-165395	88.9	67.9	120.3	86.2	104.6	77.1
EC-165690	88.6	64.5	113.7	94.6	101.2	79.6
EC-165700	60.0	51.6	111.3	79.5	86.9	65.6
EC-249514	81.1	58.4	85.1	83.5	96.2	71.0
EC-521067 B	77.7	54.2	107.0	90.7	81.4	72.5
EC-528368	67.9	59.6	135.3	91.7	87.5	75.7
EC-538153	71.8	49.4	108.2	84.0	103.6	66.7
EC-620376	75.4	52.8	119.8	82.4	91.8	67.6
EC-620378	80.7	56.8	98.2	82.3	100.3	69.6
EC-620382	72.8	53.9	113.9	71.5	85.5	62.7
EC-620387	77.8	51.7	115.1	76.0	95.9	63.9
EC-620389	77.6	72.1	104.4	82.4	96.4	77.3
EC-620395	82.9	54.1	131.1	95.5	93.7	74.8
EC-620401	81.8	55.7	120.0	85.8	106.5	70.8
EC-620406	75.5	52.5	113.1	90.6	97.8	71.6
EC-620410	82.4	56.3	111.7	81.5	67.5	68.9
EC-620417	86.2	59.7	111.2	90.9	71.3	75.3
EC-620427	82.7	63.3	118.6	79.2	71.2	71.3
EC-620429	74.7	54.7	110.6	85.9	69.0	70.3
EC-631369	71.9	47.9	111.3	85.7	63.3	66.8
EC-631379	77.3	53.7	112.4	85.5	62.6	69.6
Pusa Ruby	73.4	51.3	108.9	91.5	63.6	71.4
Arka Abha	78.1	54.7	114.1	72.9	64.7	63.8
Arka Saurabh	74.9	49.7	97.6	72.8	86.3	61.3
Arka Alok	77.3	52.2	98.7	74.7	88.0	63.5
Akshay	60.4	48.7	95.2	72.2	77.8	60.5
Anagha	72.7	54.3	97.5	72.8	85.1	63.6
CD (0.05)	5.1	6.9	13.7	14.3	8.6	5.7
CV	3.3	5.7	8.4	9.8	11.3	13..2

EC-165690 (94.6 cm). The lowest height at flowering was recorded for EC-151568 and EC-620382 (71.5 cm).

In the pooled mean, EC-151568 (111.9 cm) recorded highest plant height under polyhouse, and EC-165690 (79.6 cm) recorded highest inside rainshelter.

4.1.1.1.2 Internodal length (cm)

Significant difference was observed among the genotypes for intermodal length (Table 19). During summer under polyhouse, the maximum internodal length was reported for EC-165690 (13.4 cm), followed by EC-151568 and EC-165395 (13.1 cm). The shortest internode was observed for Akshaya (7.9 cm). Inside the rainshelter the longest internode was observed in EC-165395 (11.7 cm), followed by EC-620389 (11.4 cm). The shortest internode was observed for EC-631369 (6.0 cm).

During rainy season under polyhouse the longest internode was observed for EC-165690 (14.3 cm), followed by EC-165395 and EC-620395 (14.2 cm). The shortest internode was recorded for Akshaya (8.3 cm). Inside rainshelter the longest internode was observed for EC-165690 (13.6 cm), followed by EC-151568 and EC-620395 (12.3 cm). The shortest internode was observed for Akshaya (7.2 cm).

In the pooled mean, in both the structures EC-165690 recorded the highest internodal length (13.9 cm for polyhouse and 12.1 cm for rainshelter).

4.1.1.1.3 Plant height at harvest (cm)

Significant difference was observed among the genotypes (Table 20). During summer under polyhouse, the highest value was recorded for EC-165395 (113.8 cm), followed by EC-165690 (113.7 cm). Inside the rainshelter the highest plant height at flowering was reported for EC-620389 (95.0 cm), followed by EC-165395 and EC-165690 (92.9 cm).

Table 19: Mean performance of tomato genotypes for intermodal length

Genotypes	Intermodal length (cm)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	8.7	6.50	11.2	10.9	10.0	8.7
EC-151568	13.1	7.6	12.5	12.3	12.8	10.0
EC-157568	8.9	7.2	9.5	9.3	9.2	8.3
EC-160885	10.1	6.6	9.7	8.5	9.9	7.6
EC-163605	12.7	7.7	11.9	11.6	12.3	9.7
EC-164263	8.6	7.6	10.5	8.8	9.6	8.2
EC-164563	12.3	8.2	12.2	11.7	12.3	10.0
EC-164670	11.4	7.5	12.1	9.9	11.8	8.7
EC-165395	13.1	11.7	14.2	12.1	13.7	11.9
EC-165690	13.4	10.6	14.3	13.6	13.9	12.1
EC-165700	10.8	8.1	12.5	10.4	11.7	9.3
EC-249514	9.3	7.4	9.1	8.4	9.2	7.9
EC-521067 B	10.3	8.0	9.7	8.3	10.0	8.2
EC-528368	9.4	6.3	9.1	9.0	9.3	7.7
EC-538153	10.9	6.5	11.9	9.8	11.4	8.2
EC-620376	8.4	7.5	9.1	8.5	8.8	8.0
EC-620378	8.6	7.5	9.1	7.9	8.9	7.7
EC-620382	10.2	8.8	11.1	9.8	10.7	9.3
EC-620387	11.6	6.4	12.6	11.9	12.1	9.2
EC-620389	12.8	11.4	13.5	10.1	13.2	10.8
EC-620395	12.9	10.9	14.2	12.3	13.6	11.6
EC-620401	12.8	11.3	11.6	10.6	12.2	11.0
EC-620406	12.5	8.8	11.9	9.1	12.2	9.0
EC-620410	8.4	8.2	9.2	9.0	8.8	8.6
EC-620417	12.7	7.5	12.2	11.5	12.5	9.5
EC-620427	11.7	10.0	12.2	12.0	12.0	11.0
EC-620429	12.2	9.0	12.2	11.1	12.2	10.1
EC-631369	10.1	6.0	12.4	11.7	11.3	8.9
EC-631379	12.5	9.2	12.3	12.2	12.4	10.7
Pusa Ruby	10.2	8.2	12.2	10.4	11.2	9.3
Arka Abha	9.3	8.4	9.4	7.8	9.4	8.1
Arka Saurabh	8.7	8.0	9.6	8.6	9.2	8.3
Arka Alok	10.1	7.2	9.5	9.0	9.8	8.1
Akshay	7.9	6.3	8.3	7.2	8.1	6.8
Anagha	8.1	7.2	9.2	7.6	8.9	7.4
CD (0.05)	1.1	1.2	1.6	2.3	1.3	2.5
CV	5.0	7.3	7.5	10.0	6.0	13.3

In the rainy season under polyhouse the highest plant height at flowering was recorded for EC-151568 (157.1 cm), followed by EC-528368 (154.4 cm), and the lowest for Anagha (110.0cm). Inside rainshelter the highest value was observed for EC-620395 (114.9cm), followed by EC-164563 (113.2 cm) and EC-165690 (112.6 cm). The lowest value was recorded for Akshaya (75.5 cm).

In the pooled mean, under polyhouse EC-151568 (135.2 cm) and inside rainshelter EC-165690 (102.8 cm), recorded highest plant height at harvest.

4.1.1.1.4 Leaf area (mm^2)

During summer under polyhouse the leaf area was maximum (Table 21) for EC-631369 (135.7 mm^2), followed by Arka Saurabh (131.3mm^2). The leaf area was minimum for EC-620406 (71.0 mm^2). Inside rainshelter, maximum leaf area was observed for Arka Saurabh (88.0 mm^2), followed by EC-620410 (85.9 mm^2). The minimum leaf area was recorded for EC-165690 (24.2 mm^2).

During rainy season under polyhouse, the maximum leaf area was recorded for EC-631369 (137.0 mm^2), followed by EC-620429 (129.0 mm^2). The minimum leaf area was observed for EC-165395 (57.1 mm^2). Inside rainshelter, the maximum leaf area was observed for EC-620382 (98.9 mm^2), followed by EC-249514 (97.9 mm^2).

In the pooled mean, under polyhouse EC-631369 (136.4 mm^2) and inside rainshelter Arka Saurabh (89.5 mm^2), recorded the highest leaf area.

4.1.1.1.5 Crop duration (number of days)

Crop duration exhibited significant difference among the genotypes (Table 22). During summer evaluation under both the structure, EC620406 exhibited longest duration (129.5 days under polyhouse, and 127.4 days inside rainshelter) and Pusa Ruby exhibited shortest duration (117.5days under polyhouse and 115.6 days inside rainshelter)

Table 20: Mean performance of tomato genotypes for plant height at harvest

Genotypes	Plant height at harvest (cm)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	107.2	67.4	142.6	95.0	124.9	81.2
EC-151568	113.3	79.4	157.1	90.6	135.2	85.0
EC-157568	103.3	79.2	136.8	104.7	120.1	92.0
EC-160885	100.0	88.8	147.2	100.0	123.6	94.4
EC-163605	103.8	82.4	145.9	102.3	124.9	92.4
EC-164263	102.9	69.0	111.3	97.7	62.1	83.4
EC-164563	102.9	81.7	140.2	113.2	121.6	97.5
EC-164670	104.5	67.0	130.1	105.2	117.3	86.1
EC-165395	113.8	92.9	138.8	99.9	126.3	96.4
EC-165690	113.7	92.9	135.5	112.6	124.6	102.8
EC-165700	75.3	66.4	127.8	96.3	101.6	81.4
EC-249514	106.8	81.1	122.1	107.8	114.5	94.5
EC-521067 B	102.6	83.3	124.3	108.7	113.5	96.0
EC-528368	92.7	90.7	154.4	113.2	123.6	102.0
EC-538153	96.8	68.2	125.5	104.8	111.2	86.5
EC-620376	101.6	69.6	138.0	96.7	119.8	83.2
EC-620378	106.0	71.3	117.0	97.7	111.5	84.5
EC-620382	96.6	69.3	135.6	87.8	115.8	78.6
EC-620387	102.4	66.3	134.4	92.2	118.4	79.3
EC-620389	102.7	95.0	124.9	97.8	113.8	96.4
EC-620395	109.6	71.5	147.5	114.9	128.6	92.8
EC-620401	106.7	81.4	138.7	103.4	122.7	92.4
EC-620406	100.2	68.1	132.5	105.9	116.4	87.0
EC-620410	109.5	69.9	131.1	102.2	120.3	86.1
EC-620417	110.7	82.7	131.0	108.2	120.9	95.5
EC-620427	108.7	80.3	138.0	99.6	123.0	90.0
EC-620429	108.7	80.3	138.0	99.6	123.4	86.3
EC-631369	97.7	63.7	130.6	102.2	114.2	83.0
EC-631379	101.3	82.1	131.2	103.2	116.3	92.7
Pusa Ruby	96.9	68.0	128.5	102.2	112.7	85.1
Arka Abha	102.2	69.2	132.0	88.7	117.1	79.0
Arka Saurabh	99.4	64.6	113.2	89.3	106.3	77.0
Arka Alok	100.6	66.6	115.8	84.3	108.2	75.5
Akshay	91.0	64.9	119.7	75.5	94.9	70.2
Anagha	95.9	73.3	110.0	86.4	103.0	79.7
CD (0.05)	2.4	2.9	5.3	6.1	17.8	13.5
CV	2.9	5.0	8.8	6.1	10.7	7.6

Table 21: Mean performance of tomato genotypes for leaf area

Genotypes	Leaf area (mm^2)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	82.2	44.0	77.9	42.5	80.5	43.3
EC-151568	90.2	52.6	69.8	35.9	80.0	44.3
EC-157568	86.3	41.0	100.4	86.8	93.4	63.9
EC-160885	110.3	76.2	68.0	55.1	89.2	65.7
EC-163605	88.5	55.9	82.9	52.1	85.7	54.0
EC-164263	83.3	79.5	109.3	80.4	96.3	80.0
EC-164563	87.5	50.1	95.5	71.0	91.5	60.6
EC-164670	93.9	54.6	99.4	56.5	96.7	55.6
EC-165395	73.8	32.7	57.1	49.5	65.5	41.1
EC-165690	81.5	24.2	76.2	25.4	78.9	24.8
EC-165700	73.9	41.7	89.9	85.9	77.9	81.9
EC-249514	124.8	34.6	104.1	97.9	114.5	66.3
EC-521067 B	74.3	34.1	73.4	33.9	73.7	34.0
EC-528368	77.1	41.0	83.1	59.8	80.1	50.4
EC-538153	106.1	51.2	105.1	60.7	105.6	56.0
EC-620376	76.1	40.1	75.3	34.3	75.7	37.2
EC-620378	120.7	66.4	99.8	67.0	110.3	66.7
EC-620382	116.4	47.3	100.2	98.9	108.3	73.1
EC-620387	127.7	58.0	90.0	48.5	108.9	53.3
EC-620389	79.2	70.8	98.6	42.2	70.7	56.5
EC-620395	80.6	44.8	94.3	72.6	87.5	58.7
EC-620401	84.3	54.5	98.5	43.8	91.4	49.2
EC-620406	71.0	64.8	122.4	75.6	96.7	70.2
EC-620410	90.6	85.9	120.6	88.1	105.6	87.0
EC-620417	74.3	52.8	95.6	76.9	85.0	64.9
EC-620427	77.2	71.0	87.5	72.7	82.4	71.9
EC-620429	128.6	50.7	129.0	62.8	128.8	56.8
EC-631369	135.7	53.5	137.0	56.6	136.4	55.1
EC-631379	94.5	41.0	89.4	48.1	92.0	44.6
Pusa Ruby	81.0	45.7	93.2	53.8	87.1	49.8
Arka Abha	72.4	75.5	95.6	53.7	84.0	64.6
Arka Saurabh	131.3	88.0	111.9	91.0	121.6	89.5
Arka Alok	88.5	81.4	109.3	92.7	98.9	87.1
Akshay	89.2	49.4	88.5	50.1	88.9	49.8
Anagha	87.6	74.0	90.1	85.9	88.9	80.0
CD (0.05)	18.4	14.3	13.8	17.5	17.1	14.7
CV	12.9	12.6	13.2	10.2	15.1	16.2

Table 22: Mean performance of tomato genotypes for crop duration

Genotypes	Crop duration (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	124.5	122.6	137.6	127.6	131.1	125.1
EC-151568	122.3	126.5	149.3	133.1	135.8	129.8
EC-157568	124.5	117.5	125.1	125.0	124.8	121.3
EC-160885	119.6	122.7	131.2	134.6	125.4	128.7
EC-163605	129.0	118.5	150.6	132.8	139.8	125.7
EC-164263	126.4	124.5	136.9	125.1	131.7	124.8
EC-164563	126.3	117.4	153.5	127.3	139.9	122.4
EC-164670	127.0	126.5	151.6	133.2	139.3	129.9
EC-165395	127.5	124.5	153.5	135.1	140.5	129.8
EC-165690	128.3	123.8	150.7	127.7	139.5	125.8
EC-165700	122.6	119.6	141.5	135.5	132.1	127.6
EC-249514	125.5	122.6	130.1	135.9	127.8	129.3
EC-521067 B	127.4	121.5	150.0	137.1	138.7	129.3
EC-528368	123.6	119.6	149.8	125.7	136.7	122.7
EC-538153	128.7	124.8	133.1	133.6	130.9	129.2
EC-620376	122.6	119.6	145	138.2	133.8	128.9
EC-620378	123.8	119.5	138.4	139.6	131.1	129.6
EC-620382	129.0	124.8	152.1	138.7	140.6	131.8
EC-620387	124.6	120.5	140.1	134.4	132.4	127.5
EC-620389	126.7	122.9	150.6	133.7	138.7	128.3
EC-620395	126.5	122.9	151.4	134.3	139.0	128.6
EC-620401	128.6	126.5	150.5	138.6	139.6	132.6
EC-620406	129.5	127.4	151.1	140.1	140.3	133.8
EC-620410	128.5	126.4	153.3	140.1	140.9	133.3
EC-620417	126.7	122.5	134.6	138.1	130.7	130.3
EC-620427	127.5	126.3	152.1	138.4	139.8	132.4
EC-620429	127.5	125.5	152.6	139.4	140.1	132.5
EC-631369	124.8	119.7	134.4	138.7	129.6	129.2
EC-631379	121.5	117.5	148.3	130.5	134.9	124.0
Pusa Ruby	117.5	115.6	127.6	125.0	122.6	120.3
Arka Abha	128.5	123.4	151.5	139.0	140.0	131.2
Arka Saurabh	127.5	122.3	148.4	139.6	138.0	131.0
Arka Alok	123.7	119.4	147.4	137.5	135.6	128.5
Akshay	126.9	122.7	149.0	137.1	138.0	129.9
Anagha	127.8	125.4	145.6	132.7	136.7	129.1
CD (0.05)	1.5	2.7	2.4	1.7	2.3	2.5
CV	2.7	5.4	2.5	1.7	3.9	6.7

In the rainy season under polyhouse, the longest duration was recorded for EC-164563 and EC-165395 (153.5 days), followed by EC-620410 (153.3 days).

Inside rainshelter the longest crop duration was recorded for EC-620406 and EC-620410 (140.1 days), followed by Arka Saurabh (139.6 days). Under both the structures shortest duration was exhibited by EC-157568 (125.1 days and 125.0 days for polyhouse and rainshelter, respectively)

In the pooled mean, under polyhouse EC-620410 (140.9 days) and inside rainshelter EC-620406 (133.8 days), recorded the longest duration.

4.1.1.2 Flowering characters

4.1.1.2.1 Days to 50% flowering (no. of days)

Significant difference was observed among the genotypes (Table 23). During summer under polyhouse, the earliest to flower were EC-538153 and EC-620378 (35.0 days), followed by Arka Abha (40.0 days). EC-157568 was the late genotype (46.5 days). Inside the rainshelter the earliest to flower was EC-620395 (30.0 days), followed by EC-620401 (30.5 days) and late, EC-528368 (43.5 days).

In the rainy season under polyhouse, the earliest to flower was EC-620376 (42.0 days) followed by Anagha (42.5 days). EC-165690 and EC-620387 (48.5 days) expressed delayed flowering. Inside rainshelter, the days to 50% flowering was in the range between 45.5 days and 52.5 days. The earliest to flower was Arka Alok (45.5 days), and EC-249514, EC-521067 B and EC-538153 (52.5 days) were the late genotypes.

In the pooled mean, under polyhouse EC-620378 (39.3 days) and inside rainshelter EC-620429(38.8 days), recorded the earliest flowering.

4.1.1.2.2 Intercluster distance (cm)

Significant difference was observed among the genotypes for intercluster distance (Table 24). During summer evaluation under polyhouse, the intercluster distance was minimum for Arka Abha (8.1cm), followed by Akshaya (8.4 cm). Inside rainshelter, the shortest intercluster distance was recorded for Akshaya (7.7 cm), followed by EC-165395 (8.2 cm).

During rainy season, under polyhouse and inside rainshelter, Akshaya exhibited minimum intercluster distance (7.5 cm and 7.1 cm, respectively).

Table 23: Mean performance of tomato genotypes for days to 50% flowering

Genotypes	Days to 50% flowering (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	45.5	37.5	43.5	48.5	44.5	43.0
EC-151568	40.5	36.5	46.5	52.0	43.5	44.3
EC-157568	46.5	39.5	47.5	50.0	47.0	44.8
EC-160885	45.5	35.5	46.5	49.5	46.0	42.5
EC-163605	40.5	37.5	47.5	48.0	44.0	42.8
EC-164263	45.0	33.5	44.0	47.0	44.5	40.3
EC-164563	42.0	30.5	43.0	47.5	42.5	39.0
EC-164670	40.5	32.5	47.5	48.5	44.0	40.5
EC-165395	42.5	31.5	47.0	48.5	44.8	40.0
EC-165690	40.5	30.5	48.5	50.5	44.5	40.5
EC-165700	40.5	30.5	45.5	47.5	43.0	39.0
EC-249514	44.5	32.5	47.5	52.5	46.0	42.5
EC-521067 B	40.5	35.5	48.0	52.5	44.3	44.0
EC-528368	42.5	43.5	46.0	52.0	44.3	47.8
EC-538153	35.0	34.5	47.5	52.5	41.3	43.5
EC-620376	42.5	34.5	42.0	48.5	42.3	41.5
EC-620378	35.0	31.5	43.5	52.5	39.3	42.0
EC-620382	41.5	32.5	46.5	47.0	44.0	39.8
EC-620387	45.5	38.5	48.5	51.5	47.0	45.0
EC-620389	42.5	40.5	44.5	48.5	43.5	44.5
EC-620395	45.5	30.0	47.5	50.5	46.5	40.3
EC-620401	43.5	30.5	43.0	47.5	43.3	39.0
EC-620406	44.5	35.0	45.0	48.5	44.8	41.8
EC-620410	41.0	36.0	44.5	47.5	42.3	41.8
EC-620417	44.0	40.5	47.5	49.5	45.8	45.0
EC-620427	42.5	32.6	45.5	48.5	44.0	40.6
EC-620429	41.5	30.5	45.0	47.0	43.3	38.8
EC-631369	45.5	33.5	45.5	48.0	45.5	40.8
EC-631379	42.5	36.5	46.5	49.0	44.5	42.8
Pusa Ruby	44.5	32.5	46.5	47.5	45.5	40.0
Arka Abha	40.0	31.5	47.0	48.0	43.5	39.8
Arka Saurabh	43.5	33.5	44.7	45.6	44.1	39.6
Arka Alok	43.5	35.5	43.6	45.5	43.6	40.5
Akshaya	45.5	30.5	44.0	48.0	44.8	39.8
Anagha	44.5	31.5	42.5	48.0	43.5	39.8
CD (0.05)	2.4	3.6	3.8	2.5	3.5	2.8
CV	3.6	5.8	3.8	10.6	7.8	7.9

In the pooled mean, under polyhouse and inside rainshelter, Akshaya recorded the shortest intercluster distance (8.0 cm and 7.4 cm, respectively).

Table 24: Mean performance of tomato genotypes for intercluster distance

Genotypes	Intercluster distance (cm)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	11.2	9.5	13.4	13.8	12.3	11.7
EC-151568	12.9	9.2	14.4	14.0	13.7	11.6
EC-157568	11.0	10.1	10.9	12.7	11.0	11.4
EC-160885	12.8	12.2	15.5	13.4	14.2	12.8
EC-163605	11.5	8.5	14.0	13.6	12.8	11.1
EC-164263	11.9	8.6	14.1	13.7	13.0	11.2
EC-164563	12.8	12.1	13.0	13.9	12.9	13.0
EC-164670	12.4	10.5	13.2	12.9	12.8	11.7
EC-165395	14.2	8.2	12.5	13.4	13.4	10.8
EC-165690	12.0	8.6	13.0	10.4	12.5	9.5
EC-165700	9.3	12.0	11.0	11.4	10.2	11.7
EC-249514	11.9	9.6	12.1	13.6	12.0	11.6
EC-521067 B	13.6	12.6	12.9	11.9	13.3	12.3
EC-528368	12.2	12.4	13.3	13.3	12.8	12.9
EC-538153	9.6	9.6	10.9	11.0	10.3	10.3
EC-620376	13.4	12.0	13.3	13.4	13.4	12.7
EC-620378	13.6	10.5	12.6	13.6	13.1	12.1
EC-620382	11.7	10.3	12.4	13.0	12.1	11.7
EC-620387	10.5	8.7	9.6	10.0	10.1	9.4
EC-620389	10.2	11.0	8.1	8.4	9.2	9.7
EC-620395	10.4	8.5	11.0	10.0	10.7	9.3
EC-620401	11.9	11.5	11.8	13.4	11.9	12.5
EC-620406	12.0	11.0	12.3	13.6	12.2	12.3
EC-620410	8.6	12.0	7.6	8.8	8.1	10.4
EC-620417	10.5	13.4	11.3	12.2	10.9	12.8
EC-620427	11.9	12.4	11.6	12.4	11.8	12.4
EC-620429	12.0	12.3	12.7	13.5	12.4	12.9
EC-631369	13.0	12.3	11.3	12.5	12.2	12.4
EC-631379	13.7	10.7	12.4	14.6	13.1	12.7
Pusa Ruby	9.9	10.7	9.4	9.4	9.7	10.1
Arka Abha	8.1	9.9	8.6	9.0	8.4	9.5
Arka Saurabh	9.1	9.0	9.3	12.8	9.2	10.9
Arka Alok	11.0	12.1	12.2	12.7	11.6	12.4
Akshay	8.4	7.7	7.5	7.1	8.0	7.4
Anagha	8.5	11.0	7.7	8.1	8.1	9.6
CD (0.05)	1.6	2.2	1.7	1.9	1.8	1.7
CV	6.8	10.4	7.2	7.6	7.8	14.4

4.1.1.2.3Flowers with exerted stigma (%)

Flowers with exerted stigma was recorded in three stages over the entire crop period. There was significant difference among the genotypes for flowers with exerted stigma in all the three stages (Table 25).

4.1.1.2.3.1 Early stage of flowering

During summer evaluation under polyhouse, the flowers with exerted stigma was lowest for EC-620401 (12.0%), followed by Anagha (12.4%). Inside the rainshelter, the minimum number of flowers with exerted stigma was observed for EC-165395 and EC-620387 (13.0%).

In the rainy season under polyhouse, the stigma exertion was minimum for EC-620410 (10.3%), followed by EC-163605 (12.1%). Inside the rainshelter the stigma exertion was minimum for EC-620417 (13.7%), followed by EC-165700 (14.2%).

In the pooled mean, under polyhouse EC-620406 (13.2%) and inside rainshelter EC-620417 (13.5%), recorded the least stigma exertion.

4.1.1.2.3.2 Mid stage of flowering

During summer under polyhouse, EC-620410 recorded the minimum stigma exertion (18.1%), followed by EC-620417 (18.2%). Inside rainshelter, minimum stigma exertion was observed in EC-164263 (19.0%), followed by EC-620401 (19.6%).

In the rainy season under polyhouse, the stigma exertion was recorded minimum for EC-164263 (12.0%), followed by EC-631369 (14.6%). Inside rainshelter, EC-538153 recorded minimum stigma exertion (12.1%), followed by EC-165700 (14.0%).

In the pooled mean, under polyhouse EC-620401 (15.8%) and inside rainshelter EC-538153 (18.0%), recorded the least stigma exertion.

Table 25: Mean performance of tomato genotypes for flowers with exerted stigma

Genotypes	Flowers with exerted stigma (%)*																		
	Early stage of flowering						Mid stage of flowering						Late stage of flowering						
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	23.9(5.0)	13.8(3.7)	14.3(3.8)	19.6(5.7)	19.1	16.7	24.2(4.9)	22.9(4.8)	24.0(4.9)	27.3(5.8)	24.1	25.1	41.4(6.43)	27.6(5.3)	30.5(5.5)	33.0(6.2)	36.0	30.3
EC-151568	23.2(4.8)	20.0(4.4)	26.6(5.2)	19.8(5.5)	24.9	19.9	24.7(5.0)	35.1(5.9)	24.9(5.0)	30.8(4.4)	24.8	33.0	42.0(6.48)	31.0(5.6)	20.6(4.5)	43.2(6.6)	31.3	37.1
EC-157568	26.5(5.1)	17.9(4.2)	23.8(4.9)	30.4(5.3)	25.2	24.2	24.4(4.9)	25.2(5.0)	26.8(5.2)	31.1(5.4)	25.6	28.2	36.6(6.1)	36.0(6.0)	31.0(5.6)	46.0(6.8)	33.8	41.0
EC-160885	14.1(3.8)	36.6(5.9)	15.4(3.9)	34.5(6.7)	14.8	35.6	26.9(5.2)	41.7(6.5)	22.0(4.8)	31.1(5.8)	24.5	36.4	38.8(6.23)	46.2(6.8)	24.4(4.9)	52.0(7.8)	31.6	49.1
EC-163605	30.8(5.5)	15.7(4.0)	12.1(3.5)	28.6(6.0)	14.9	22.2	25.6(5.1)	39.8(6.1)	15.3(3.9)	27.5(5.3)	20.5	33.7	40.2(6.3)	32.0(5.7)	36.6(5.8)	47.9(6.9)	38.4	40.0
EC-164263	17.7(4.2)	15.0(3.9)	20.7(4.5)	19.3(4.7)	19.2	17.15	21.6(4.6)	19.0(4.3)	12.0(3.5)	18.2(4.2)	16.8	18.6	23.9(4.9)	27.6(5.3)	19.5(4.5)	21.6(4.6)	25.6	20.6
EC-164563	22.5(4.7)	14.9(3.9)	21.6(4.6)	26.9(4.3)	22.1	20.9	28.1(5.3)	28.7(5.4)	30.0(5.5)	20.7(5.0)	29.1	24.7	29.3(5.4)	30.9(5.6)	34.1(5.8)	25.5(5.2)	31.7	28.2
EC-164670	16.0(4.0)	15.3(3.9)	15.4(3.9)	21.9(5.5)	15.7	18.6	25.5(5.1)	23.1(4.9)	30.8(5.5)	23.4(4.6)	28.2	23.3	38.9(6.2)	33.9(5.8)	19.5(4.5)	32.8(6.2)	29.2	33.4
EC-165395	14.8(3.8)	13.0(3.6)	12.8(3.6)	14.5(4.8)	13.8	13.8	27.2(5.3)	21.4(4.6)	27.9(5.3)	21.0(5.2)	27.6	21.2	34.9(5.9)	34.4(5.9)	27.6(5.3)	23.8(4.9)	31.4	29.1
EC-165690	15.2(3.9)	15.1(3.9)	13.5(3.7)	18.3(4.2)	14.4	16.7	21.6(4.6)	21.0(4.6)	23.8(4.9)	20.4(5.0)	22.7	22.1	33.9(5.8)	32.0(5.7)	34.6(5.9)	36.9(6.1)	34.3	34.5
EC-165700	17.7(4.2)	23.7(4.9)	12.8(3.6)	14.2(4.4)	15.3	19.0	24.9(5.0)	50.2(7.1)	15.4(3.9)	14.0(3.2)	20.2	32.1	37.7(6.1)	36.0(6.0)	19.2(4.3)	37.0(6.1)	28.5	36.5
EC-249514	13.3(3.7)	23.4(4.8)	16.8(4.1)	16.6(5.0)	15.1	20.0	24.8(5.0)	42.0(6.5)	18.9(4.3)	18.0(4.3)	21.9	30.0	35.1(5.9)	32.9(5.7)	35.6(6.0)	37.8(6.5)	35.4	35.4
EC-521067 B	29.0(5.4)	17.9(4.2)	21.4(4.6)	15.5(4.4)	17.4	16.7	26.1(5.1)	25.6(5.1)	26.3(5.1)	24.1(3.9)	26.2	24.9	50.4(7.1)	34.2(5.8)	26.7(5.2)	32.2(4.9)	38.6	33.2
EC-528368	15.1(3.9)	13.9(3.7)	15.0(3.9)	19.7(4.4)	15.1	16.8	28.7(5.4)	27.8(5.3)	21.5(4.6)	25.2(5.6)	25.1	26.5	33.7(5.8)	37.5(6.1)	33.5(5.8)	30.0(5.5)	33.6	33.8
EC-538153	13.4(3.7)	17.5(4.2)	16.2(4.0)	20.8(5.0)	14.8	19.2	21.8(4.7)	23.8(4.9)	17.5(4.2)	12.1(2.7)	19.7	18.0	27.0(5.2)	24.0(4.9)	16.0(4.0)	24.9(5.6)	21.5	24.5
EC-620376	17.8(4.2)	15.6(3.9)	16.8(4.1)	17.5(6.5)	17.3	16.6	24.3(4.9)	25.0(5.0)	16.6(4.1)	35.6(4.2)	20.5	30.3	30.0(5.5)	34.3(5.9)	39.4(6.0)	31.9(7.7)	34.7	33.1
EC-620378	13.9(3.7)	16.8(4.1)	16.0(4.0)	20.5(4.9)	15.0	18.7	20.1(4.5)	23.9(4.9)	23.2(4.8)	17.2(3.0)	21.7	20.6	25.8(5.1)	30.1(5.5)	16.1(4.0)	24.6(5.3)	21.0	27.4

*on parenthesis transformation values are given

PH – polyhouse; RS – rainshelter

Table 25: Continued

Genotypes	Flowers with exerted stigma (%)*																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	21.7(4.6)	26.6(5.2)	22.4(4.7)	33.8(5.9)	22.1	30.2	26.0(5.1)	56.9(7.5)	30.8(5.5)	30.0(4.1)	28.4	43.5	44.6(6.7)	38.9(6.2)	40.3(5.9)	40.7(7.5)	42.5	39.8
EC-620387	16.3(4.0)	13.0(3.6)	22.9(4.7)	16.0(4.4)	19.6	14.5	25.0(5.0)	22.0(4.7)	17.6(4.2)	24.3(5.8)	21.3	23.2	28.5(5.3)	24.0(4.9)	23.9(4.9)	19.5(4.4)	26.1	21.8
EC-620389	16.9(4.1)	24.3(4.9)	15.9(4.0)	17.0(5.9)	16.4	20.7	22.9(4.8)	25.0(5.0)	23.9(4.3)	26.6(5.6)	23.4	25.8	23.9(4.9)	24.0(4.9)	23.9(4.9)	17.5(4.3)	23.9	20.8
EC-620395	13.5(3.7)	25.7(5.1)	15.9(4.0)	16.1(4.1)	14.7	20.9	25.6(5.1)	23.3(4.8)	15.6(3.9)	17.7(3.8)	20.6	20.5	21.1(4.6)	23.8(4.9)	18.4(4.3)	18.0(4.7)	19.8	20.9
EC-620401	12.0(3.5)	14.0(3.7)	15.6(3.9)	16.1(4.1)	13.8	15.1	18.6(4.3)	19.6(4.4)	15.4(3.9)	17.1(3.0)	15.8	18.4	23.6(4.9)	23.8(4.9)	18.5(4.3)	18.0(4.7)	21.1	20.9
EC-620406	13.8(3.7)	15.2(3.9)	12.6(3.6)	16.2(4.5)	13.2	15.7	22.5(4.7)	23.3(4.8)	17.4(4.2)	23.9(4.0)	20.2	23.6	24.4(4.9	23.6(4.9)	18.4(4.3)	19.3(5.3)	21.4	21.5
EC-620410	16.5(4.1)	13.2(3.6)	10.3(3.2)	15.4(4.3)	13.4	14.3	18.1(4.3)	22.0(4.7)	17.8(4.2	16.1(4.4)	21.5	19.1	21.1(4.6)	16.3(4.0)	18.5(4.3)	18.0(4.7)	19.8	17.2
EC-620417	13.2(3.6)	13.3(3.6)	13.6(3.7)	13.7(3.5)	13.4	13.5	18.2(4.3)	22.1(4.7)	19.2(4.4)	17.3(3.0)	18.7	19.7	25.8(5.1)	24.0(4.9)	23.9(4.9)	16.2(4.3)	24.9	20.1
EC-620427	21.1(4.5)	20.5(4.5)	27.5(5.2)	39.7(6.6)	24.3	30.1	26.5(5.2)	36.4(6.0)	21.4(5.6)	33.8(6.3)	24.0	35.1	43.3(6.6)	37.6(6.1)	42.5(6.0)	37.2(7.1)	42.9	37.4
EC-620429	20.9(4.5)	15.1(3.9)	22.5(4.7)	20.0(4.2)	21.7	17.6	27.3(5.2)	32.6(5.7)	27.0(5.2)	33.2(6.3)	27.2	32.9	43.0(6.6)	34.1(5.8)	46.4(5.8)	35.0(4.7)	44.7	34.6
EC-631369	15.0(4.5)	13.5(3.7)	14.6(3.9)	16.0(5.7)	14.8	14.8	20.3(4.5)	25.2(5.0)	14.6(5.8)	24.9(5.6)	17.5	25.1	28.5(5.3)	25.3(5.0)	25.4(5.0)	23.5(5.0)	27.0	24.4
EC-631379	15.7(3.9)	33.9(5.8)	26.9(5.2)	21.9(6.6)	21.3	27.9	21.3(4.6)	23.5(4.8)	15.5(4.2)	15.1(3.5	18.4	19.3	25.8(5.1)	27.0(5.2)	21.1(4.6)	21.3(4.8)	23.5	24.2
Pusa Ruby	19.7(4.4)	16.4(4.0)	28.0(5.3)	33.1(6.5)	23.9	24.8	22.8(4.8)	24.6(5.0)	27.0(5.2)	27.6(5.8)	24.9	26.1	38.8(6.2)	37.7(6.1)	44.1(6.6)	38.0(6.7)	41.5	37.9
Arka Abha	22.6(3.7)	26.9(3.6)	26.9(5.2)	21.8(4.8)	24.8	24.4	30.1(5.5)	37.0(6.0)	23.7(4.2)	36.5(6.5)	26.9	36.8	34.9(5.9)	38.0(6.2)	40.7(6.1)	34.6(7.6)	37.8	36.3
Arka Saurabh	17.8(4.2)	16.6(4.1)	14.5(3.8)	23.4(5.2)	16.2	20.0	23.9(4.9)	29.2(5.4)	18.1(4.2)	15.8(3.5)	21.0	22.5	35.7(6.0)	37.1(6.1)	32.2(5.7)	30.6(5.0)	34.0	33.9
Arka Alok	21.8(4.7)	21.0(4.6)	13.0(3.6)	23.5(4.7)	17.4	22.3	23.8(4.9)	35.0(5.8)	19.4(5.5)	22.1(5.0)	21.6	28.6	33.9(5.8)	32.9(5.7)	43.2(6.6)	34.3(5.1)	38.6	33.6
Akshaya	12.5(3.5)	21.5(4.6)	14.0(3.7)	17.0(4.4)	13.3	19.3	26.8(5.2)	31.9(5.6)	23.6(4.9)	19.8(4.6)	25.2	25.9	37.0(6.1)	33.7(5.8)	42.3(6.5)	26.3(5.3)	39.7	30.0
Anagha	12.4(3.5)	15.2(3.9)	18.9(4.3)	17.0(4.7)	15.7	16.1	23.2(4.9)	27.9(5.3)	22.5(4.8)	21.7(5.2)	22.9	24.8	34.0(5.8)	34.9(5.9)	38.9(6.2)	24.1(4.9)	36.5	29.5
CD (0.05)	1.1	1.1	2.0	1.5	7.8	9.6	0.6	1.4	1.0	5.2	10.5	13.8	0.8	1.3	1.5	1.5	13.2	10.8
CV	12.8	12.5	17.1	16.5	11.7	13.6	6.1	12.8	12.8	10.9	16.4	15.3	6.9	10.2	13.2	13.4	18.5	16.7

*on parenthesis transformation values are given

PH- polyhouse; RS- rainshelter

4.1.1.2.3.3 Late stage of flowering

During summer under polyhouse, the minimum stigma exertion was recorded in EC-620410 (21.1%), followed by EC-620401 (23.6%). Inside rainshelter, EC-620410 recorded minimum stigma exertion (16.3%), followed by EC-620406 (23.6%).

In the rainy season under polyhouse, EC-620378 recorded minimum stigma exertion (16.1%), followed by EC-620395 and EC-620406 (18.4%). Inside rainshelter, EC-620417 recorded minimum stigma exertion (16.2%), followed by EC-620389 (17.5%).

In the pooled mean, under polyhouse EC-620395 and EC-620410 (19.8%) and inside rainshelter EC-620410 (17.2%), recorded the least stigma exertion.

4.1.1.2.4 Number of flowers per cluster (No.)

Number of flowers per cluster was recorded in three stages over the entire crop period. There was significant difference among the genotypes for number of flowers per cluster in all the three stages (Table 26).

4.1.1.2.4.1Early stage of flowering

During summer evaluation, under polyhouse, maximum number of flowers per cluster was observed for EC-620376 (8.0), followed by EC-163605 (7.9). Inside the rainshelter maximum number of flowers per cluster was recorded for EC-165395 (9.5), followed by EC-165690 (9.0).

In the rainy season evaluation under polyhouse, maximum number of flowers were observed for EC-620376 (8.0), followed by Arka Abha (7.8). Inside rainshelter, EC-165395 recorded maximum number of flowers per cluster (8.0), followed by EC-528368 (7.7) and EC-160885 (7.6).

In the pooled mean, under polyhouse EC-620376 (8.0) and inside rainshelter EC-165395 (8.6), recorded maximum number of flowers per cluster.

4.1.1.2.4.2 Mid stage of flowering

During summer season under polyhouse, EC-620382 recorded maximum number of flowers per cluster (8.2), followed by EC-620429 and Arka Abha (7.7). Inside rainshelter EC-165395 and EC-620382 recorded maximum number of flowers per cluster (8.5), followed by EC-165690 (8.3).

In the rainy season under polyhouse, EC-620410 recorded the highest value (7.5), followed by EC-163605 and EC-620382 (7.4). Inside rainshelter, maximum number of flowers per cluster was observed for EC-165395 and EC-165690 (8.5), followed by EC-620401 (8.0).

In the pooled mean, under polyhouse EC-620382 (7.8) and inside rainshelter EC-165395 (8.5), recorded maximum number of flowers per cluster.

4.1.1.2.4.3 Late stage of flowering

During summer under polyhouse EC-620382 (6.2) and EC-620410 (6.0) recorded highest number of flowers per cluster, followed by EC-620401 (5.7). Inside rainshelter the highest number of flowers per cluster was for EC-165690 (7.1), followed by Arka Abha (7.0) and EC-165395 (6.9).

In the rainy season under polyhouse, EC-620410 (6.5) was the highest, followed by EC-620406 (6.1). Inside rainshelter, EC-165395 (6.5) recorded the highest value, followed by EC-165690 (6.0).

In the pooled mean, under polyhouse EC-620410 (6.3) and inside rainshelter EC-165690 (6.6), recorded maximum number of flowers per cluster.

Table 26: Mean performance of tomato genotypes for number of flowers per cluster

Genotypes	Number of flowers per cluster (no.)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	4.7	7.0	4.2	7.0	4.5	7.0	6.4	7.0	4.9	7.6	3.5	7.3	4.5	5.5	4.9	4.5	4.7	5.0
EC-151568	5.6	7.4	4.5	6.0	5.1	6.7	6.6	7.1	5.4	6.2	6.0	6.7	4.8	5.6	3.8	4.6	4.3	5.1
EC-157568	5.7	5.6	5.2	5.4	5.5	5.5	5.4	5.4	4.4	5.6	4.9	5.5	5.2	4.2	3.7	3.2	4.5	3.5
EC-160885	6.5	6.9	6.0	7.6	6.3	7.3	7.0	7.0	5.7	7.4	6.4	7.2	4.7	5.0	4.9	5.1	4.8	5.1
EC-163605	7.9	6.2	5.0	7.1	6.5	6.7	4.4	5.3	7.4	7.4	5.9	6.4	5.0	4.6	4.8	3.4	4.9	4.0
EC-164263	7.1	7.8	6.9	6.5	7.0	7.2	7.0	7.0	7.0	6.9	7.0	7.0	5.5	5.0	5.4	4.4	5.5	4.7
EC-164563	6.9	6.4	6.8	7.4	6.9	6.9	7.0	6.4	7.3	7.6	7.2	7.0	3.8	5.5	3.9	3.5	3.9	4.5
EC-164670	5.9	7.0	5.3	6.1	5.6	6.6	7.4	7.4	5.3	6.3	6.4	6.9	3.8	4.1	2.9	4.4	3.4	4.3
EC-165395	5.5	9.5	4.8	8.0	5.2	8.6	4.5	8.5	4.5	8.5	4.5	8.5	3.8	6.9	3.5	6.5	3.7	6.7
EC-165690	4.9	9.0	5.4	7.5	5.2	8.3	5.2	8.3	4.8	8.5	5.0	8.4	3.6	7.1	3.8	6.0	3.7	6.6
EC-165700	5.0	5.1	5.1	5.4	5.1	5.3	5.4	5.4	5.7	5.7	5.6	5.6	4.1	3.4	3.3	2.9	3.7	3.2
EC-249514	6.8	6.2	6.6	6.1	6.7	6.2	6.0	6.9	6.4	6.4	6.2	6.7	4.5	4.9	3.5	4.4	4.0	4.7
EC-521067 B	7.3	6.9	7.2	5.9	7.3	6.4	6.7	6.8	6.6	6.9	6.7	6.9	4.9	5.2	4.4	4.3	4.7	4.8
EC-528368	6.1	7.4	6.7	7.7	6.4	7.6	5.2	7.1	6.9	7.7	6.1	7.4	4.7	6.0	4.5	4.4	4.6	5.2
EC-538153	5.1	7.0	5.8	6.0	5.5	6.5	4.7	6.5	5.9	6.5	5.3	6.5	3.7	4.1	3.7	3.3	3.7	3.7
EC-620376	8.0	6.2	8.0	6.0	8.0	6.1	6.4	7.0	6.7	6.5	6.6	6.8	4.0	5.2	5.1	4.5	4.6	4.9
EC-620378	6.1	7.5	7.0	5.8	6.6	6.7	7.4	7.4	6.9	6.5	7.2	7.0	5.5	5.8	5.0	3.1	5.3	4.5

Table 26: Continued

Genotypes	Number of flowers per cluster (no.)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	6.9	8.6	7.5	7.5	7.2	8.1	8.2	8.5	7.4	7.5	7.8	8.0	6.2	6.5	5.6	5.6	5.9	6.1
EC-620387	5.6	7.0	4.5	5.8	5.1	6.4	4.9	6.4	5.6	6.7	5.3	6.6	3.2	4.7	4.7	3.2	4.0	4.0
EC-620389	7.0	6.0	6.0	5.8	6.5	5.9	4.9	4.9	6.0	6.4	5.5	5.7	3.5	4.0	3.7	3.5	3.6	3.8
EC-620395	6.5	7.5	3.5	5.8	5.0	6.7	6.6	6.6	4.0	6.1	5.3	6.4	5.0	5.0	4.5	4.3	4.8	4.7
EC-620401	7.1	7.5	7.0	7.5	7.1	7.5	6.6	7.5	7.0	8.0	6.8	7.8	5.7	5.2	6.0	5.1	5.9	5.2
EC-620406	7.5	6.5	6.9	7.0	7.2	6.8	7.3	7.7	6.5	7.0	6.9	7.4	5.5	5.9	6.1	5.5	5.8	5.7
EC-620410	7.2	7.0	7.3	7.2	7.3	7.1	7.5	7.5	7.5	7.9	7.5	7.7	6.0	6.3	6.5	5.2	6.3	5.8
EC-620417	6.4	5.4	4.5	6.3	5.5	5.9	6.0	4.9	5.3	6.4	5.7	5.7	3.7	3.6	3.2	3.1	3.5	3.4
EC-620427	6.9	7.0	6.7	6.1	6.8	6.6	7.2	7.2	6.7	6.7	7.0	7.0	4.7	6.1	5.4	5.0	5.1	5.6
EC-620429	7.0	7.4	6.5	6.0	6.8	6.7	7.7	7.3	7.0	7.7	7.4	7.5	5.2	6.2	5.0	5.3	5.1	5.8
EC-631369	5.0	5.9	5.3	5.9	5.2	5.9	3.9	5.5	6.0	5.9	5.0	5.7	3.5	4.5	3.4	4.2	3.5	4.4
EC-631379	3.6	5.2	5.0	5.9	4.3	5.6	5.6	5.5	5.0	6.1	5.3	5.8	3.5	5.0	3.3	2.3	3.4	3.7
Pusa Ruby	6.7	6.0	6.5	5.8	6.6	5.9	4.3	4.5	5.0	5.2	4.7	4.9	4.0	4.0	2.7	3.0	3.4	3.5
Arka Abha	7.0	7.5	7.8	7.5	7.4	7.5	7.7	7.4	6.5	7.6	7.1	7.5	5.6	7.0	6.0	5.1	5.8	6.1
Arka Saurabh	5.4	5.0	4.7	6.3	5.1	5.7	4.6	5.0	4.5	4.5	4.6	4.8	3.2	4.0	3.2	3.4	3.2	3.7
Arka Alok	4.9	5.2	4.8	6.2	4.9	5.7	4.3	5.6	4.5	6.6	4.4	6.1	3.0	4.2	2.0	3.0	2.5	3.6
Akshay	7.5	6.4	7.0	7.0	7.3	6.7	7.4	6.7	6.9	6.3	7.2	6.5	5.2	4.2	5.0	5.2	5.1	4.7
Anagha	5.8	7.4	4.7	6.1	5.3	6.8	6.7	6.4	5.7	7.0	6.2	6.7	3.7	4.2	5.0	4.0	4.4	4.1
CD (0.05)	1.6	1.1	1.2	1.5	1.3	1.4	0.8	1.6	1.6	1.2	1.1	1.1	1.5	1.7	1.8	0.6	1.0	1.4
CV	12.2	8.4	9.3	11.6	10.8	12.1	6.1	11.7	12.4	8.7	10.3	8.2	17.4	16.6	18.9	7.3	11.1	15.0

4.1.1.2.5 Pollen viability (%)

Pollen viability was recorded in three stages over the entire crop period. Significant difference was observed among the genotypes for pollen viability in all the three stages in both the seasons and for both the growing conditions (Table 27).

4.1.1.2.5.1 Early stage of flowering

During summer evaluation under polyhouse, the highest pollen viability was recorded for EC-538153 (56.2%), followed by EC-620387 and EC-620410 (56.1%). Inside rainshelter, the highest pollen viability was observed for EC-165395 (66.7%), followed by EC-620387(65.6%).

In the rainy season under polyhouse, the genotype EC-620401 recorded highest pollen viability (65.9%), followed by EC-620410 (63.0%). Inside rainshelter, the pollen viability was recorded highest for EC-538153 (64.1%), followed by EC-165700 (63.8%).

In the pooled mean, under polyhouse EC-620401 (60.6%) and inside rainshelter and EC-620387 (64.5%), recorded maximum pollen viability.

4.1.1.2.5.2 Mid stage of flowering

During summer under polyhouse, the highest pollen viability was recorded for EC-538153 (56.7%), followed by EC-620389 (55.6%). Inside rainshelter, the pollen viability was recorded highest for EC-620389 (67.1%), followed by EC-631379 (66.6%).

In the rainy season under polyhouse, the highest pollen viability was recorded for EC-165700 (66.0%), followed by EC-620406 (64.0%). Inside rainshelter, highest pollen viability was recorded for EC-165690 (63.9%), followed by EC-620376 (62.7%).

In the pooled mean, under polyhouse EC-620389 (59.5%) and inside rainshelter EC- 165690 (64.0%), recorded the maximum pollen viability.

4.1.1.2.5.3 Late stage of flowering

During summer under polyhouse, the pollen viability was highest for EC-164263 (54.0%), followed by EC-620389 (52.6%). Inside rainshelter, the pollen viability was highest for EC-620417 (62.9%), followed by EC-620406 (61.0%).

In the rainy season under polyhouse, the highest pollen viability was recorded for EC-538153 (58.4%), followed by EC-620417 (56.2%). Inside rainshelter, the pollen viability was maximum for EC-164263 (58.5%), followed by EC-165690 (57.2%).

In the pooled mean, under polyhouse and inside rainshelter EC-164263 recorded maximum pollen viability (55.9% and 58.2%, respectively).

1.1.2.6 Length of the style (cm)

Length of the style was recorded in three stages over the entire crop period. Significant difference was observed among the genotypes for length of the style in both the seasons and for both the structures (Table 28).

4.1.1.2.6.1 Early stage of flowering

In the summer evaluation under polyhouse, the shortest style was observed for EC-145057 (0.5 cm), followed by EC-157568 and EC-620376 (0.6 cm). Inside rainshelter, the shortest style was observed for EC-620376 (0.51 cm), followed by Pusa Ruby (0.54 cm).

In the rainy season under polyhouse, the shortest style was observed for EC-145057 (0.53 cm), followed by EC-620376 (0.67 cm). Inside rainshelter, the style length was minimum in EC-145057 (0.44 cm), followed by EC-157568 (0.56 cm).

In the pooled mean, under polyhouse EC-145057 (0.52 cm) and inside rainshelter EC-157568 (0.56 cm), recorded the minimum style length.

Table 27: Mean performance of tomato genotypes for pollen viability

Genotypes	Pollen viability (%)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	41.9	45.5	52.6	55.7	47.3	50.6	41.6	42.9	54.6	54.8	48.1	48.9	34.6	41.0	34.5	47.20	34.6	44.1
EC-151568	44.6	47.8	55.7	53.3	50.2	50.6	43.9	45.4	56.6	54.9	50.3	50.2	34.9	36.6	48.4	43.4	41.7	40.0
EC-157568	48.6	50.4	56.6	50.1	52.6	50.3	41.5	47.1	52.5	56.4	47.0	51.8	37.0	41.1	44.4	38.0	40.7	39.6
EC-160885	51.3	54.4	51.9	53.7	51.6	54.1	51.0	54.9	56.2	60.1	53.6	57.5	44.3	53.6	47.8	38.3	46.1	46.0
EC-163605	48.3	55.0	46.1	50.5	47.2	52.8	41.6	55.5	52.5	50.0	47.1	52.8	37.2	48.7	40.9	49.9	39.1	49.3
EC-164263	54.8	59.1	62.4	61.1	58.6	60.1	54.5	60.3	60.9	62.1	57.7	61.2	54.0	57.8	57.7	58.5	55.9	58.2
EC-164563	46.6	54.4	54.1	56.1	53.5	55.3	41.0	51.1	54.6	54.6	47.8	52.9	38.7	50.0	42.0	48.1	40.4	49.1
EC-164670	44.9	51.7	53.8	56.9	49.4	54.3	43.0	52.0	63.0	52.4	53.0	52.2	36.9	47.6	47.5	50.1	42.2	48.9
EC-165395	46.6	66.7	53.5	61.2	50.1	64.0	41.5	64.1	54.7	59.6	48.1	61.9	37.5	57.9	46.7	54.6	42.1	56.3
EC-165690	52.2	62.2	54.9	63.7	53.4	63.0	44.7	64.1	52.6	63.9	48.7	64.0	37.9	57.8	48.1	57.2	43.0	57.5
EC-165700	53.3	60.6	58.5	63.5	55.9	62.2	50.1	62.6	66.0	55.3	58.1	58.5	42.3	58.3	46.9	49.3	44.6	53.9
EC-249514	44.4	49.3	47.5	55.9	46.0	52.6	39.7	45.5	60.7	49.5	50.2	47.5	34.6	45.4	41.2	47.5	37.9	46.5
EC-521067 B	43.6	48.6	50.8	55.2	47.2	51.9	39.1	51.6	56.0	42.7	47.6	47.2	33.7	47.3	45.0	46.3	39.4	46.8
EC-528368	46.0	62.0	55.2	60.5	50.6	61.3	41.1	63.2	56.8	54.5	49.0	58.9	39.8	59.6	45.2	46.3	42.5	53.0
EC-538153	56.2	61.8	61.2	64.1	58.7	63.0	56.7	58.6	58.0	62.4	57.4	60.5	45.2	56.6	58.4	55.9	51.8	56.3
EC-620376	53.3	63.2	53.9	63.0	53.6	63.1	47.8	62.8	60.9	62.7	54.4	62.8	41.3	60.6	47.9	50.0	44.6	55.3
EC-620378	49.8	55.1	49.4	48.8	49.6	52.0	46.5	56.0	56.4	53.4	51.5	54.7	40.0	50.5	44.5	43.9	42.3	47.2

Table 27: Continued

Genotypes	Pollen viability (%)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	49.1	54.1	47.2	53.7	48.2	53.9	43.4	55.9	48.2	51.4	45.8	53.7	38.3	48.0	47.8	48.6	43.1	48.3
EC-620387	56.1	65.6	61.9	63.4	59.0	64.5	53.1	58.5	56.7	57.8	54.9	58.2	50.6	57.4	53.7	55.7	52.2	56.6
EC620389	55.5	59.8	62.3	60.0	58.9	59.9	55.6	67.1	63.3	53.1	59.5	60.1	52.6	60.5	51.0	52.8	51.8	56.7
EC-620395	42.0	48.4	46.3	59.2	44.2	53.8	48.6	55.5	56.9	53.4	52.8	54.5	46.2	51.6	49.5	48.7	47.6	50.2
EC-620401	54.4	63.2	65.9	61.0	60.6	62.1	51.0	63.5	62.8	58.6	56.9	61.1	48.0	59.5	52.5	54.2	49.4	55.1
EC-620406	55.1	64.3	62.7	62.7	58.9	63.5	50.0	62.0	64.0	57.1	57.0	59.6	49.0	61.0	53.4	51.9	49.7	56.0
EC-620410	56.1	64.4	63.0	60.3	59.6	62.4	51.9	63.6	61.5	61.2	56.7	62.4	48.4	59.3	54.2	53.5	49.8	56.4
EC-620417	51.9	60.1	60.9	58.8	56.4	59.5	48.9	61.6	61.0	57.0	55.0	59.3	47.2	62.9	56.2	52.1	51.7	57.5
EC-620427	44.2	55.1	47.4	52.5	45.8	53.8	41.5	51.5	55.2	49.0	48.4	50.3	35.4	51.3	38.2	42.8	36.8	47.1
EC-620429	48.3	54.6	46.7	57.5	47.5	56.1	46.9	51.4	46.0	51.4	46.5	51.4	43.9	50.8	40.3	50.9	42.1	50.9
EC-631369	52.2	62.0	59.9	61.1	56.1	61.6	49.5	61.1	56.7	57.6	53.1	59.4	51.1	59.4	54.4	54.9	52.8	57.2
EC-631379	51.5	60.8	56.2	60.3	53.9	60.6	53.6	66.6	61.3	57.6	57.5	62.1	46.8	58.3	52.0	52.8	49.4	55.6
Pusa Ruby	44.0	51.7	54.4	55.8	49.2	53.8	39.7	45.5	50.5	42.1	45.1	43.8	33.4	41.1	45.6	42.2	39.5	41.7
Arka Abha	48.7	53.8	45.7	52.9	47.2	53.4	43.1	56.1	53.4	46.0	48.3	51.1	37.1	55.9	37.7	40.7	37.4	48.3
Arka Saurabh	47.7	54.6	54.1	55.1	50.9	54.9	43.0	51.5	54.5	45.6	48.8	48.6	39.6	48.4	44.3	50.9	42.0	49.7
Arka Alok	51.1	54.9	46.1	49.4	48.6	52.2	46.5	54.8	51.5	42.6	49.0	48.7	41.0	45.2	45.8	46.9	43.4	46.1
Akshaya	48.4	55.9	51.4	55.6	49.9	55.8	44.4	53.6	57.6	51.4	51.0	52.5	41.4	48.0	49.3	50.1	45.4	49.1
Anagha	47.1	47.0	50.2	56.7	48.7	51.9	44.7	50.9	57.2	52.9	51.0	51.9	38.7	44.9	44.6	47.5	41.7	46.2
CD (0.05)	3.3	2.8	3.4	2.5	2.5	2.0	3.1	2.6	2.5	3.2	2.0	2.5	2.2	1.8	2.5	3.0	2.5	2.8
CV	3.3	4.2	5.2	6.3	6.8	6.1	3.4	3.8	6.9	4.8	5.6	14.7	4.1	3.9	7.9	7.1	6.7	9.7

4.1.1.2.6.2 Mid stage of flowering

During summer evaluation under polyhouse, the shortest style was recorded for EC-145057 (0.57 cm), followed by EC-620376 (0.62 cm). Inside the rainshelter, the minimum style length was observed for Pusa Ruby (0.54 cm), followed by EC-620427 (0.55 cm).

In the rainy season under polyhouse, the minimum style length was recorded for EC-145057 (0.53 cm), followed by EC-620376 (0.65cm). Inside the rainshelter, the shortest style was observed for EC-145057 (0.48 cm), followed by EC-157568 (0.61 cm).

In the pooled mean, under polyhouse EC-145057 (0.55 cm) and inside rainshelter EC-145057 and EC-157568 (0.6 cm), recorded the shortest style.

4.1.1.2.6.3 Late stage of flowering

During summer evaluation under polyhouse, EC-145057 recorded shortest style (0.6 cm), followed by EC-620376 (0.64 cm). Inside the rainshelter, the minimum style length was recorded for EC-620427 (0.56 cm), followed by EC-620376 and Pusa Ruby (0.59 cm).

In the rainy season under polyhouse, the shortest style was recorded for EC-145057 (0.52 cm), followed by EC-620376 (0.67 cm). Inside rainshelter, shortest style length recorded for EC-145057 (0.48 cm), followed by EC-620378 (0.63 cm).

In the pooled mean, under both the structures, EC-145057 recorded the shortest style (0.56 cm and 0.6 cm, respectively).

Table 28: Mean performance of tomato genotypes for length of the style

Genotypes	Length of the style (cm)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	0.5	0.7	0.53	0.44	0.52	0.57	0.57	0.73	0.53	0.48	0.55	0.6	0.6	0.72	0.52	0.48	0.56	0.6
EC-151568	0.85	0.87	0.87	0.71	0.86	0.79	0.84	0.88	0.79	0.72	0.82	0.8	0.79	0.86	0.79	0.65	0.79	0.75
EC-157568	0.60	0.56	0.69	0.56	0.65	0.56	0.7	0.6	0.72	0.61	0.71	0.6	0.7	0.65	0.73	0.64	0.71	0.65
EC-160885	0.85	0.86	0.88	0.86	0.87	0.86	0.88	0.88	0.85	0.88	0.87	0.88	0.85	0.89	0.92	0.85	0.89	0.87
EC-163605	0.7	0.84	0.78	0.84	0.74	0.84	0.84	0.85	0.8	0.85	0.82	0.85	0.82	0.85	0.79	0.84	0.81	0.85
EC-164263	0.77	0.84	0.74	0.87	0.76	0.86	0.78	0.85	0.8	0.84	0.79	0.84	0.81	0.86	0.82	0.85	0.82	0.86
EC-164563	0.90	0.87	0.92	0.92	0.91	0.9	0.90	0.90	0.92	0.91	0.91	0.91	0.93	0.94	0.91	0.88	0.92	0.91
EC-164670	0.85	0.86	0.86	0.89	0.86	0.88	0.88	0.88	0.89	0.87	0.89	0.88	0.88	0.91	0.9	0.89	0.89	0.9
EC-165395	0.85	0.84	0.88	0.8	0.87	0.82	0.88	0.85	0.88	0.85	0.88	0.85	0.87	0.89	0.89	0.89	0.88	0.89
EC-165690	0.85	0.78	0.89	0.77	0.87	0.78	0.85	0.83	0.88	0.76	0.87	0.79	0.89	0.84	0.91	0.75	0.9	0.8
EC-165700	0.74	0.55	0.7	0.74	0.72	0.65	0.78	0.61	0.70	0.75	0.74	0.68	0.73	0.66	0.7	0.78	0.71	0.72
EC-249514	0.86	0.89	0.83	0.82	0.85	0.86	0.84	0.90	0.87	0.82	0.86	0.86	0.86	0.94	0.87	0.82	0.86	0.88
EC-521067 B	0.7	0.87	0.7	0.65	0.70	0.76	0.71	0.90	0.66	0.67	0.69	0.78	0.72	0.93	0.72	0.68	0.72	0.81
EC-528368	0.61	0.61	0.7	0.67	0.66	0.64	0.72	0.64	0.73	0.66	0.73	0.65	0.71	0.67	0.71	0.68	0.71	0.67
EC-538153	0.8	0.64	0.91	0.88	0.86	0.76	0.9	0.61	0.89	0.89	0.9	0.75	0.91	0.66	0.91	0.88	0.91	0.77
EC-620376	0.60	0.51	0.67	0.68	0.64	0.6	0.62	0.56	0.65	0.7	0.64	0.63	0.64	0.59	0.67	0.67	0.65	0.63
EC-620378	0.73	0.83	0.74	0.64	0.74	0.74	0.76	0.86	0.7	0.64	0.73	0.75	0.75	0.88	0.76	0.63	0.75	0.76

Table 28: Continued

Genotypes	Length of the style (cm)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	0.8	0.89	0.89	0.88	0.85	0.89	0.9	0.89	0.93	0.86	0.92	0.87	0.89	0.9	0.89	0.88	0.89	0.89
EC-620387	0.84	0.90	0.86	0.85	0.87	0.88	0.87	0.93	0.89	0.84	0.88	0.88	0.90	0.94	0.87	0.85	0.88	0.9
EC-620389	0.75	0.56	0.73	0.74	0.74	0.65	0.72	0.6	0.72	0.73	0.72	0.66	0.72	0.64	0.72	0.91	0.72	0.77
EC-620395	0.84	0.65	0.85	0.84	0.85	0.75	0.87	0.64	0.87	0.84	0.76	0.74	0.86	0.68	0.86	0.86	0.86	0.77
EC-620401	0.75	0.67	0.74	0.75	0.75	0.71	0.8	0.71	0.76	0.79	0.78	0.74	0.8	0.69	0.74	0.77	0.77	0.73
EC-620406	0.79	0.73	0.78	0.7	0.79	0.72	0.77	0.76	0.75	0.72	0.76	0.74	0.76	0.86	0.79	0.72	0.78	0.79
EC-620410	0.86	0.74	0.84	0.82	0.85	0.78	0.84	0.75	0.86	0.81	0.85	0.78	0.86	0.79	0.84	0.84	0.85	0.82
EC-620417	0.78	0.83	0.86	0.77	0.82	0.80	0.84	0.87	0.85	0.76	0.85	0.81	0.85	0.88	0.88	0.76	0.86	0.82
EC-620427	0.77	0.59	0.75	0.74	0.76	0.67	0.79	0.55	0.79	0.74	0.79	0.65	0.75	0.56	0.76	0.74	0.75	0.65
EC-620429	0.83	0.69	0.83	0.84	0.83	0.77	0.86	0.74	0.84	0.84	0.85	0.79	0.86	0.77	0.81	0.88	0.83	0.82
EC-631369	0.81	0.84	0.85	0.77	0.83	0.81	0.82	0.85	0.88	0.79	0.85	0.82	0.85	0.88	0.88	0.79	0.86	0.83
EC-631379	0.86	0.73	0.84	0.76	0.85	0.75	0.88	0.76	0.87	0.8	0.88	0.78	0.87	0.79	0.86	0.77	0.87	0.78
Pusa Ruby	0.7	0.54	0.77	0.87	0.74	0.71	0.71	0.54	0.8	0.87	0.76	0.71	0.75	0.59	0.82	0.77	0.78	0.68
Arka Abha	0.75	0.78	0.75	0.67	0.75	0.73	0.76	0.78	0.78	0.69	0.77	0.74	0.77	0.82	0.76	0.71	0.77	0.76
Arka Saurabh	0.78	0.82	0.78	0.81	0.78	0.82	0.78	0.84	0.79	0.81	0.78	0.82	0.81	0.89	0.78	0.79	0.79	0.84
Arka Alok	0.76	0.89	0.76	0.74	0.76	0.82	0.76	0.88	0.75	0.76	0.76	0.82	0.79	0.93	0.76	0.77	0.77	0.85
Akshay	0.7	0.67	0.71	0.67	0.71	0.67	0.72	0.70	0.72	0.68	0.72	0.69	0.72	0.73	0.72	0.68	0.72	0.71
Anagha	0.79	0.75	0.82	0.76	0.81	0.76	0.82	0.77	0.85	0.77	0.84	0.77	0.79	0.77	0.77	0.78	0.78	0.77
CD (0.05)	0.85	0. 69	0.63	0.80	0.06	0.19	0.94	0.57	0.71	0.66	0.08	0.26	0.87	0.55	0.76	0.65	0.46	0.17
CV	5.4	4.5	3.9	5.2	3.7	12.3	5.8	3.7	4.4	4.3	4.7	12.1	5.4	3.4	4.7	4.1	2.8	12.0

4.1.1.2.7Anther length (cm)

Anther length was recorded in three stages over the entire crop period. There was significant difference among the genotypes for anther length during both the seasons and for both the structures (Table 29).

4.1.1.2.7.1 Early stage of flowering

In the summer evaluation under polyhouse, the highest anther length was observed for EC-164563 (0.93 cm), followed by EC-165395 (0.9 cm). Inside rainshelter, the anther length was observed to be maximum for EC-249514 and Arka Alok (0.91 cm).

In the rainy season under polyhouse, the longest anther was observed for EC-164563 (0.93 cm), followed by EC-538153 (0.92 cm). Inside the rainshelter, the longest anther was observed for EC-164563 (0.92 cm), followed by EC-164670 (0.89 cm).

In the pooled mean, under polyhouse and inside rainshelter, EC-164563 recorded longest anther (0.93 cm and 0.91 cm, respectively).

4.1.1.2.7.2 Mid stage of flowering

During summer season under polyhosue, the longest anther was observed for EC-164563 (0.93 cm), followed by EC-620382(0.92 cm). The shortest anther was observed for EC-145057 (0.59 cm). Inside the rainshelter, the longest anther was observed for EC-164563 (0.94 cm), followed by EC-521067 B (0.92 cm).

In the rainy season under polyhouse, the longest anther was observed for EC-620382 (0.95 cm), followed by EC-164563 (0.94 cm). Inside rainshelter, the anther length was maximum for EC-164563 (0.93 cm), followed by EC-538153 (0.89 cm).

In the pooled mean, under polyhouse and inside rainshelter, EC-164563 recorded the longest anther (0.94cm).

4.1.1.2.7.3 Late stage of flowering

During summer evaluation under polyhouse, the longest anther was observed for EC-164563 (0.95 cm), followed by EC-164670, EC-165690 and EC-620382 (0.91 cm). Inside the rainshelter, the longest anther was observed for EC-164563 (0.95 cm), followed by EC-249514 and EC-620387 (0.94 cm).

In the rainy season under polyhouse, the longest anther was observed for EC-160885 (0.94 cm). Inside rainshelter, the anther length was maximum for EC-165395 (0.9 cm), followed by EC-164670 (0.89 cm).

In the pooled mean, under polyhouse and inside rainshelter, EC-164563 recorded the longest anther (0.93 cm and 0.92 cm, respectively).

4.1.1.2.8 Days to first fruit set (No. of days)

There was significant difference among the genotypes for days to fruit set in both the seasons under polyhouse and rainshelter (Table 30). During summer under polyhouse, EC-538153 took minimum days (38.2 days) for fruit set, followed by EC-620378 (39.9 days). Inside rainshelter, EC-620395 (33.2 days) set fruits early, followed by EC-165690 (34.1 days).

During rainy season under polyhouse, the earliest to set fruit was EC-151568 (44.2 days), followed by EC-620376 (44.5 days). EC-160885 took maximum days for first fruit set (48.4 days). Inside the rainshelter, the earliest to set fruit was Akshaya (46.0 days), followed by Arka Alok (47.0 days).

In the pooled mean, under polyhouse EC-620378 and inside rainshelter Akshaya, were the earliest to set fruit (42.5 days and 40.2 days, respectively).

Table 29: Mean performance of tomato genotypes for anther length

Genotypes	Anther length (cm)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	0.56	0.72	0.55	0.48	0.56	0.60	0.59	0.75	0.55	0.49	0.57	0.62	0.63	0.67	0.50	0.48	0.57	0.58
EC-151568	0.84	0.88	0.88	0.7	0.86	0.79	0.85	0.9	0.78	0.72	0.82	0.81	0.8	0.87	0.78	0.65	0.79	0.76
EC-157568	0.6	0.58	0.7	0.57	0.65	0.58	0.73	0.65	0.73	0.62	0.73	0.64	0.74	0.67	0.75	0.67	0.75	0.67
EC-160885	0.88	0.84	0.88	0.83	0.88	0.84	0.88	0.9	0.87	0.88	0.88	0.89	0.88	0.88	0.94	0.84	0.91	0.86
EC-163605	0.79	0.83	0.8	0.84	0.8	0.85	0.86	0.86	0.82	0.85	0.84	0.86	0.84	0.86	0.80	0.84	0.82	0.85
EC-164263	0.81	0.85	0.77	0.88	0.79	0.87	0.81	0.86	0.82	0.84	0.82	0.85	0.84	0.88	0.84	0.86	0.84	0.87
EC-164563	0.93	0.89	0.93	0.92	0.93	0.91	0.93	0.94	0.94	0.93	0.94	0.94	0.95	0.95	0.91	0.88	0.93	0.92
EC-164670	0.88	0.88	0.88	0.89	0.88	0.89	0.9	0.89	0.89	0.88	0.9	0.89	0.91	0.92	0.91	0.89	0.91	0.91
EC-165395	0.9	0.87	0.9	0.83	0.90	0.85	0.91	0.88	0.92	0.87	0.92	0.88	0.9	0.91	0.91	0.90	0.91	0.91
EC-165690	0.89	0.81	0.9	0.78	0.9	0.8	0.9	0.86	0.89	0.77	0.9	0.82	0.91	0.86	0.92	0.76	0.92	0.81
EC-165700	0.77	0.55	0.72	0.75	0.75	0.65	0.78	0.61	0.73	0.75	0.76	0.68	0.74	0.65	0.73	0.78	0.74	0.72
EC-249514	0.88	0.91	0.85	0.83	0.87	0.87	0.87	0.91	0.86	0.83	0.87	0.87	0.89	0.94	0.89	0.83	0.89	0.89
EC-521067 B	0.73	0.88	0.7	0.65	0.72	0.77	0.74	0.92	0.69	0.67	0.72	0.8	0.75	0.93	0.73	0.69	0.74	0.81
EC-528368	0.72	0.63	0.72	0.69	0.72	0.66	0.74	0.65	0.75	0.65	0.75	0.65	0.74	0.67	0.72	0.69	0.73	0.68
EC-538153	0.89	0.66	0.92	0.88	0.91	0.77	0.89	0.64	0.91	0.89	0.90	0.77	0.87	0.68	0.92	0.86	0.9	0.76
EC-620376	0.69	0.55	0.7	0.69	0.7	0.63	0.7	0.58	0.67	0.7	0.69	0.64	0.69	0.63	0.67	0.65	0.68	0.64
EC-620378	0.75	0.87	0.75	0.65	0.75	0.76	0.77	0.88	0.72	0.65	0.75	0.77	0.77	0.87	0.75	0.64	0.76	0.76

Table 29: Continued

Genotypes	Anther length (cm)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	0.89	0.9	0.91	0.88	0.90	0.89	0.92	0.9	0.95	0.88	0.94	0.89	0.91	0.92	0.92	0.88	0.92	0.90
EC-620387	0.85	0.89	0.87	0.84	0.86	0.7	0.87	0.91	0.87	0.84	0.87	0.88	0.89	0.94	0.87	0.84	0.88	0.89
EC-620389	0.77	0.55	0.72	0.73	0.75	0.64	0.75	0.6	0.70	0.74	0.73	0.67	0.75	0.65	0.73	0.77	0.74	0.71
EC-620395	0.86	0.64	0.85	0.85	0.86	0.75	0.88	0.64	0.85	0.84	0.87	0.74	0.88	0.67	0.87	0.85	0.88	0.76
EC-620401	0.79	0.71	0.76	0.75	0.78	0.73	0.81	0.73	0.77	0.76	0.79	0.75	0.82	0.71	0.77	0.77	0.8	0.74
EC-620406	0.82	0.75	0.8	0.73	0.81	0.74	0.8	0.79	0.76	0.73	0.78	0.76	0.81	0.86	0.81	0.73	0.81	0.8
EC-620410	0.89	0.76	0.87	0.84	0.88	0.80	0.86	0.78	0.89	0.84	0.88	0.81	0.87	0.81	0.85	0.85	0.86	0.83
EC-620417	0.79	0.81	0.84	0.8	0.82	0.81	0.83	0.87	0.85	0.78	0.84	0.83	0.86	0.87	0.86	0.76	0.86	0.82
EC-620427	0.79	0.63	0.76	0.75	0.78	0.69	0.82	0.61	0.82	0.73	0.82	0.67	0.78	0.6	0.78	0.74	0.78	0.67
EC-620429	0.87	0.72	0.84	0.84	0.86	0.78	0.89	0.77	0.84	0.84	0.87	0.81	0.89	0.78	0.83	0.88	0.86	0.83
EC-631369	0.82	0.85	0.86	0.77	0.84	0.81	0.81	0.87	0.86	0.8	0.84	0.84	0.86	0.88	0.88	0.8	0.87	0.84
EC-631379	0.87	0.76	0.85	0.74	0.86	0.75	0.89	0.77	0.89	0.81	0.89	0.79	0.9	0.79	0.89	0.75	0.9	0.77
Pusa Ruby	0.75	0.57	0.75	0.84	0.75	0.71	0.74	0.58	0.82	0.86	0.78	0.72	0.77	0.59	0.83	0.87	0.80	0.73
Arka Abha	0.77	0.82	0.78	0.69	0.78	0.76	0.81	0.83	0.81	0.71	0.81	0.77	0.8	0.87	0.79	0.71	0.8	0.79
Arka Saurabh	0.8	0.86	0.8	0.82	0.80	0.84	0.8	0.87	0.81	0.81	0.81	0.84	0.82	0.92	0.81	0.81	0.82	0.87
Arka Alok	0.77	0.91	0.77	0.76	0.77	0.84	0.77	0.91	0.76	0.78	0.77	0.85	0.8	0.93	0.79	0.78	0.8	0.86
Akshaya	0.71	0.7	0.73	0.69	0.72	0.7	0.73	0.73	0.74	0.69	0.74	0.71	0.74	0.74	0.73	0.71	0.74	0.73
Anagha	0.81	0.77	0.84	0.77	0.83	0.77	0.85	0.79	0.82	0.76	0.84	0.78	0.82	0.77	0.82	0.79	0.82	0.78
CD (0.05)	0.60	0.53	0.60	0.77	0.04	0.18	0.80	0.53	0.66	0.60	0.05	0.18	0.75	0.44	0.73	0.65	0.05	0.19
CV	3.7	3.4	3.7	5.0	2.7	11.7	4.8	3.3	4.0	3.8	2.8	11.4	4.5	2.7	4.4	4.2	2.9	11.2

Table 30: Mean performance of tomato genotypes for days to first fruit set

Genotypes	Days to first fruit set (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	47.2	38.0	45.7	49.8	46.5	43.9
EC-151568	44.6	37.8	44.2	55.2	44.4	46.5
EC-157568	48.0	41.4	47.5	52.5	47.8	47.0
EC-160885	48.2	39.6	48.4	51.0	48.3	45.3
EC-163605	46.5	40.1	48.5	50.0	47.5	45.1
EC-164263	47.1	35.2	46.9	49.5	47.0	42.4
EC-164563	46.8	34.4	46	48.5	46.4	41.5
EC-164670	44.8	38.1	49.5	50.5	47.2	44.3
EC-165395	46.4	39.2	49.2	51.5	47.8	45.4
EC-165690	43.0	34.1	50	53.5	46.5	43.8
EC-165700	43.4	34.7	47.5	48.0	45.5	41.4
EC-249514	47.6	36.2	49.5	55.0	48.6	45.6
EC-521067 B	45.3	42.1	49.5	53.5	47.4	47.8
EC-528368	47.9	45.1	48.5	55.3	48.2	50.2
EC-538153	38.2	37.2	48.5	55.0	43.4	46.1
EC-620376	46.2	38.7	44.5	49.5	45.4	44.1
EC-620378	39.9	35.1	45	54.0	42.5	44.6
EC-620382	43.8	35.1	48	48.5	45.9	41.8
EC-620387	50.5	43.5	49.5	53.5	50.0	48.5
EC-620389	46.4	43.3	46.4	49.5	46.4	46.4
EC-620395	49.0	33.2	49.5	51.4	49.3	42.3
EC-620401	45.5	34.6	45	48.5	45.3	41.6
EC-620406	46.5	38.2	47.5	50.0	47.0	44.1
EC-620410	46.7	39.5	45	48.5	45.9	44.0
EC-620417	50.1	45.8	48	50.2	49.1	48.0
EC-620427	45.9	34.2	46.5	49.5	46.2	41.9
EC-620429	45.9	34.8	46.7	48.5	46.3	41.7
EC-631369	47.4	35.6	46.5	49.5	47.0	42.6
EC-631379	47.0	41.4	48.5	50.0	47.8	45.7
Pusa Ruby	46.2	35.4	47.5	48.5	46.9	42.0
Arka Abha	43.2	34.4	48	50.0	45.6	42.2
Arka Saurabh	46.6	38.6	46.5	48.0	46.6	43.3
Arka Alok	47.9	39.3	45	47.0	46.5	43.2
Akshay	47.1	34.3	45	46.0	46.1	40.2
Anagha	46.7	35.3	45	49.5	45.9	42.4
CD (0.05)	2.5	3.2	3.3	2.4	2.0	2.5
CV	4.3	7.2	3.7	5.2	4.1	8.6

4.1.1.3 Fruit characters and yield

4.1.1.3.1 Days from anthesis to fruit maturity (no. of days)

During summer under polyhouse, the minimum days were taken by EC-151568 (38.4 days), followed by EC-160885 (41.1 days) (Table 31). Inside rainshelter, the minimum days were taken by EC-164670 (36.1 days), followed by EC-620417 (39.3 days), and EC-145057 (39.6 days).

In the rainy season under polyhouse, EC-620395 took minimum days from anthesis to fruit maturity (39.1 days), followed by EC-620389 (39.7 days). Inside rainshelter, EC-528368 recorded minimum days from anthesis to fruit maturity (35.2 days), followed by EC-164670 (37.1 days).

In the pooled mean, under polyhouse EC-151568 (40.2 days) and inside rainshelter EC-164670 (36.6 days), recorded minimum days from anthesis to fruit maturity.

4.1.1.3.2 Days to first fruit harvest (No. of days)

There was significant difference among the genotypes for days to first fruit harvest for both the seasons and under both the structures (Table 32). In the summer season under polyhouse, the earliest to harvest was EC-164670 (82.4 days), followed by Arka Abha (83.3 days). Inside rainshelter, EC-620429 recorded minimum days to first harvest (74.7 days), followed by EC-620427 (75.0 days).

In the rainy season under polyhouse, the minimum days were taken by EC-620382 (83.9 days), followed by EC-620378 and EC-165690 (85.4 days). Inside rainshelter, the earliest to harvest was Arka Abha (85.4 days), followed by EC-620376 (85.6 days).

In the pooled mean, under polyhouse EC-164670 and Arka Abha (85.0 days) and inside rainshelter EC-620427 (81.6 days), recorded minimum days to first fruit harvest.

Table 31: Mean performance of tomato genotypes for days from anthesis to fruit maturity

Genotypes	Days from anthesis to fruit maturity (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	43.8	39.6	46.5	39.2	45.2	39.4
EC-151568	38.4	45.3	41.9	44.2	40.2	44.8
EC-157568	47.5	43.4	41.6	40.7	44.6	42.1
EC-160885	41.1	44.5	39.9	43.3	40.5	43.9
EC-163605	47.4	47.0	44.7	44.9	46.1	46.0
EC-164263	48.9	41.4	43.2	42.5	46.1	42.0
EC-164563	44.7	44.2	47.1	39.5	45.9	41.9
EC-164670	45.6	36.1	42.5	37.1	44.1	36.6
EC-165395	42.3	41.5	43.7	41.0	43.0	41.3
EC-165690	44.1	43.1	40.4	38.0	42.3	40.6
EC-165700	44.0	41.1	44.3	42.2	44.2	41.7
EC-249514	46.9	44.4	46.1	44.6	46.5	44.5
EC-521067 B	47.9	43.1	43.8	38.5	45.9	40.8
EC-528368	46.8	41.6	42.2	35.2	44.5	38.4
EC-538153	48.5	45.6	47.1	45.5	47.8	45.6
EC-620376	45.9	41.1	46.8	39.2	46.4	40.2
EC-620378	42.1	42.7	41.4	39.7	41.8	41.2
EC-620382	46.1	43.0	42.4	45.6	44.3	44.3
EC-620387	48.8	43.6	48.2	46.2	48.5	44.9
EC-620389	43.0	42.6	39.7	39.5	41.4	41.1
EC-620395	46.1	45.4	39.1	37.7	42.6	41.6
EC-620401	46.4	41.1	42.4	41.3	44.4	41.2
EC-620406	46.8	41.7	46.2	45.3	46.5	43.5
EC-620410	46.3	40.9	45.5	45.6	45.9	43.3
EC-620417	48.0	39.3	46.3	47.3	47.2	43.3
EC-620427	47.4	40.9	48.0	42.4	47.7	41.7
EC-620429	46.2	41.2	42.4	44.9	44.3	43.1
EC-631369	46.3	43.1	47.4	47.6	46.9	45.4
EC-631379	43.4	40.0	42.6	45.1	43.0	42.6
Pusa Ruby	43.9	43.0	43.6	43.2	43.8	43.1
Arka Abha	47.00	41.5	43.4	42.4	45.2	42.0
Arka Saurabh	49.3	41.9	45.3	45.8	47.3	43.9
Arka Alok	44.8	43.7	44.0	38.8	44.4	41.3
Akshay	43.8	43.7	45.7	38.5	44.8	41.1
Anagha	47.0	42.4	47.2	43.5	47.1	43.0
CD (0.05)	2.0	2.4	2.5	2.5	3.7	3.3
CV	3.9	3.7	4.4	5.9	4.1	6.1

Table 32: Mean performance of tomato genotypes for days to first fruit harvest

Genotypes	Days to first fruit harvest (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	95.9	78.7	95.3	96.9	95.0	87.8
EC-151568	91.5	88.9	88.5	93.9	90.0	91.4
EC-157568	92.9	87.6	90.3	95.9	91.6	91.8
EC-160885	85.9	87.1	89.1	97.9	87.5	92.5
EC-163605	93.1	89.4	93.2	95.5	93.2	92.5
EC-164263	86.5	82.4	94.4	99.8	90.5	91.1
EC-164563	90.7	79.5	88.5	94.9	89.6	87.2
EC-164670	82.4	81.5	87.6	86.5	85.0	84.0
EC-165395	95.0	83.0	99.0	90.0	97.0	86.5
EC-165690	85.6	81.0	85.4	92.4	85.5	86.7
EC-165700	86.0	79.3	95.1	95.5	90.6	87.4
EC-249514	86.6	85.0	95.7	93.1	91.2	89.1
EC-521067 B	93.4	89.1	90.0	87.0	91.7	88.1
EC-528368	92.9	89.9	89.1	92.1	91.0	91.0
EC-538153	87.3	87.1	91.0	93.2	89.2	90.2
EC-620376	86.9	83.5	94.4	85.6	90.7	84.6
EC-620378	88.6	78.8	85.4	85.9	87.0	82.4
EC-620382	86.3	83.1	83.9	94.4	85.1	88.8
EC-620387	86.0	84.2	93.2	94.0	89.6	89.1
EC-620389	89.9	85.6	88.5	93.4	89.2	89.5
EC-620395	88.3	82.4	90.2	85.7	89.3	84.1
EC-620401	93.8	79.5	88.5	91.1	91.2	85.3
EC-620406	86.4	85.4	90.0	97.6	88.2	91.5
EC-620410	84.2	78.9	95.6	98.2	89.9	88.6
EC-620417	92.1	86.8	96.6	98.5	94.4	94.2
EC-620427	87.3	75.0	95.8	88.1	91.6	81.6
EC-620429	93.6	74.7	90.6	94.1	92.1	84.4
EC-631369	94.2	79.4	96.9	97.0	95.6	88.2
EC-631379	86.9	82.8	93.1	97.7	90.0	90.3
Pusa Ruby	95.5	88.5	88.4	93.4	92.0	91.0
Arka Abha	83.3	81.1	86.6	85.4	85.0	83.3
Arka Saurabh	92.8	83.4	96.0	91.2	94.4	87.3
Arka Alok	86.1	87.0	94.7	91.1	90.4	89.1
Akshay	85.4	80.5	94.1	89.9	89.8	85.2
Anagha	87.3	78.2	93.4	96.1	90.4	87.2
CD (0.05)	2.8	3.2	2.2	2.5	3.5	4.3
CV	3.7	3.0	3.4	4.1	3.9	4.5

4.1.1.3.3 Number of fruits per cluster (No.)

Number of fruits per cluster was taken in three stages over the entire crop period. There was significant difference among the genotypes for number of fruits per cluster for both the seasons and for both the structures (Table 33).

4.1.1.3.3.1 Early stage of flowering

During summer evaluation under polyhouse, the maximum number of fruits per cluster was recorded for EC-620410 (4.8), followed by EC-620401 (4.2). Inside the rainshelter, EC-165690 (5.8) recorded maximum number of fruits per cluster, followed by EC-165395 (5.5).

In the rainy season under polyhouse, EC-620406 recorded maximum number of fruits per cluster (4.5), followed by EC-620401 and EC-620410 (4.2). Inside the rainshelter, EC-620401, EC-620406 and EC-620410 recorded maximum number of fruits per cluster (4.5).

In the pooled mean, under polyhouse EC-620410 (4.5) and inside rainshelter EC-620401 (4.8), recorded maximum number of fruits per cluster.

4.1.1.3.3.2 Mid stage of flowering

During summer evaluation under polyhouse, EC-165690 recorded maximum number of fruits per cluster (4.4), followed by EC-620406 (4.1). Inside rainshelter, EC-165690 recorded maximum number of fruits per cluster (6.5), followed by EC-165395 (5.8).

In the rainy season under polyhouse, EC-620401 (4.5) recorded maximum number of fruits per cluster, followed by EC-620406 and EC-528368 (4.2). Inside the rainshelter, EC-620401 recorded maximum number of fruits per cluster (4.5), followed by EC-620406 (4.4).

In the pooled mean, under polyhouse and inside rainshelter, EC-620401 recorded maximum number of fruits per cluster (4.4 and 4.5, respectively).

4.1.1.3.3.3 Late stage of flowering

During summer under polyhouse, EC-620410 recorded highest value (3.7), followed by EC-620401 (3.5). Inside the rainshelter, EC-165690 recorded the highest number of fruits per cluster (4.8), followed by EC-165395 (4.3) and EC-620410 (4.0).

In the rainy season under polyhouse, EC-620410 recorded highest number of fruits per cluster (4.0), followed by EC-620401 (3.8). Inside rainshelter, the highest number of fruits per cluster was recorded for EC-620406 (4.5), followed by EC-620410 (4.2).

In the pooled mean, under polyhouse EC-620410 (3.9) and inside rainshelter EC-165690 (4.2), recorded maximum number of fruits per cluster.

4.1.1.3.4 Fruit set per cent (%)

Fruit set per cent was taken at three stages over the entire crop period. There was significant difference among the genotypes for fruit set per cent for different seasons as well as for growing structures (Table 34).

4.1.1.3.4.1 Early stage of flowering

During summer evaluation under polyhouse, the fruit set per cent was maximum for EC-164263 (62.4%), followed by EC-620410 (61.3%.). Inside rainshelter, fruit set per cent was highest for EC-165395 (67.9%), followed by EC-620401 (66.5%).

In the rainy season under polyhouse, fruit set per cent was maximum for EC-165700 (68.3%), followed by EC-620410 (66.4%). Inside rainshelter, the fruit set per cent was maximum for EC-620401 (65.4%), followed by EC-620406 (64.2%), and EC-620410 (63.6%).

In the pooled mean, under polyhouse EC-620410 (63.9%) and inside rainshelter EC-620401 (66.0%), recorded maximum fruit set per cent.

Table 33: Mean performance of tomato genotypes for number of fruits per cluster

Genotypes	Number of fruits per cluster (no.)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	2.3	4.2	2.0	2.5	2.2	3.4	2.4	3.7	2.4	2.4	2.4	3.1	1.5	2.4	1.5	1.4	1.5	1.9
EC-151568	2.2	3.2	2.0	2.9	2.1	3.1	2.5	3.2	2.2	2.6	2.4	2.9	1.5	2.5	1.4	1.5	1.5	2.0
EC-157568	2.9	3.5	2.4	2.0	2.7	2.8	2.9	3.0	2.2	2.4	2.6	2.7	2.2	2.2	1.4	1.4	1.8	1.8
EC-160885	3.0	2.7	2.7	2.5	2.9	2.6	3.0	3.6	2.9	2.5	3.0	3.1	2.0	1.5	1.7	1.6	1.9	1.6
EC-163605	2.7	4.1	2.4	2.2	2.6	3.2	2.2	2.5	3.0	2.5	2.6	2.5	1.5	2.2	1.5	1.6	1.5	1.9
EC-164263	3.4	3.8	3.0	3.0	3.2	3.4	3.5	3.5	4.0	3.5	3.8	3.5	3.1	2.0	2.5	2.5	2.8	2.3
EC-164563	3.5	3.0	3.5	2.6	3.5	2.8	3.5	2.5	4.0	3.0	3.8	2.8	1.5	3.2	1.5	2.6	1.5	2.9
EC-164670	3.0	3.9	3.0	2.7	3.0	3.3	3.4	3.5	3.0	3.5	3.2	3.5	1.5	2.1	1.0	1.8	1.3	2.0
EC-165395	3.9	5.5	3.0	2.2	3.5	3.9	3.7	5.8	3.8	3.6	3.8	4.7	2.2	4.3	2.5	3.5	2.4	3.9
EC-165690	3.8	5.8	3.2	2.9	3.5	4.4	4.4	6.5	3.5	3.2	3.95	4.9	2.5	4.8	2.2	3.5	2.4	4.2
EC-165700	3.5	2.4	3.5	2.5	3.5	2.5	2.7	2.5	3.0	2.3	2.9	2.4	1.5	1.7	2.0	1.4	1.8	1.6
EC-249514	3.0	3.6	3.2	3.0	3.1	3.3	2.7	3.4	3.0	3.1	2.9	3.3	1.5	2.6	1.9	1.9	1.7	2.3
EC-521067 B	3.4	3.5	3.0	3.7	3.2	3.6	3.4	3.2	3.2	4.2	3.3	3.7	2.2	2.8	2.0	2.0	2.1	2.4
EC-528368	4.0	2.9	4.0	4.3	4.0	3.6	4.0	4.6	4.2	3.5	4.1	4.1	1.8	2.2	3.0	2.2	2.4	2.2
EC-538153	2.8	2.7	2.5	2.0	2.7	2.4	2.5	2.7	2.7	2.5	2.6	2.6	1.5	1.5	1.5	1.2	1.5	1.4
EC-620376	3.5	3.4	3.5	3.0	3.5	3.2	3.5	4.2	2.5	3.9	3.0	4.1	2.0	1.7	2.0	2.0	2.0	1.9
EC-620378	3.2	4.5	2.9	3.0	3.1	3.8	2.9	4.2	3.0	3.0	3.0	3.6	2.4	3.0	2.0	2.1	2.2	2.6

Table 33: Continued

Genotypes	Number of fruits per cluster (no.)																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	3.4	3.5	3.5	4.0	3.5	3.8	3.5	3.2	3.5	3.2	3.5	3.4	3.2	3.0	3.5	3.5	3.4	3.3
EC-620387	3.0	3.0	2.9	2.2	3.0	2.6	2.7	2.4	3.0	2.8	2.9	2.6	1.5	1.7	2.0	1.5	1.8	1.6
EC-620389	3.7	2.0	3.0	2.2	3.4	2.1	2.7	2.3	3.2	2.5	3.0	2.4	1.5	1.7	1.9	1.7	1.7	1.7
EC-620395	2.9	3.8	2.0	3.4	2.5	3.6	2.7	3.0	1.5	3.1	2.1	3.1	1.7	2.5	2.0	2.0	1.9	2.3
EC-620401	4.2	5.0	4.2	4.5	4.2	4.8	4.0	4.0	4.5	4.5	4.4	4.5	3.5	3.6	3.8	4.0	3.7	3.8
EC-620406	4.0	4.5	4.5	4.5	4.3	4.5	4.1	4.0	4.2	4.4	4.2	4.2	3.2	3.5	3.5	4.5	3.4	4.0
EC-620410	4.8	4.5	4.2	4.5	4.5	4.5	3.8	3.7	4.0	3.8	3.9	3.8	3.7	4.0	4.0	4.2	3.9	4.1
EC-620417	2.5	3.2	2.4	2.4	2.5	2.8	2.4	3.0	2.0	2.5	2.2	2.8	1.5	2.0	1.0	1.5	1.3	1.8
EC-620427	3.1	3.3	3.9	3.5	3.5	3.4	2.8	3.0	3.0	3.0	2.9	3.0	3.0	3.5	3.0	2.0	3.0	3.0
EC-620429	2.9	3.4	2.7	3.1	2.8	3.3	3.0	3.8	3.5	3.0	3.3	3.4	2.8	3.5	3.0	3.5	2.9	3.5
EC-631369	2.5	3.0	2.5	1.9	2.5	2.5	2.0	2.7	2.0	2.6	2.0	2.7	1.5	1.5	1.5	1.8	1.5	1.7
EC-631379	2.0	3.0	2.5	3.2	2.3	3.1	2.0	3.0	2.0	3.5	2.0	3.3	1.5	2.0	1.5	2.2	1.5	2.1
Pusa Ruby	3.5	3.2	3.5	3.0	3.5	3.1	2.5	2.0	2.0	3.0	2.3	2.5	2.0	1.5	2.3	1.0	2.2	1.3
Arka Abha	3.3	3.8	3.0	3.4	3.2	3.6	3.2	3.5	3.0	2.8	3.1	3.2	2.0	3.0	3.0	2.5	2.3	2.8
Arka Saurabh	3.0	2.8	2.0	3.0	2.5	2.9	2.5	2.5	2.0	2.5	2.3	2.5	1.5	1.5	1.5	1.5	1.5	1.5
Arka Alok	2.0	2.5	2.5	2.8	2.3	2.7	2.0	2.3	2.5	2.5	2.3	2.4	1.0	1.5	1.0	1.0	1.0	1.3
Akshaya	3.0	4.0	4.0	4.0	3.5	4.0	3.0	4.0	4.0	4.0	3.5	4.0	3.2	3.0	3.5	3.2	3.4	3.1
Anagha	3.0	3.5	3.0	3.5	3	3.5	3.0	3.5	3.0	3.5	3	3.5	1.2	3.0	3.0	2.5	2.1	2.8
CD (0.05)	1.5	1.0	1.1	1.2	0.9	1.7	1.3	1.1	1.3	1.3	0.9	1.3	1.1	1.0	1.5	1.2	0.7	1.0
CV	19.4	11.2	14.4	16.6	12.4	14.0	18.3	13.1	17.1	16.6	13.5	18.4	16.9	16.1	18.7	16.5	16.1	20.1

4.1.1.3.4.2 Mid stage of flowering

During summer evaluation under polyhouse, EC-620401 recorded maximum fruit set per cent (60.6%), followed by EC-620410 (60.3%). Inside rainshelter, EC-620406 recorded maximum value (68.4%), followed by EC-165690 (68.3%).

In the rainy season evaluation under polyhouse, EC-620410 recorded highest fruit set per cent (68.2%), followed by EC-620406 (67.4%). The least fruit set per cent was observed for EC-249514 (46.4%). Inside the rainshelter, the fruit set per cent was highest for EC-620410 (64.0%), followed by EC-164263 (63.6%) and EC-620406 (62.5%). EC-145057 recorded minimum fruit set per cent (32.2%).

In the pooled mean, under polyhouse EC-620410 (64.3%) and inside rainshelter EC-620406 (65.5%), recorded maximum fruit set per cent.

4.1.1.3.4.3 Late stage of flowering

During summer under polyhouse, fruit set per cent was recorded maximum for EC-620401 (59.6%), followed by EC-620410 (59.4%). The fruit set per cent was minimum for EC-163605 (32.0%). Inside the rainshelter, EC-165690 recorded highest fruit set per cent (64.4%), followed by EC-620410 (63.8%). The least value for fruit set per cent was for EC-160885 (30.9%).

In the rainy season under polyhouse, EC-528368 recorded highest fruit set per cent (66.4%), followed by EC-620406 (64.6%). The minimum fruit set per cent was noticed for EC-145057 (31.9%). Inside rainshelter, EC-620401 (60.6%) recorded maximum fruit set per cent, followed by EC-620406 (59.5%). EC-145057 and EC-160885 recorded least fruit set per cent (32.0%).

In the pooled mean, under polyhouse EC-620401 (61.5%) and inside rainshelter EC-620410 (61.4%), recorded maximum fruit set per cent.

Table 34: Mean performance of tomato genotypes for fruit set per cent

Genotypes	Fruit set per cent																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	49.2	57.5	47.4	37.4	48.3	47.5	37.5	52.5	49.4	32.2	43.5	42.4	33.3	43.2	31.9	32.0	32.6	37.6
EC-151568	39.5	43.3	44.5	36.4	42.0	39.9	38.5	45.4	40.4	32.8	39.5	39.1	32.4	46.3	36.6	32.5	34.5	39.4
EC-157568	50.8	62.5	46.2	37.3	48.5	49.9	53.6	56.3	50.7	42.5	52.2	49.4	42.6	52.5	37.3	43.7	40.0	48.1
EC-160885	46.3	39.7	45.4	32.3	45.9	36.0	42.4	51.5	50.5	33.4	46.5	42.5	42.7	30.9	34.7	32.0	38.7	31.5
EC-163605	34.7	66.4	48.3	35.3	41.5	50.9	50.4	49.7	37.3	34.2	43.9	42.0	32.0	47.4	32.3	47.3	32.2	47.4
EC-164263	62.4	61.5	58.2	61.1	60.3	61.3	50.6	50.5	57.3	63.6	54.0	57.1	53.4	40.5	64.3	56.6	58.9	48.6
EC-164563	44.7	46.6	51.6	60.5	48.2	53.6	54.5	39.3	61.6	55.6	58.1	47.5	39.5	58.3	38.3	52.5	38.9	55.4
EC-164670	50.5	55.3	56.3	44.7	53.4	50.0	45.7	47.4	56.5	55.5	51.1	51.5	39.4	51.4	33.4	32.9	36.4	42.2
EC-165395	58.6	67.9	42.7	58.3	50.7	63.1	54.4	65.6	48.4	57.5	51.4	61.6	43.3	62.6	42.7	53.3	43.0	58.0
EC-165690	52.6	64.4	43.4	56.3	48.0	60.4	51.3	68.3	49.3	55.3	50.3	61.8	40.5	64.4	40.3	52.3	40.4	58.4
EC-165700	45.4	47.6	68.3	46.5	56.9	47.1	50.9	46.5	52.8	40.5	51.9	43.5	36.6	55.7	36.5	46.9	36.6	51.3
EC-249514	44.7	58.5	47.8	49.4	46.3	54.0	39.1	49.5	46.4	48.4	42.8	49.0	44.4	53.4	54.8	43.5	49.6	48.5
EC-521067 B	46.8	50.7	55.5	62.4	51.2	56.6	48.4	40.5	48.4	60.4	48.4	50.5	44.3	53.6	45.4	46.5	44.9	50.1
EC-528368	39.3	39.3	58.5	55.7	48.9	47.5	50.5	63.5	60.6	23.9	55.6	43.7	38.6	36.6	66.4	53.6	52.5	45.1
EC-538153	48.5	58.6	50.4	54.6	49.5	56.6	45.5	55.3	52.3	52.2	48.9	53.8	40.7	50.5	48.5	48.4	44.6	49.5
EC-620376	43.6	54.4	43.6	50.3	43.6	52.4	54.6	60.5	49.7	50.5	52.2	55.5	50.2	32.3	39.7	39.9	45.0	36.1
EC-620378	52.6	57.5	41.4	51.5	47.0	54.5	39.3	56.3	43.7	54.8	41.5	55.6	43.5	51.3	40.6	42.5	42.1	46.9

Table 34: Continued

Genotypes	Fruit set per cent																	
	Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	42.7	42.7	50.3	37.6	46.5	40.2	45.5	47.3	53.6	50.6	49.6	49.0	46.4	36.3	42.6	46.3	44.5	41.3
EC-620387	59.9	59.9	64.4	60.3	62.2	60.1	56.1	61.5	58.5	57.8	57.3	59.7	57.4	56.4	64.2	58.3	60.8	57.9
EC-620389	53.5	58.5	54.5	60.2	54.0	59.4	58.6	59.4	61.6	57.5	60.1	58.5	52.2	55.5	58.2	54.5	55.2	55.0
EC-620395	54.7	64.4	57.3	58.3	56.0	61.4	52.5	62.5	53.6	55.2	53.1	58.9	54.3	58.5	52.8	51.5	53.6	55.0
EC-620401	58.2	66.5	60.7	65.4	59.5	66.0	60.6	62.8	64.5	60.9	62.6	61.9	59.6	57.3	63.4	60.6	61.5	59.0
EC-620406	60.5	66.4	65.1	64.2	62.8	65.3	59.4	68.4	67.4	62.5	63.4	65.5	57.3	59.4	64.6	59.5	61.0	59.5
EC-620410	61.3	64.4	66.4	63.6	63.9	64.0	60.3	62.5	68.2	64.0	64.3	63.3	59.4	63.8	61.6	58.9	60.5	61.4
EC-620417	58.4	61.6	58.5	57.5	58.5	59.6	54.4	62.6	59.5	53.8	57.0	58.2	55.3	58.5	59.5	51.5	57.4	55.0
EC-620427	39.6	59.4	54.0	41.6	46.8	50.5	40.5	55.3	50.4	48.5	45.5	51.9	40.6	55.3	32.4	48.4	36.5	51.9
EC-620429	50.6	51.3	47.4	32.4	49.0	41.9	49.2	51.2	50.5	49.7	49.9	50.5	42.7	33.5	44.4	42.7	43.6	38.1
EC-631369	55.6	59.8	56.5	61.3	56.1	60.6	51.3	57.5	57.4	58.8	54.4	58.2	56.5	62.4	60.4	52.6	58.5	57.5
EC-631379	55.4	64.3	64.5	54.4	60.0	59.4	55.7	66.4	61.5	53.6	58.6	60.0	56.5	60.3	60.5	52.8	58.5	56.6
Pusa Ruby	50.5	53.5	53.3	51.5	51.9	52.5	58.6	44.6	40.2	50.7	49.4	47.7	50.4	37.3	41.5	33.8	46.0	35.6
Arka Abha	54.6	56.3	50.4	42.5	52.5	49.4	50.5	54.2	40.5	52.6	45.5	53.4	42.6	50.4	45.4	43.5	44.0	47.0
Arka Saurabh	48.7	56.5	42.4	47.5	45.6	52.0	54.4	50.5	44.5	46.3	49.5	48.4	42.5	37.5	46.6	44.4	44.6	41.0
Arka Alok	40.5	48.4	52.4	45.4	46.5	46.9	46.4	41.3	55.6	45.9	51.0	43.6	33.3	35.4	50.4	33.8	41.9	34.6
Akshaya	56.2	61.4	57.6	59.3	56.9	60.4	54.5	60.6	58.3	54.7	56.4	57.7	56.5	57.3	58.3	48.5	57.4	52.9
Anagha	54.4	54.4	58.3	57.3	56.4	55.9	55.4	67.2	52.3	57.5	53.9	62.4	32.2	57.3	59.8	47.2	46.0	52.3
CD (0.05)	6.2	5.9	6.4	5.5	13.0	15.2	7.4	7.1	6.6	19.7	11.7	13.4	5.5	6.8	6.2	5.4	12.4	13.1
CV	5.5	5.2	6.0	5.4	12.5	14.4	7.0	6.5	6.1	19.5	17.5	16.6	5.8	6.8	6.2	5.5	13.3	13.5

4.1.1.3.5 Number of fruits per plant (No.)

There was significant difference among the genotypes for both the seasons and for both the growing structures (Table 35). In the summer season under polyhouse, the number of fruits per plant was in the range between 10.0 and 23.2. EC-165700 (23.2) recorded the highest value, followed by EC-620406 (19.9). Inside rainshelter, the highest number of fruits per plant was recorded for EC-165690 (71.9), followed by EC-165395 (67.6).

During rainy seaons under polyhouse, the maximum number of fruits per plant was observed for EC-620410 (24.6), followed by EC-620406 (23.8). Inside rainshelter, the maximum number of fruits per plant was recorded for EC-165690 (67.0), followed by EC-165395 (65.6).

In the pooled mean, under polyhouse EC-151568 (22.4) and inside rainshelter EC-165690 (69.5), recorded maximum number of fruits per plant.

4.1.1.3.6 Locule number per fruit (No.)

In the summer season evaluation under polyhouse, the minimum locule number was observed for EC-620376 (2.2), followed by EC-145057, EC-151568, EC-165700 and EC-620417 (2.5) (Table 36). Inside rainshelter, the minimum locule number was observed for EC-521067 B (2.3), followed by EC-528368 (2.5).

In the rainy season under polyhouse, the minimum number of locules were observed for EC-521067 B (2.0), followed by EC-164563, EC-165700, EC-620376 and EC-631379 (2.4). Inside rainshelter, EC-620376 exhibited minimum locule number (2.6), followed by EC-164563, EC-528368 and EC-620395 (2.7).

In the pooled mean, under polyhouse EC-620376 (2.3) and inside rainshelter EC-528368 (2.6), recorded minimum locule number per fruit.

Table 35: Mean performance of tomato genotypes for number of fruits per plant

Genotypes	Number of fruits per plant (no.)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	15.4	17.3	19.3	20	17.4	18.7
EC-151568	22.4	33.6	22.3	43.5	22.4	38.6
EC-157568	12.5	15.8	16.4	16	14.5	15.9
EC-160885	17.6	35.8	14.8	12.1	16.2	23.9
EC-163605	15.5	18.7	17.5	17.6	16.5	18.2
EC-164263	18	27.5	19.7	22.4	18.9	25.0
EC-164563	15.5	19.5	14.9	19.6	15.2	19.6
EC-164670	14.5	18	15.4	23.1	15.0	20.6
EC-165395	13.2	67.6	15.4	65.6	14.3	66.6
EC-165690	14.1	71.9	16.1	67	15.1	69.5
EC-165700	23.2	34.4	20.4	39.6	21.8	37.0
EC-249514	13.4	18.8	17.5	15.3	15.5	17.1
EC-521067 B	16.7	16.6	15.4	19.1	16.1	17.9
EC-528368	19.8	28.5	23.7	44.2	21.8	36.4
EC-538153	15.3	19.2	20.3	19.3	17.8	19.3
EC-620376	19.6	42.5	16.2	46.9	17.9	44.7
EC-620378	12.1	18.3	17.9	20.8	15.0	19.6
EC-620382	14.3	16.2	23	24	18.7	20.1
EC-620387	10.6	18.2	16.4	11.3	13.5	14.8
EC-620389	14	19.3	16.5	17.9	15.3	18.6
EC-620395	16.4	21.9	18.5	17.5	17.5	19.7
EC-620401	18.3	21.7	22.5	24.8	20.4	23.3
EC-620406	19.9	20.2	23.8	23.1	21.9	21.7
EC-620410	18.4	22.5	24.6	22.4	21.5	22.5
EC-620417	17.2	19.1	22.6	20.6	19.9	19.9
EC-620427	13.5	16.1	16.6	17.7	15.1	16.9
EC-620429	15.5	17.8	16.3	17.4	15.9	17.6
EC-631369	17.1	20.6	22.6	20.9	19.9	20.8
EC-631379	18.5	22.6	15.6	16.1	17.1	19.4
Pusa Ruby	15.1	19.3	18.1	15.2	16.6	17.3
Arka Abha	15.6	16.1	18.1	19.1	16.9	17.6
Arka Saurabh	13.5	13.6	13	14.4	13.3	14.0
Arka Alok	13.8	15.3	16.7	17.4	15.3	16.4
Akshay	17.4	23.5	21.5	22.5	19.5	23.0
Anagha	13.2	15.7	17.5	20.5	15.4	18.1
CD (0.05)	2.9	2.5	2.0	2.0	2.6	3.2
CV	8.5	12.3	14.2	15.8	15.6	12.8

Table 36: Mean performance of tomato genotypes for locule number per fruit

Genotypes	Locule number per fruit (no.)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	2.5	3.4	3.4	3.4	3.0	3.4
EC-151568	2.5	3.7	3.1	3.1	2.8	3.4
EC-157568	3.2	4.8	2.6	3	2.9	3.9
EC-160885	3.4	3.4	3.2	3.4	3.3	3.4
EC-163605	3.2	3.4	2.8	3.8	3.0	3.6
EC-164263	2.7	3.3	2.8	3.5	2.8	3.4
EC-164563	3.1	3.4	2.4	2.7	2.8	3.1
EC-164670	3.6	5	3.4	5	3.5	5.0
EC-165395	2.6	3.1	2.7	2.9	2.7	3.0
EC-165690	2.8	3.3	2.8	2.8	2.8	3.1
EC-165700	2.5	2.7	2.4	3.4	2.5	3.1
EC-249514	3.5	4.6	3.2	4	3.4	4.3
EC-521067 B	2.6	2.3	2	3.6	2.3	3.0
EC-528368	3.3	2.5	2.6	2.7	3.0	2.6
EC-538153	3.6	3.5	3.1	3.4	3.4	3.5
EC-620376	2.2	2.7	2.4	2.6	2.3	2.7
EC-620378	3.2	3.6	3.2	3.8	3.2	3.7
EC-620382	3.7	4.5	4.2	4.4	4.0	4.5
EC-620387	2.8	3.6	3.4	3.6	3.1	3.6
EC-620389	5.2	5.5	4.5	5.8	4.9	5.7
EC-620395	3.6	4.4	2.5	2.7	3.1	3.6
EC-620401	2.8	3.5	3.3	3.7	3.1	3.6
EC-620406	3.5	3.5	3	3.4	3.3	3.5
EC-620410	3	3.9	3.4	3.4	3.2	3.7
EC-620417	2.5	2.9	2.7	4.1	2.6	3.5
EC-620427	3.5	4.2	3.1	3.4	3.3	3.8
EC-620429	3.3	3.7	3	3.5	3.2	3.6
EC-631369	3.2	3.6	3.1	4.7	3.2	4.2
EC-631379	2.6	2.6	2.4	3.2	2.5	2.9
Pusa Ruby	3.6	5.4	3.3	3.5	3.5	4.5
Arka Abha	4.4	4.5	4.4	4.5	4.4	4.5
Arka Saurabh	3.5	5	4.4	4.8	4.0	4.9
Arka Alok	3	4	2.9	3.6	3.0	3.8
Akshay	6.4	5.5	5.3	5.8	5.9	5.7
Anagha	6.5	6.6	5.5	5.5	6.0	6.1
CD (0.05)	0.001	0.001	0.001	0.001	0.001	0.001
CV	5.0	6.9	5.0	11.9	11.2	13.8

4.1.1.3.7 Pericarp thickness (cm)

There was significant difference among the genotypes for pericarp thickness in both the seasons under both the growing structures (Table 37). During summer under polyhouse, the maximum pericarp thickness was observed for EC-620427 (0.90 cm), followed by EC-620429 (0.84 cm). Inside raishelter, the maximum pericarp thickness was observed for EC-620406 and EC-620429 (0.84 cm), followed by EC-620410 (0.83 cm).

In the rainy season evaluation under polyhouse, the pericarp thickness was maximum for EC-620427 (0.91 cm), followed by EC-620406 (0.87 cm). Inside the rainshelter, the maximum pericarp thickness was recorded for EC-620427 (0.86 cm), followed by EC-631369 (0.82 cm).

In the pooled mean, under polyhouse EC-620427 (0.91 cm) and inside rainshelter EC-620406 (0.82 cm), recorded maximum pericarp thickness.

4.1.1.3.8 Average fruit weight (g)

There was significant difference among the genotypes in both the seasons under both the growing structures (Table 38). During summer evaluation under polyhouse, the highest average fruit weight was observed for EC-620417 (86.3 g), followed by EC-620387 (85.8 g). Inside the rainshelter, the average fruit weight was highest for EC-538153 (94.2 g), followed by EC-620387 (93.6 g).

In the rainy season under polyhouse, the average fruit weight was recorded maximum for EC-631369 (98.2 g), followed by EC-538153 (97.5 g). Inside rainshelter, the average fruit weight was maximum for EC-538153 (95.3 g), followed by EC-620395 (91.2g).

In the pooled mean, under polyhouse EC-620387 (90.8 g) and inside rainshelter EC-538153 (94.8 g), recorded maximum average fruit weight.

Table 37: Mean performance of tomato genotypes for pericarp thickness

Genotypes	Pericarp thickness (cm)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	0.41	0.52	0.54	0.47	0.48	0.50
EC-151568	0.46	0.60	0.54	0.56	0.50	0.58
EC-157568	0.61	0.44	0.65	0.63	0.63	0.54
EC-160885	0.37	0.53	0.42	0.47	0.40	0.50
EC-163605	0.37	0.27	0.28	0.52	0.33	0.40
EC-164263	0.59	0.63	0.49	0.42	0.54	0.53
EC-164563	0.54	0.67	0.67	0.54	0.61	0.61
EC-164670	0.51	0.46	0.52	0.50	0.52	0.48
EC-165395	0.34	0.43	0.37	0.40	0.36	0.42
EC-165690	0.34	0.42	0.38	0.41	0.36	0.42
EC-165700	0.26	0.29	0.20	0.21	0.23	0.25
EC-249514	0.54	0.38	0.53	0.51	0.54	0.45
EC-521067 B	0.57	0.50	0.54	0.50	0.56	0.50
EC-528368	0.29	0.49	0.20	0.18	0.25	0.34
EC-538153	0.78	0.48	0.81	0.76	0.80	0.62
EC-620376	0.29	0.44	0.26	0.29	0.28	0.37
EC-620378	0.55	0.44	0.51	0.49	0.53	0.47
EC-620382	0.70	0.68	0.58	0.61	0.64	0.65
EC-620387	0.63	0.65	0.59	0.61	0.61	0.63
EC-620389	0.73	0.68	0.78	0.76	0.76	0.72
EC-620395	0.60	0.64	0.67	0.67	0.64	0.66
EC-620401	0.82	0.81	0.81	0.78	0.82	0.74
EC-620406	0.85	0.84	0.87	0.80	0.86	0.82
EC-620410	0.82	0.83	0.82	0.75	0.82	0.79
EC-620417	0.70	0.74	0.73	0.71	0.72	0.73
EC-620427	0.90	0.74	0.91	0.86	0.91	0.80
EC-620429	0.89	0.84	0.85	0.78	0.87	0.81
EC-631369	0.76	0.79	0.86	0.82	0.81	0.81
EC-631379	0.63	0.72	0.59	0.22	0.61	0.47
Pusa Ruby	0.33	0.51	0.34	0.31	0.34	0.41
Arka Abha	0.68	0.54	0.61	0.58	0.65	0.56
Arka Saurabh	0.57	0.65	0.57	0.50	0.57	0.58
Arka Alok	0.55	0.63	0.52	0.56	0.54	0.60
Akshay	0.53	0.60	0.54	0.53	0.54	0.57
Anagha	0.52	0.48	0.58	0.54	0.55	0.51
CD (0.05)	0.1	0.3	0.1	0.1	0.1	0.2
CV	6.4	8.4	5.2	9.9	7.6	18.5

Table 38: Mean performance of tomato genotypes for average fruit weight

Genotypes	Average fruit weight (g)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	34.4	35.5	37.2	31.6	35.8	33.6
EC-151568	37.5	38.5	37.6	32.1	37.6	35.3
EC-157568	32.1	37.6	38.9	31.1	35.5	34.4
EC-160885	41.6	44.4	32.9	32.5	37.3	38.5
EC-163605	39.9	45.9	25.5	29.3	32.7	37.6
EC-164263	67.7	73.5	78.2	64.2	73.0	68.9
EC-164563	52.4	58.0	46.0	44.5	49.2	51.3
EC-164670	39.8	46.5	28.9	31.8	34.4	39.2
EC-165395	23.4	25.1	22.9	21.9	23.2	23.5
EC-165690	26.8	28.4	23.4	23.2	25.1	25.8
EC-165700	8.1	12.2	7.5	4.2	7.8	8.2
EC-249514	45.2	55.3	48.8	43.1	47.0	49.2
EC-521067 B	40.0	48.7	33.7	33.0	36.9	40.9
EC-528368	8.0	11.2	6.4	14.3	7.2	12.8
EC-538153	70.6	94.2	97.5	95.3	84.1	94.8
EC-620376	8.4	10.9	9.4	13.6	8.9	12.3
EC-620378	54.2	58.5	56.9	52.2	55.6	55.4
EC-620382	65.2	65.4	68.8	63.8	67.0	64.6
EC-620387	85.8	93.6	95.8	73.6	90.8	83.6
EC-620389	64.3	70.2	74.6	72.0	69.5	71.1
EC-620395	61.2	92.4	78.7	91.2	70.0	91.8
EC-620401	75.5	89.3	88.4	82.7	82.0	86.0
EC-620406	70.8	83.3	89.5	85.3	80.2	84.3
EC-620410	75.2	90.4	89.7	87.5	82.5	89.0
EC-620417	86.3	72.4	77.7	72.0	82.0	72.2
EC-620427	64.1	73.2	68.4	62.1	66.3	67.7
EC-620429	68.6	71.9	70.3	68.4	69.5	70.2
EC-631369	65.1	70.8	98.2	58.7	81.7	64.8
EC-631379	69.4	71.9	63.4	56.9	66.4	64.4
Pusa Ruby	38.2	38.2	39.0	33.8	38.6	36.0
Arka Abha	62.1	72.0	74.6	62.7	68.4	67.4
Arka Saurabh	58.7	69.1	68.9	71.1	63.8	70.1
Arka Alok	56.0	69.0	68.6	69.5	62.3	69.3
Akshay	57.3	64.4	62.0	65.4	59.7	64.9
Anagha	67.2	71.3	68.1	71.2	67.7	71.3
CD (0.05)	3.6	3.5	2.2	3.0	2.5	3.0
CV	5.1	6.3	4.8	8.1	10.5	9.1

4.1.1.3.9 Yield per plant (g)

There was significant difference among the genotypes for yield per plant in both the seasons under both the structures (Table 39). During summer under polyhouse, the maximum yield per plant was recorded for EC-620406 (1373.9 g), followed by EC-620410 (1323.1 g). Inside rainshelter, the maximum yield per plant was recorded for EC-620410 (1875.0 g), followed by EC-620401 (1745.6 g).

In the rainy season evaluation under polyhouse, the yield per plant was maximum for EC-620410 (1727.3 g), followed by EC-620406 (1625.9 g). Inside rainshelter, the maximum yield per plant was recorded for EC-620410 (1875.0 g), followed by EC-620401 (1764.3 g).

In the pooled mean, under polyhouse and inside rainshelter, EC-620410 recorded maximum fruit yield per plant (1525.2 g and 1866.0 g, respectively).

4.1.1.3.10 Fruit yield per plot (kg)

There was significant difference among the genotypes for fruit yield per plot in both the seasons under different growing structures (Table 40). During summer under polyhouse, the highest fruit yield per plot was recorded for EC-620406 (8.2 kg), followed by EC-620410 (7.9 kg). Inside rainshelter, the maximum fruit yield per plot was recorded for EC-620410 (11.3 kg), followed by EC-620401 (10.6 kg).

In the rainy season under polyhouse, EC-620410 recorded the highest fruit yiled per plot (10.4 kg), followed by EC-620406 (9.8 kg). Inside rainshelter the fruit yield per plot was recorded highest for EC-620410 (11.1 kg), followed by EC-620401 (10.5 kg).

In the pooled mean, under polyhouse and inside rainshelter EC-620410 recorded maximum fruit yield per plot (9.2 kg and 11.2 kg, respectively).

Table 39: Mean performance of tomato genotypes for yield per plant

Genotypes	Yield per plant (g)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	325.5	452.1	680.1	623.3	502.8	537.7
EC-151568	412.2	270.7	547.1	426.8	479.7	348.8
EC-157568	389.9	430.1	549.5	578.6	469.7	504.4
EC-160885	347.8	378.3	436	470.6	391.9	424.5
EC-163605	526.6	462.9	399.2	624.3	462.9	543.6
EC-164263	1067.1	1263.1	1314.4	1436.6	1190.8	1349.9
EC-164563	694.1	643.2	610.1	947.6	652.1	795.4
EC-164670	451.7	475.4	371.2	963.6	411.5	719.5
EC-165395	319.5	1289.3	348.4	1505.8	334.0	1397.6
EC-165690	376.5	1452.2	367.7	1688.3	372.1	1570.3
EC-165700	535.2	121.5	117.8	448.8	326.5	285.2
EC-249514	586.7	787.4	755.7	776.1	671.2	781.8
EC-521067 B	552.5	499.8	486.3	840	519.4	669.9
EC-528368	132.3	245.7	148	472.3	140.2	359.0
EC-538153	746.5	1262.6	1262.1	1164.5	1004.3	1213.6
EC-620376	136	146.7	128.1	409.5	132.1	278.1
EC-620378	679.1	881.8	952.1	751.7	815.6	816.8
EC-620382	1007.3	1208.1	1237.5	1250.9	1122.4	1229.5
EC-620387	617.5	1210.6	1332.8	930.7	975.2	1070.7
EC-620389	864.9	1273.4	1148	1135.9	1006.5	1204.7
EC-620395	739.9	1466.1	1205.6	1387.7	972.8	1426.9
EC-620401	1156.1	1745.6	1505.7	1764.3	1330.9	1755.0
EC-620406	1373.9	1665.3	1625.9	1685.6	1499.9	1675.5
EC-620410	1323.1	1857	1727.3	1875	1525.2	1866.0
EC-620417	1135.1	1143.4	1462.1	1256.5	1298.6	1200.0
EC-620427	843.9	936.2	1005	1091.6	924.5	1013.9
EC-620429	986.1	1026	1017.9	1138.8	1002.0	1082.4
EC-631369	1012.4	1192.2	1324.5	1357.2	1168.5	1274.7
EC-631379	723.1	421.2	858.1	1074.2	790.6	747.7
Pusa Ruby	462.2	509.1	652.2	425.1	557.2	467.1
Arka Abha	941.5	947.2	1167.1	1029.9	1054.3	988.6
Arka Saurabh	742.5	904.5	815.5	943.7	779.0	924.1
Arka Alok	723.5	965.6	1033.8	1036.4	878.7	1001.0
Akshay	935.6	1209	1009.2	1147.1	972.4	1178.1
Anagha	786.9	987.4	987.4	1057.7	887.2	1022.6
CD (0.05)	248.3	325.7	238.7	285.4	212.5	258.5
CV	13.5	14.7	17.3	13.5	12.6	15.6

Table 40: Mean performance of tomato genotypes for yield per plot

Genotypes	Yield per plot (kg)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	2.0	3.7	4.1	2.7	3.0	3.2
EC-151568	2.5	2.6	3.3	1.6	2.9	2.1
EC-157568	2.3	3.5	3.3	2.6	2.8	3.0
EC-160885	2.1	2.8	2.6	2.3	2.4	2.5
EC-163605	3.2	3.8	2.4	2.8	2.8	3.3
EC-164263	6.4	8.6	7.9	7.6	7.1	8.1
EC-164563	4.2	5.7	3.7	3.9	3.9	4.8
EC-164670	2.7	5.8	2.2	2.9	2.5	4.3
EC-165395	1.9	9.0	2.1	7.7	2.0	8.4
EC-165690	2.3	10.1	2.2	8.7	2.2	9.4
EC-165700	3.2	2.7	0.7	0.7	2.0	1.7
EC-249514	3.5	4.7	4.5	4.7	4.0	4.7
EC-521067 B	3.3	5.0	2.9	3.0	3.1	4.0
EC-528368	0.8	2.8	0.9	0.3	0.8	1.6
EC-538153	4.5	7.0	7.6	7.6	6.0	7.3
EC-620376	0.8	2.5	0.8	0.9	0.8	1.7
EC-620378	4.1	4.5	5.7	5.3	4.9	4.9
EC-620382	6.0	7.3	7.4	7.5	6.7	7.4
EC-620387	3.7	5.6	8.0	7.3	5.9	6.4
EC-620389	5.2	6.8	6.9	7.6	6.0	7.2
EC-620395	4.4	8.3	7.2	8.8	5.8	8.6
EC-620401	6.9	10.6	9.0	10.5	8.0	10.5
EC-620406	8.2	10.1	9.8	10.0	9.0	10.1
EC-620410	7.9	11.3	10.4	11.1	9.2	11.2
EC-620417	6.8	7.5	8.8	6.9	7.8	7.2
EC-620427	5.1	6.6	6.0	5.6	5.5	6.1
EC-620429	5.9	6.8	6.1	6.2	6.0	6.5
EC-631369	6.1	8.1	8.0	7.2	7.0	7.6
EC-631379	4.3	6.5	5.2	2.5	4.7	4.5
Pusa Ruby	2.8	2.6	3.9	3.1	3.3	2.8
Arka Abha	5.7	6.2	7.0	5.7	6.3	5.9
Arka Saurabh	4.5	5.7	4.9	5.4	4.7	5.5
Arka Alok	4.3	6.2	6.2	5.8	5.3	6.0
Akshay	5.6	6.9	6.1	7.3	5.8	7.1
Anagha	4.7	6.4	5.9	5.9	5.3	6.1
CD (0.05)	0.7	0.9	0.8	0.5	0.5	0.8
CV	3.5	4.7	5.8	8.3	4.2	7.2

4.1.1.4 Biochemical / Quality characters

4.1.1.4.1 TSS (^{0}B)

During summer evaluation under polyhouse, the range observed was between 5.4 and 6.2. EC-164563 and Arka Alok recorded highest value (6.2). Inside rainshelter, EC-164263, EC-164563 and EC-620406 recorded highest TSS (6.4) (Table 41).

In the rainy season under polyhouse, TSS was recorded in the range between 5.5 and 6.3. The highest was recorded for EC-249514 (6.3), followed by EC-521067B and EC-538153 (6.2). Inside rainshelter, the highest value was observed for EC-157568 (6.2), followed by EC-164263 and EC-631369 (6.1) (Table 41).

4.1.1.4.2 Lycopene (mg/ 100g fresh weight)

There was significant difference among the genotypes for lycopene in both the seasons under both the structures (Table 42). During summer under polyhouse, the lycopene content was recorded highest for EC-528368 and Anagha (13.1 mg / 100 g fresh fruit), followed by Arka Abha (13.0 mg / 100 g fresh fruit). Inside rainshelter, the highest lycopene content was recorded for Anagha (12.7 mg / 100 g fresh fruit), followed by EC-538153 (12.1 mg / 100 g fresh fruit).

In the rainy season under polyhouse, the lycopene content was observed to be highest for Anagha (13.8 mg / 100 g fresh fruit), followed by Arka Saurabh (12.6 mg / 100 g fresh fruit). Inside rainshelter, the highest lycopene content was recorded for EC-151568 (12.0 mg / 100 g fresh fruit), followed by EC-528368 (11.8 mg / 100 g fresh fruit).

In the pooled mean, under polyhouse EC-528368 and EC-538153 (12.9 mg / 100 g fresh fruit) and inside rainshelter Anagha 12.0 mg / 100 g fresh fruit respectively), recorded maximum lycopene content.

Table 41: Mean performance of tomato genotypes for TSS

Genotypes	TSS (˚Brix)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	5.7	5.5	5.8	5.7	5.8	5.6
EC-151568	5.8	5.6	5.5	5.6	5.7	5.6
EC-157568	5.7	5.7	5.6	6.2	5.7	6.0
EC-160885	6.0	6.3	6.1	5.3	6.1	5.8
EC-163605	5.8	5.7	5.7	5.8	5.8	5.8
EC-164263	5.9	6.4	5.6	6.1	5.8	6.3
EC-164563	6.2	6.4	5.9	5.6	6.1	6.0
EC-164670	5.7	5.7	5.8	5.6	5.8	5.7
EC-165395	5.7	5.3	5.9	6.0	5.8	5.7
EC-165690	5.8	6.0	5.7	5.8	5.8	5.9
EC-165700	5.6	6.1	5.7	6.0	5.7	6.1
EC-249514	6.1	5.8	6.3	5.4	6.2	5.6
EC-521067 B	6.1	5.6	6.2	5.5	6.2	5.6
EC-528368	5.6	6.3	5.9	5.4	5.8	5.9
EC-538153	6.0	5.7	6.2	5.8	6.1	5.8
EC-620376	5.7	5.6	5.8	5.9	5.8	5.8
EC-620378	6.0	6.3	6.0	5.7	6.0	6.0
EC-620382	5.9	5.6	5.9	5.6	5.9	5.6
EC-620387	5.8	5.5	5.7	5.9	5.8	5.7
EC-620389	5.7	5.6	5.6	5.9	5.7	5.8
EC-620395	5.6	5.6	5.5	5.6	5.6	5.6
EC-620401	5.9	5.7	5.6	5.9	5.8	5.8
EC-620406	6.0	6.4	5.8	5.9	5.9	6.2
EC-620410	5.9	5.6	5.7	5.8	5.8	5.7
EC-620417	5.8	5.6	5.9	5.6	5.9	5.6
EC-620427	5.8	5.7	5.9	5.7	5.9	5.7
EC-620429	5.6	5.7	5.5	6.0	5.6	5.9
EC-631369	5.4	5.5	5.5	6.1	5.5	5.8
EC-631379	5.8	5.7	6.1	5.3	6.0	5.5
Pusa Ruby	6.0	5.8	6.1	5.4	6.1	5.6
Arka Abha	5.7	5.7	5.9	5.5	5.8	5.6
Arka Saurabh	5.5	5.5	5.6	5.6	5.6	5.6
Arka Alok	6.2	5.7	5.8	5.6	6.0	5.7
Akshay	5.8	5.8	5.9	5.6	5.9	5.7
Anagha	5.7	5.5	5.5	5.3	5.6	5.4
CD (0.05)	0.2	0.4	0.2	0.4	0.3	0.3
CV	5.6	3.3	6.1	3.4	2.3	4.9

Table 42: Mean performance of tomato genotypes for lycopene

Genotypes	Lycopene (mg / 100 g fruit weight)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	11.2	10.3	11.9	10.0	11.6	10.2
EC-151568	12.3	9.2	12.5	12.0	12.2	10.9
EC-157568	9.0	7.9	10.3	9.9	9.7	8.9
EC-160885	9.5	8.2	12.4	10.6	11.0	9.4
EC-163605	10.8	9.3	11.2	10.9	11.0	10.1
EC-164263	10.1	9.1	9.5	9.0	9.8	9.1
EC-164563	11.1	8.9	11.5	11.0	11.3	10.0
EC-164670	11.8	7.4	10.4	9.7	11.1	8.6
EC-165395	9.8	8.0	10.2	9.5	10.0	8.8
EC-165690	9.0	7.2	8.3	7.3	8.7	7.3
EC-165700	10.6	8.9	10.7	10.3	10.7	9.6
EC-249514	10.9	8.3	9.5	8.9	10.2	8.6
EC-521067 B	11.3	10.3	10.4	10.4	10.9	10.4
EC-528368	13.1	11.1	12.7	11.8	12.9	11.5
EC-538153	12.8	12.1	12.9	10.6	12.9	11.4
EC-620376	11.1	11.0	9.5	8.2	10.3	9.6
EC-620378	9.8	9.1	9.1	8.8	9.5	9.0
EC-620382	10.1	8.4	11.6	10.2	10.9	9.3
EC-620387	10.9	10.1	10.3	9.5	10.6	9.8
EC-620389	9.0	8.6	8.2	8.1	8.6	8.4
EC-620395	9.9	8.1	11.8	10.8	10.9	9.5
EC-620401	10.2	9.9	11.4	10.2	10.8	10.1
EC-620406	12.0	8.9	11.1	10.5	11.6	9.7
EC-620410	11.0	9.2	10.8	10.0	10.9	9.6
EC-620417	8.0	10.1	9.3	8.9	8.7	9.5
EC-620427	9.4	8.9	10.4	9.9	9.9	9.4
EC-620429	12.0	10.4	10.9	10.4	11.5	10.4
EC-631369	12.8	9.1	9.7	8.6	11.3	8.9
EC-631379	10.1	8.8	9.1	9.1	9.6	9.0
Pusa Ruby	12.0	9.9	10.9	9.2	11.5	9.6
Arka Abha	13.0	11.2	9.5	9.5	11.3	10.4
Arka Saurabh	8.8	8.2	12.6	11.5	10.7	9.9
Arka Alok	9.9	7.7	10.4	9.5	10.2	8.6
Akshay	9.0	8.0	9.1	8.7	9.1	8.4
Anagha	13.1	12.7	13.8	11.3	13.5	12.0
CD (0.05)	0.004	0.002	0.002	0.003	0.001	0.002
CV	1.8	1.5	2.4	1.9	2.3	1.8

4.1.1.4.3 Ascorbic acid (mg / 100g fresh weight)

There was significant difference among the genotype for ascorbic acid (Table 43). In the summer evaluation under polyhouse, the highest ascorbic acid content was recorded for Pusa Ruby (24.6 mg / 100 g fresh weight), followed by EC-165690 (23.8 mg / 100 g fresh weight). In the rainshelter, the ascorbic acid content was highest for EC-528368 (26.1 mg / 100 g fresh weight), followed by Arka Abha (25.2 mg / 100 g fresh weight).

In the rainy season under polyhouse, EC-620401 recorded highest ascorbic acid content (21.7 mg / 100 g fresh weight), followed by EC-620382 (21.6 mg / 100 g fresh weight). Inside the rainshelter, the highest ascorbic acid content was recorded for EC-163605 and EC-620382 (25.2 mg / 100 g fresh weight), followed by EC-165690 and EC-620417 (25.1 mg / 100 g fresh weight).

In the pooled mean, under polyhouse Pusa Ruby (22.6 mg / 100 g fresh weight) and inside rainshelter EC-163605 (24.9 mg / 100 g fresh weight), recorded maximum ascorbic acid content.

4.1.1.4.4 Acidity (%)

There observed significant difference among the genotypes in both the seasons under both the structures (Table 44). During summer under polyhouse, the acidity per cent was recorded highest for Arka Alok (0.24 per cent), followed by Arka Saurabh and Pusa Ruby (0.22 per cent). Inside the rainshelter, the highest value was recorded for EC-157568 (0.37 per cent), followed by EC-165700, EC-620395 and Arka Abha (0.36 per cent).

In the rainy season under polyhouse, the highest acidity was recorded for EC-249514 (0.24 per cent), followed by EC-165700 and Akshaya (0.23 per cent). Inside the rainshelter, the acidity was observed to be highest for EC-249514 (0.46 per cent) followed by Arka Abha (0.45 per cent).

In the pooled mean, under polyhouse Arka Alok (0.22 per cent) and inside rainshelter Arka Abha (0.41 per cent), recorded maximum acidity per cent.

Table 43: Mean performance of tomato genotypes for ascorbic acid

Genotypes	Ascorbic acid (mg / 100 g fresh weight)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	19.9	22.0	18.7	21.1	19.3	21.6
EC-151568	18.3	20.9	17.5	17.6	17.9	19.3
EC-157568	20.3	23.1	19.6	21.5	20.0	22.3
EC-160885	21.2	23.5	19.8	24.6	20.5	24.1
EC-163605	19.8	24.6	17.8	25.2	18.8	24.9
EC-164263	16.9	22.3	19.7	24.8	18.3	23.6
EC-164563	18.5	20.8	17.7	20.3	18.1	20.6
EC-164670	19.7	20.0	18.1	19.2	18.9	19.6
EC-165395	18.5	20.5	19.7	21.8	18.3	21.2
EC-165690	23.8	24.0	19.0	25.1	21.4	24.6
EC-165700	22.2	24.2	21.1	23.1	21.7	23.7
EC-249514	20.2	21.9	19.2	21.7	19.7	21.8
EC-521067 B	20.0	20.8	19.7	23.1	19.9	22.0
EC-528368	22.1	26.1	20.1	23.0	21.1	24.6
EC-538153	17.4	22.1	20.3	22.8	18.9	22.5
EC-620376	20.2	23.7	21.1	23.2	20.7	23.5
EC-620378	22.1	22.8	16.8	24.7	21.6	23.8
EC-620382	18.4	20.5	21.6	25.2	20.0	22.9
EC-620387	19.5	24.0	21.1	22.8	20.3	23.4
EC-620389	18.1	21.8	20.2	23.6	19.2	22.7
EC-620395	18.7	21.0	21.3	22.6	20.0	21.8
EC-620401	22.1	24.0	21.7	22.9	21.9	23.5
EC-620406	17.0	21.6	18.4	22.8	17.7	22.2
EC-620410	19.9	23.1	17.7	23.2	18.8	23.2
EC-620417	18.8	21.0	19.2	25.1	19.0	23.1
EC-620427	17.0	23.8	19.1	23.6	18.1	23.7
EC-620429	21.4	21.5	20.2	23.1	20.8	22.3
EC-631369	20.1	23.5	21.0	23.6	20.6	23.6
EC-631379	16.4	20.9	19.1	22.8	17.8	21.7
Pusa Ruby	24.6	25.1	20.5	21.2	22.6	23.2
Arka Abha	18.9	25.2	21.5	24.0	20.2	24.6
Arka Saurabh	19.2	24.1	20.4	21.4	19.8	22.8
Arka Alok	17.9	22.0	19.4	23.7	18.7	22.9
Akshay	19.1	22.6	20.7	20.8	19.9	21.7
Anagha	19.1	24.1	17.9	24.1	18.5	24.1
CD (0.05)	2.6	2.7	2.6	2.9	2.3	2.8
CV	6.0	6.0	6.6	6.4	7.2	6.1

Table 44: Mean performance of tomato genotypes for acidity

Genotypes	Acidity (per cent)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	0.17	0.34	0.19	0.23	0.18	0.29
EC-151568	0.18	0.19	0.14	0.27	0.16	0.23
EC-157568	0.17	0.37	0.12	0.36	0.17	0.37
EC-160885	0.17	0.21	0.17	0.31	0.17	0.26
EC-163605	0.19	0.2	0.15	0.24	0.17	0.22
EC-164263	0.17	0.21	0.18	0.4	0.17	0.30
EC-164563	0.18	0.26	0.2	0.32	0.19	0.29
EC-164670	0.2	0.21	0.13	0.21	0.16	0.21
EC-165395	0.21	0.27	0.13	0.3	0.17	0.28
EC-165690	0.21	0.34	0.19	0.41	0.20	0.38
EC-165700	0.19	0.36	0.23	0.36	0.20	0.36
EC-249514	0.2	0.33	0.24	0.46	0.21	0.39
EC-521067 B	0.20	0.31	0.17	0.38	0.19	0.34
EC-528368	0.18	0.29	0.17	0.34	0.18	0.31
EC-538153	0.21	0.26	0.20	0.40	0.21	0.33
EC-620376	0.2	0.25	0.14	0.31	0.17	0.28
EC-620378	0.19	0.22	0.2	0.3	0.19	0.25
EC-620382	0.21	0.22	0.17	0.27	0.19	0.24
EC-620387	0.17	0.24	0.18	0.37	0.17	0.30
EC-620389	0.19	0.31	0.17	0.25	0.18	0.28
EC-620395	0.19	0.36	0.18	0.41	0.18	0.38
EC-620401	0.14	0.17	0.13	0.37	0.13	0.27
EC-620406	0.12	0.26	0.14	0.36	0.13	0.31
EC-620410	0.20	0.22	0.18	0.23	0.19	0.23
EC-620417	0.20	0.26	0.15	0.23	0.17	0.24
EC-620427	0.22	0.32	0.18	0.37	0.2	0.35
EC-620429	0.19	0.29	0.17	0.26	0.18	0.27
EC-631369	0.15	0.32	0.16	0.41	0.15	0.36
EC-631379	0.21	0.28	0.20	0.33	0.21	0.30
Pusa Ruby	0.22	0.26	0.17	0.33	0.2	0.29
Arka Abha	0.21	0.36	0.21	0.45	0.21	0.41
Arka Saurabh	0.22	0.35	0.21	0.39	0.21	0.37
Arka Alok	0.24	0.26	0.19	0.33	0.22	0.29
Akshay	0.21	0.25	0.23	0.33	0.21	0.29
Anagha	0.21	0.22	0.18	0.26	0.2	0.24
CD (0.05)	0.02	0.07	0.04	0.11	0.04	0.1
CV	6.0	11.9	11.4	16.9	10.3	14.9

4.1.1.4.5 Cholorophyll content (mg / 100 g plant tissue)

There was significant difference among the genotypes for chlorophyll content (Table 45).

4.1.1.4.5.1Cholorophyll a

During summer evaluation under polyhouse, the chlorophyll a was recorded highest for EC-620378 (1.16 mg / 100 g plant tissue), followed by EC-165395 (0.95 mg / 100 g plant tissue). Inside the rainshelter the chlorophyll a was recorded highest for EC-249514 (0.42 mg / 100 g plant tissue), followed by EC-620417 and Arka Alok (0.41 mg / 100 g plant tissue).

In the rainy season under polyhouse, the chlorophyll a was recorded highest for EC-620429 (1.50 mg / 100 g plant tissue), followed by EC-151568 (1.49 mg / 100 g plant tissue). Inside the rainshelter, the highest chlorophyll a was recorded for the genotype EC-620395 (0.55 m g / 100 g plant tissue), EC-620389 (0.53 m g / 100 g plant tiss).

In the pooled mean, under polyhouse EC-620378 (1.16 mg / 100 g plant tissue) and inside rainshelter EC-165690 (0.46 mg / 100 g plant tissue), recorded maximum chlorophyll a content.

4.1.1.4.5.2Cholorophyll b

During summer under the polyhouse, the highest cholorophyll b was recorded for EC-163605 (0.33 mg / 100 g plant tissue). Inside the rainshelter, the chlorophyll b content was recorded maximum for EC-620417 and Arka Alok (0.14 mg / 100 g plant tissue).

In the rainy season under polyhouse, the chlorophyll b was observed to be maximum for EC-631369 (0.43 mg / 100 g plant tissue). Inside the raishelter, the highest chlorophyll b content was recorded for Pusa Ruby and EC-164670 (0.18 mg / 100 g plant tissue).

In the pooled mean, under polyhouse EC-163605 (0.36 mg / 100 g plant tissue) and inside rainshelter EC-620410 (0.15 mg / 100 g plant tissue), recorded maximum chlorophyll b content.

4.1.1.4.5.3 Total cholorophyll

During summer under polyhouse, the highest total cholorophyll content was recorded for EC-620378 (1.84 mg / 100 g plant tissue). Inside the rainshelter, the highest total cholorophyll content was recorded for EC-620417 and Arka Alok (0.83 mg / 100 g plant tissue).

In the rainy season under polyhouse, the highest total cholorophyll content was recorded for EC-164263(2.62 mg / 100 g plant tissue). Inside the rainshelter, the highest total cholorophyll content was recorded for EC-620389 (1.15 mg / 100 g plant tissue), followed by EC-620395 (1.1 mg / 100 g plant tissue).

In the pooled mean, under polyhouse EC-620387 (2.06 mg / 100 g plant tissue) and inside rainshelter Arka Saurabh (0.86 mg / 100 g plant tissue), recorded maximum total chlorophyll content.

4.1.1.5 Incidence of pest and diseases

4.1.1.5.1 Bacterial wilt incidence (%)

There was significant difference among the genotypes for bacterial wilt incidence in both the seasons under both the structures (Table 46). During summer evaluation the bacterial wilt incidence ranged from 0% to 68.8% in both growing structures. Under polyhouse 22 genotypes *viz:*EC-151568, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-528368, EC-538153, EC-620376, EC-620378, EC-620382, EC-620387, EC-620395, EC-620427, EC-620429, EC-631379, Arka Abha, Arka Saurabh, Akshaya and Anagha recorded 0% wilt incidence, thus showing resistance. The genotype Pusa Ruby recorded highest wilt per cent (68.8%), followed by EC-157568 (65.2%). Inside rainshelter 15 genotypes EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-528368, EC-538153, EC-

620376, EC-620382, EC-620427, EC-620429, Arka Abha, Akshaya and Anagha exhibited resistance reaction recording 0% wilting. Inside rainshelter also Pusa Ruby (68.8%) recorded highest wilt per cent, followed by EC-145057 and EC-157568 (62.5%). Maximum and minimum per cent incidence was same for both the structures. Polyhouse exhibited more genotypes under resistant category.

In the rainy season under polyhouse the bacterial wilt per cent was in the range between 0% and 50.0%. Twenty genotypes, *viz:* EC-151568, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B, EC-528368, EC-620376, EC-620382, EC-620389, EC-620395, EC-620401, EC-620427, EC-620429, EC-631379, Arka Abha, Akshaya and Anagha recorded 0% wilt incidence showing resistance reaction. The highest wilt incidence was recorded in Pusa Ruby (50.0%) followed by EC-249514 and Arka Alok (43.8%). Inside the rainshelter the bacterial wilt incidence was in the range between 0% and 75.0%. Inside rainshelter, eleven genotypes *viz:* EC-164670, EC-165395, EC-165700, EC-620376, EC-620378, EC-620382, EC-620427, EC-620429, Arka Abha, Akshaya and Anagha exhibited resistance reaction recording 0% wilting. The highest wilt per cent was for Pusa Ruby (75.0%), followed by EC-157568 and EC-164263 (68.8%). Bacterial wilt incidence was more severe in the rainy season. In the rainy season also per cent wilt incidence and number of genotypes wilting were less under polyhouse.

In the pooled mean, under polyhouse and inside rainshelter Pusa Ruby recorded maximum wilting, (59.4% and 71.9% respectively).

Table 45: Mean performance of tomato genotypes for chlorophyll

Genotypes	Chlorophyll (mg / 100 g plant tissue)																	
	Chlorophyll a						Chlorophyll b						Total chlorophyll					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-145057	0.56	0.27	1.3	0.37	0.93	0.32	0.18	0.10	0.37	0.15	0.28	0.13	1.06	0.59	2.38	0.83	1.42	0.71
EC-151568	0.63	0.34	1.49	0.36	1.06	0.35	0.22	0.11	0.40	0.12	0.31	0.11	1.13	0.65	2.5	0.73	1.3	0.69
EC-157568	0.47	0.31	0.93	0.39	0.7	0.35	0.24	0.11	0.30	0.13	0.27	0.12	1.19	0.65	1.84	0.76	1.52	0.70
EC-160885	0.82	0.35	0.98	0.42	0.9	0.39	0.29	0.11	0.31	0.11	0.30	0.11	1.66	0.68	1.96	0.77	1.81	0.73
EC-163605	0.62	0.31	1.13	0.38	0.87	0.35	0.33	0.10	0.39	0.14	0.36	0.12	1.55	0.62	2.34	0.78	1.95	0.7
EC-164263	0.42	0.32	1.41	0.38	0.92	0.35	0.27	0.11	0.36	0.12	0.32	0.11	1.26	0.41	2.62	0.73	1.94	0.57
EC-164563	0.34	0.30	0.9	0.32	0.62	0.31	0.30	0.10	0.29	0.13	0.30	0.11	1.25	0.58	1.73	0.72	1.49	0.65
EC-164670	0.69	0.32	1.09	0.43	0.89	0.38	0.30	0.10	0.29	0.18	0.30	0.14	1.55	0.62	2.03	0.97	1.79	0.8
EC-165395	0.95	0.4	1.29	0.36	1.12	0.38	0.28	0.12	0.38	0.16	0.33	0.14	1.76	0.76	2.31	0.86	2.04	0.81
EC-165690	0.88	0.39	1.43	0.50	1.16	0.46	0.25	0.13	0.39	0.11	0.32	0.12	1.66	0.76	2.3	0.86	1.98	0.81
EC-165700	0.49	0.36	1.16	0.44	0.82	0.40	0.28	0.12	0.41	0.12	0.35	0.12	1.36	0.73	2.23	0.82	1.8	0.77
EC-249514	0.39	0.42	1.04	0.44	0.72	0.43	0.30	0.13	0.31	0.11	0.31	0.12	1.25	0.83	1.86	0.78	1.56	0.80
EC-521067 B	0.55	0.4	0.90	0.47	0.73	0.43	0.25	013	0.29	0.11	0.27	0.12	1.23	0.74	1.90	0.82	1.57	0.78
EC-528368	0.4	0.40	1.11	0.38	0.75	0.39	0.25	0.13	0.30	0.15	0.28	0.14	1.27	0.80	2.22	0.82	1.74	0.81
EC-538153	0.55	0.28	1.38	0.39	0.97	0.33	0.26	0.11	0.40	0.15	0.33	0.13	1.35	0.59	2.28	0.85	1.82	0.72
EC-620376	0.81	0.29	1.22	0.34	1.02	0.32	0.29	0.10	0.38	0.12	0.33	0.11	1.66	0.58	2.11	0.73	1.89	0.65
EC-620378	1.16	0.30	1.16	0.33	1.16	0.32	0.24	0.11	0.30	0.11	0.27	0.11	1.84	0.64	2.27	0.68	2.05	0.66

Table 45: Continued

Genotypes	Chlorophyll (mg / 100 g plant tissue)																	
	Chlorophyll a						Chlorophyll b						Total chlorophyll					
	Summer season		Rainy season		Mean		Summer season		Rainy season		Mean		Summer season		Rainy season		Mean	
	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS	PH	RS
EC-620382	0.8	0.35	1.26	0.43	1.03	0.39	0.27	0.12	0.29	0.12	0.28	0.12	1.65	0.67	2.18	0.82	1.91	0.75
EC-620387	0.76	0.28	1.05	0.47	0.91	0.38	0.29	0.10	0.42	0.17	0.36	0.13	1.67	0.58	2.46	0.98	2.06	0.78
EC-620389	0.75	0.23	1.04	0.53	0.89	0.38	0.28	0.08	0.38	0.16	0.33	0.12	1.55	0.48	2.08	1.15	1.81	0.81
EC-620395	0.62	0.31	0.86	0.55	0.74	0.43	0.31	0.09	0.29	0.15	0.30	0.12	1.53	0.58	2.45	1.1	1.99	0.84
EC-620401	0.8	0.29	1.21	0.47	1.0	0.38	0.30	0.09	0.31	0.15	0.30	0.12	1.66	0.57	2.2	0.93	1.93	0.75
EC-620406	0.80	0.36	1.15	0.44	0.98	0.4	0.29	0.12	0.31	0.14	0.30	0.13	1.64	0.72	2.08	0.89	1.86	0.81
EC-620410	0.77	0.36	1.12	0.44	0.95	0.4	0.22	0.12	0.38	0.17	0.30	0.15	1.44	0.71	2.23	0.83	1.84	0.77
EC-620417	0.50	0.41	0.93	0.44	0.72	0.42	0.25	0.14	0.41	0.12	0.33	0.13	1.26	0.83	2.31	0.82	1.79	0.83
EC-620427	0.57	0.40	1.12	0.38	0.85	0.39	0.25	0.13	0.30	0.14	0.28	0.14	1.38	0.8	2.2	0.79	1.79	0.79
EC-620429	0.63	0.38	1.50	0.37	1.07	0.38	0.24	0.13	0.27	0.14	0.26	0.13	1.36	0.79	2.35	0.80	1.85	0.8
EC-631379	0.53	0.28	1.16	0.37	0.85	0.33	0.26	0.10	0.43	0.14	0.35	0.12	1.25	0.72	2.35	0.8	1.8	0.76
EC-631379	0.53	0.29	0.96	0.36	0.75	0.33	0.26	0.09	0.40	0.13	0.33	0.11	1.4	0.57	1.62	0.74	1.51	0.66
Pusa Ruby	0.44	0.28	1.29	0.48	0.87	0.38	0.28	0.10	0.34	0.18	0.31	0.14	1.28	0.58	2.44	1.02	1.86	0.8
Arka Abha	0.45	0.36	1.16	0.44	0.81	0.40	0.26	0.12	0.32	0.16	0.29	0.14	1.25	0.72	2.2	0.91	1.73	0.82
Arka Saurabh	0.36	0.37	1.34	0.49	0.85	0.43	0.29	0.12	0.31	0.16	0.30	0.14	1.25	0.73	2.22	0.98	1.73	0.86
Arka Alok	0.43	0.41	1.07	0.47	0.75	0.44	0.28	0.14	0.25	0.13	0.27	0.13	1.27	0.83	1.81	0.99	1.54	0.91
Akshaya	0.53	0.31	0.9	0.46	0.67	0.38	0.29	0.10	0.29	0.16	0.29	0.13	1.37	0.63	1.84	0.97	1.60	0.80
Anagha	0.44	0.31	1.08	0.45	0.76	0.38	0.29	0.10	0.30	0.16	0.29	0.13	1.37	0.65	1.96	0.94	1.03	0.79
CD (0.05)	0.09	0.04	0.20	0.03	0.05	0.03	0.06	0.03	0.22	0.03	0.04	0.02	0.21	0.11	0.37	0.06	0.29	0.11
CV	7.73	6.17	8.76	3.52	18.9	14.4	3.38	3.77	10.6	3.14	15.2	16.3	7.34	8.36	8.32	3.39	18.8	15.4

Table 46: Scoring of genotypes for bacterial wilt incidence

Reaction	Genotypes				Combined and pooled mean	
	Summer evaluation		Rainy season evaluation			
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
R (<10%)	EC-151568, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-528368, EC-538153, EC-620376, EC-620378, EC-620382, EC-620395, EC-620427, EC-620429, EC-631379, Arka Abha, Arka Saurabh, Akshaya and Anagha	EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-528368, EC-538153, EC-620376, EC-620382, EC-620427, EC-620429, Arka Abha, Akshaya and Anagha	EC-151568, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B, EC-528368, EC-620376, EC-620382, EC-620389, EC-620395, EC-620401, EC-620427, EC-620429, EC-631379, Arka Abha, Akshaya and Anagha	EC-164670, EC-165395, EC-165700, EC-620376, EC-620378, EC-620382, EC-620427, EC-620429, Arka Abha, Akshaya and Anagha	EC-151568, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-528368, , EC-620376, EC-620382, EC-620395, EC-620427, EC-620429, EC-631379, Arka Abha, Arka Saurabh, Akshaya and Anagha	EC-164670, EC-165395, EC-165700, EC-620376, EC-620382, EC-620427, EC-620429, Arka Abha, Akshaya and Anagha
MR (10 2-%)	EC-145057, EC-160885, EC-249514, EC-521067 B, EC-620387, EC-620406, EC-620410, EC-631369, Arka Alok	EC-151568	EC-145057, EC-620378,	EC-521067 B, EC-631369,	EC-145057, EC-249514, EC-521067 B, EC-538153,, EC-620378	EC-538153, EC-163605, EC-164563, EC-165690, EC-528368, EC-538153, EC-620378,
MS (20-30%)	EC-620417,	EC-249514, EC-620378, EC-620406, EC-620410, EC-631369, EC-631379, Arka Saurabh, Arka Alok	EC-157568, EC-160885, EC-620387, EC-620410,	EC-145057, EC-160885, EC-165690, EC-538153, EC-620387, EC-620395,	EC-157568, EC-160885, EC-620387, EC-620410, EC-620417, EC-631369, Arka Alok	EC-151568, EC-249514, EC-521067 B, EC-620395, EC-620401, Arka Alok
S (30- 70 %)	EC-157568, EC-620389, EC-620401, Pusa Ruby	EC-145057, EC-157568, EC-160885, EC-164263, EC-521067 B, EC-620387, EC-620389, EC-620395, EC-620401, EC-620417, Pusa Ruby	EC-164263, EC-249514, EC-538153, EC-620406, EC-620417, EC-631369, Pusa Ruby, Arka Saurabh, Arka Alok	EC-151568, EC-157568, EC-163605, EC-164263, EC-164563, EC-249514, EC-528368, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-631379, Arka Saurabh, Arka Alok	EC-620401, EC-620406, Pusa Ruby	EC-145057, EC-157568, EC-160885, Ec-164263, EC_620387, EC-620389, EC-620406, EC-620410, EC-620417, Pusa Ruby, Arka Saurabh
HS (>70%)				Pusa Ruby		

4.1.1.5.2 Fruit cracking (%)

Fruit cracking was observed in both the seasons in both the growing structures. The scoring is given in the Table 47. Under polyhouse in summer evaluation, thirty one genotypes *viz:* EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B , EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-6313, Pusa Ruby , Arka Abha , Arka Alok , Akshaya and Anagha were resistant to fruit cracking (0%), thus the score zero. There was only one genotype with score one, EC-164263 (12.6%). EC-620378 (20.3%), EC-620395 (20.3%) and Arka Saurabh (18.7%) recorded score 2. Inside rainshelter, twenty nine genotypes *viz:* EC-145057, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha were resistant (0%) and recorded score zero. EC-538153 (10.4%) recorded score one.

In the rainy season fruit crack incidence was higher. Under polyhouse, thirty genotypes *viz:* EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B , EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-6313, Pusa Ruby , Arka Abha , Arka Alok , Akshaya and Anagha were resistant to fruit cracking (0%), thus the score zero. Two genotypes, EC-164563 (13.2%) and EC-249514 (11.5%), recorded score one. EC-620378 (20.5%) recorded score two and EC-620395 (38.3%) and Arka Saurabh (30.7%) recorded score three. Inside rainshelter, EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-538153, EC-620376, EC-620382, EC-

620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Akshaya and Anagha were resistant (0%) and recorded zero score. EC-249514 (10.7%), EC-521067 B (13.5%), EC-528368 (9.7%), EC-620387 (14.5%) and EC-620395 (12.5%) exhibited score one. EC-620389 (22.5%) recorded score two and EC-620378 (40.2%), Arka Saurabh (35.3%) and Arka Alok (32.5%) recorded score three.

4.1.1.5.3 Blossom end rot (%)

Blossom end rot was observed in both the seasons in both the growing structures. Scoring is given in Table 48. In the summer evaluation under polyhouse, thirty one genotypes *viz:* EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha were resistant (0%) and the score was zero. EC-164263 (7.5%) exhibited score one. Inside rainshelter, thirty genotypes *viz:* EC-145057, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-620376, EC-620378, EC-620382, EC-620387, EC-620389, EC-620395, EC-620401, EC-620406, EC-620410, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha were resistant (0%) and the score was zero. Only one genotype, EC-538153 (14.5%), recorded score one.

In the rainy season the incidence was more. Under polyhouse thirty genotypes *viz:* EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha were resistant (0%) and the score was zero. EC-249514 (7.5%) recorded score one. EC-164563 (26.8%) and Arka Saurabh (25.5%) recorded score three. Inside rainshelter, twenty six genotypes *viz:* EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-538153, EC-620376, EC-620382, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Akshaya and Anagha were resistant (0%) and the score was zero. The genotypes, EC-249514 (10.5%), EC-521067 B (10.5%), EC-528368, EC-620387 (12.4%) and EC-620395 (13.6%), recorded the score one. Two genotypes, EC-620378 (21.5%) and EC-620389 (20.8%), recorded the score two. Arka Saurabh (27.5%) and Arka Alok (30.2%) recorded score three.

4.1.1.5.4 Incidence of other pest and diseases

The leaf minor and fruit borer attacks were observed. Leaf minor attck was noticed only inside the rainshelter. During summer evaluation the attack was noticed in seven genotypes EC-157568, EC-164563, EC-249514, EC-620378, EC-620417, EC-631379 and Pusa Ruby. The infestation ranged between 12.4% and 22.5%. The highest infestation was observed in the genotype Pusa Ruby (22.5%). In the rainy season only five genotypes EC-249514, EC-620395, EC-620417, EC-631379 and Arka Saurabh recorded leaf minor infestation in the rainy season. The highest infestation was observed in the genotype EC-620395 (28.7%).

The fruit borer attack was observed for both the seasons under both the structures. EC-163605, EC-620378 and EC-631369 recorded fruit borer attack in the summer evaluation under polyhouse condition. In the rainshelter the genotypes EC-165700, EC-249514, EC-521067 B, EC-538153, EC-620387 and EC-620389 recorded infestation. In the rainy season under polyhouse only EC-163605 and EC-249514 recorded the infestation. In the rainshelter the genotypes EC-249514 and EC-620387 recorded the infestation.

Table 47: Scoring of genotypes for fruit crack infestation

Score	Genotypes			
	Summer evaluation		Rainy season evaluation	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter
0	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya, Anagha	EC-145057, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya, Anagha	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya, Anagha	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-538153, EC-620376, EC-620382, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Akshaya, Anagha
1	EC-164263	EC-538153	EC-164563 and EC-249514,	EC-249514, EC-521067 B, EC-528368, EC-620387 and EC-620395
2	EC-620378, EC-620395 and Arka Saurabh	EC-164263 and EC-620378	EC-620378	EC-620389
3		EC-151568, EC-620395 and Arka Saurabh	EC-620395 and Arka Saurabh	EC-620378, Arka Saurabh and Arka Alok
4	Nil	Nil	Nil	Nil
5	Nil	Nil	Nil	Nil

Table 48: Scoring of genotypes for Blossom End Rot infestation

Score	Genotypes			
	Summer evaluation		Rainy season evaluation	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter
0	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha	EC-145057, EC-157568, EC-160885, EC-163605, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-249514, EC-521067 B, EC-528368, EC-620376, EC-620378, EC-620382, EC-620387, EC-620389, EC-620395, EC-620401, EC-620406, EC-620410, EC-620427, EC-620429,EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164670, EC-165395, EC-165690, EC-165700, EC-521067 B, EC-528368, EC-538153, EC-620376, EC-620382, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Arka Alok, Akshaya and Anagha	EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164563, EC-164670, EC-165395, EC-165690, EC-165700, EC-538153, EC-620376, EC-620382, EC-620401, EC-620406, EC-620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Akshaya and Anagha
1	EC-164263	EC-538153	EC-249514	EC-249514, EC-521067 B, EC-528368, EC-620387, and EC-620395
2	EC-620378, EC-620395 and Arka Saurabh	EC-164263 and EC-620417	EC-620378 and EC-620395	EC-620378 and EC-620389
3		EC-151568 and Arka Saurabh	EC-164563 and Arka Saurabh	Arka Saurabh and Arka Alok
4	Nil	Nil	Nil	Nil
5	Nil	Nil	Nil	Nil

Table 49: Scoring of susceptible genotypes for leaf minor infestation - rainshelter

Genotype	Score	
	Summer season	Rainy season
	Score	Score
EC-157568	2	1
EC-164563	2	1
EC-249514	2	1
EC-620378	2	1
EC-620395	1	3
EC-620417	2	2
EC-631379	2	2
Pusa Ruby	2	1
Arka Saurabh	1	2

Table 50: Scoring of susceptible genotypes for fruit borer infestation

Genotype	Score			
	Summer season		Rainy season	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-151568	0	3	0	0
EC-164263	1	0	0	0
EC-164563	0	0	1	0
EC-249514	0	0	1	1
EC-521067 B	0	0	0	1
EC-528368	0	0	0	1
EC-538153	0	1	0	0
EC-620378	2	0	2	3
EC-620387	0	2	0	1
EC-620389	0	3	2	0
EC-620395	2	0	3	1
Arka Saurabh	2	3	3	3
Arka Alok	0	0	0	3

4.1.1.6 Shelf life (No. of days)

There was significant difference among the genotypes for shelf life in both the seasons under both the structures (Table 51). During summer evaluation under polyhouse, the shelf life varied between 3.5 days and 11.5 days. The longest shelf life was recorded for EC-620395 (11.5 days), followed by EC-620406 (10.6 days). Inside rainshelter, the shelf life was in the range between 3.2 days and 9.2 days. The longest shelf life was observed for EC-620387 and EC-620401 (9.2 days), followed by EC-620395 and EC-620410 (9.0 days).

In the rainy season under polyhouse, the shelf life was in the range between 5.0 days and 14.5 days. The longest shelf life was recorded for EC-620395 (14.5 days) followed by EC-620387 (14.2 days). Inside rainshelter, the shelf life was in the range between 4 days and 11.5 days. The longest shelf life was recorded for EC-620395 and Arka Alok (11.5 days), followed by EC-620406 (11.2 days).

In the pooled analysis, under polyhouse and inside rainshelter EC-620395 recorded maximum shelf life (13 days and 10.3 days, respectively).

4.1.2 Performance of genotypes for qualitative characters

The qualitative observations were taken on fruit size, fruit shape, immature fruit skin colour, presence of green shoulders, fruit colour, fruit surface and blossom end fruit shape (Table 52 – 55 and Plate 6).

4.1.2.1 Fruit size

The fruit size of the genotypes varied from very small, small, medium and medium large, in both the seasons under both the growing structures. The medium large fruits were born in EC-620406, EC-620410, EC-620427and EC-620429 for both the seasons under different growing structures. The genotype EC-620401 produced medium large fruits irrespective of season and structure.

Table 51: Mean performance of tomato genotypes for shelf life

Genotypes	Shelf life (no. of days)					
	Summer season		Rainy season		Mean	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	5.5	3.5	7.1	7.9	6.3	5.7
EC-151568	4.5	4.9	7.1	8.5	5.8	6.7
EC-157568	6.8	5.5	8.2	6.3	7.5	5.9
EC-160885	3.1	3.5	7.5	7	5.3	5.3
EC-163605	6.3	6.8	6	5.5	6.2	6.2
EC-164263	10	8.5	10.2	8.2	10.1	8.4
EC-164563	8.5	6.9	6.5	5	7.5	6.0
EC-164670	6.6	4.5	8	6.5	7.3	5.5
EC-165395	6.5	5	9.5	7	8.0	6.0
EC-165690	5.5	4.8	7.5	7.5	6.5	6.2
EC-165700	5	3.5	5	4.3	5.0	3.9
EC-249514	7.2	6.9	10	8.2	8.6	7.6
EC-521067 B	8.2	7.9	10.5	8.3	9.4	8.1
EC-528368	4.5	3.5	5	5	4.8	4.3
EC-538153	10	8.5	12.5	11	11.3	9.8
EC-620376	5.2	3.5	5	4	5.1	3.8
EC-620378	7.5	6.5	10	8.5	8.8	7.5
EC-620382	9.5	8.5	12	10	10.8	9.3
EC-620387	10	9.2	14.2	10.7	12.1	10.0
EC-620389	10	8.2	13.5	10	11.8	9.1
EC-620395	11.5	9	14.5	11.5	13.0	10.3
EC-620401	10.2	9.2	13.2	10.5	11.7	9.9
EC-620406	10.5	8.9	13.6	11.2	12.1	10.1
EC-620410	10	9	12.5	10	11.3	9.5
EC-620417	9	7.5	12	9	10.5	8.3
EC-620427	7.5	7.5	10	9.2	8.8	8.4
EC-620429	8.5	8.4	13.5	9.5	11.0	9.0
EC-631369	8.5	8.1	11.3	9.6	9.9	8.9
EC-631379	5	3.3	11	9	8.0	6.2
Pusa Ruby	4.5	3.2	7	5	5.8	4.1
Arka Abha	7.8	6.5	8.5	6	8.2	6.3
Arka Saurabh	8.5	7.5	9	7.5	8.8	7.5
Arka Alok	9.5	8	10	11.5	9.8	9.8
Akshay	9	7.5	10	7.5	9.5	7.5
Anagha	7.5	6.5	9	7	8.3	6.8
CD (0.05)	1.3	1.1	1.5	1.5	1.3	1.2
CV	8.3	11.2	12.5	13.6	10.8	8.5

4.1.2.2 Fruit shape

The fruit shape varied from flat round, slightly flattened, round, oval, heart shaped, banana type and plum shaped among the genotypes. The heart shape was seen only in one genotype; Arka Saurabh. EC-620401, EC-620427 and EC-620429 were plum shaped. EC-620406 and EC-620410 were oval shaped.

4.1.2.3 Immature fruit skin colour

The immature fruit skin colour was either greenish white or light green or green or dark green irrespective of season and structure. The genotypes EC-620401 and EC-620410 were greenish white and genotype EC-620376 was dark green.

4.1.2.4 Presence of green shoulders

The green shoulders were observed only in three genotypes inside rainshelter, EC-249514, Arka Abha and Akshaya.

4.1.2.5 Mature fruit colour

The genotypes exhibited yellow, orange, red, crimson, pink, tangarine, yellow and red, tangarine and red, yellow, tangarine and red colours for mature fruit. The polyhouse fruits were more red coloured in both the seasons.

4.1.2.6 Fruit surface

Fruit surface was either smooth or corrugated. Irrespective of season and growing structure, the fruit surface was same for each genotype.

4.1.2.7 Blossom end fruit shape

The blossom end fruit shape was either indented or flat or pointed. The genotypes EC-164563, EC-620382 and EC-620410 were indented. The genotypes EC-538153, EC-620378, EC-620395, EC-620417, Pusa Ruby and Arka Saurabh were pointed, while other genotypes were flat.

Table 52: Fruit size and shape of screened tomato genotypes

Genotypes	Fruit size				Fruit shape			
	Summer evaluation		Rainy season evaluation		Summer evaluation		Rainy season evaluation	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-151568	Medium	Medium	Medium	Medium	Slightly flattened	Slightly flattened	Slightly flattened	Slightly flattened
EC-157568	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-160885	Medium	Medium	Medium	Medium	Banana type	Banana type	Banana type	Banana type
EC-163605	Medium	Medium	Small	Small	Round	Round	Round	Round
EC-164263	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-164563	Medium	Medium	Medium	Medium	Flat round	Flat round	Flat round	Flat round
EC-164670	Medium	Medium	Small	Medium	Round	Round	Round	Round
EC-165395	Small	Small	Small	Small	Round	Round	Round	Round
EC-165690	Small	Small	Small	Small	Round	Round	Round	Round
EC-165700	Very small	Very small	Very small	Very small	Round	Round	Round	Round
EC-249514	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-521067 B	Medium	Medium	Medium	Medium	Oval	Oval	Oval	Oval
EC-528368	Very small	Very small	Very small	Very small	Oval	Oval	Oval	Oval
EC-538153	Medium	Medium	Medium	Medium	Banana type	Banana type	Banana type	Banana type
EC-620376	Very small	Very small	Very small	Very small	Round	Round	Round	Round
EC-620378	Medium	Medium	Medium	Medium	Banana type	Banana type	Banana type	Banana type

Table 52: Continued

Genotypes	Fruit size				Fruit shape			
	Summer season		Rainy season n		Summer season		Rainy season	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-620382	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-620387	Medium	Medium	Medium	Medium	Plum shaped	Plum shaped	Plum shaped	Plum shaped
EC-620389	Medium	Medium	Medium	Medium	Flat round	Flat round	Flat round	Flat round
EC-620395	Medium	Medium	Medium	Medium	Plum shaped	Plum shaped	Plum shaped	Plum shaped
EC-620401	Medium	Medium large	Medium large	Medium large	Plum shaped	Plum shaped	Plum shaped	Plum shaped
EC-620406	Medium large	Medium large	Medium large	Medium large	Oval	Oval	Oval	Oval
EC-620410	Medium large	Medium large	Medium large	Medium large	Oval	Oval	Oval	Oval
EC-620417	Medium	Medium	Medium	Medium	Banana type	Banana type	Banana type	Banana type
EC-620427	Medium large	Medium large	Medium large	Medium large	Plum shaped	Plum shaped	Plum shaped	Plum shaped
EC-620429	Medium large	Medium large	Medium large	Medium large	Plum shaped	Plum shaped	Plum shaped	Plum shaped
EC-631369	Medium	Medium	Medium	Medium	Round	Round	Round	Round
EC-631379	Medium	Medium	Medium	Medium	Slightly flattened	Slightly flattened	Slightly flattened	Slightly flattened
Pusa Ruby	Medium	Medium	Medium	Medium	Oval	Oval	Oval	Oval
Arka Abha	Medium	Medium	Medium large	Medium large	Flat round	Flat round	Flat round	Flat round
Arka Saurabh	Medium	Medium	Medium	Medium	Heart shape	Heart shape	Heart shape	Heart shape
Arka Alok	Medium	Medium	Medium	Medium	Round	Round	Round	Round
Akshaya	Medium	Medium	Medium	Medium	Slightly flattened	Slightly flattened	Slightly flattened	Slightly flattened
Anagha	Medium	Medium	Medium	Medium	Slightly flattened	Slightly flattened	Slightly flattened	Slightly flattened

Table 53: Immature fruit colour and presence of green shoulders of screened tomato genotypes

Genotypes	Immature fruit colour				Presence of green shoulders			
	Summer season		Rainy season		Summer season		Rainy season	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-151568	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-157568	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-160885	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-163605	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-164263	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-164563	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-164670	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-165395	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-165690	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-165700	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent
EC-249514	Light green	Light green	Light green	Light green	Absent	Present	Absent	Present
EC-521067 B	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-528368	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-538153	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620376	Dark green	Dark green	Dark green	Dark green	Absent	Absent	Absent	Absent
EC-620378	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620382	Light green	Light green	Light green	Light green	Absent	Absent	Absent	Absent

Table 53: Continued

Genotypes	Immature fruit colour				Presence of green shoulders			
	Summer season		Rainy season		Summer season		Rainy season	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-620387	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620389	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620395	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620401	Greenish white	Greenish white	Greenish white	Greenish white	Absent	Absent	Absent	Absent
EC-620406	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620410	Greenish white	Greenish white	Greenish white	Greenish white	Absent	Absent	Absent	Absent
EC-620417	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620427	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-620429	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-631369	Green	Green	Green	Green	Absent	Absent	Absent	Absent
EC-631379	Green	Green	Green	Green	Absent	Absent	Absent	Absent
Pusa Ruby	Green	Green	Green	Green	Absent	Absent	Absent	Absent
Arka Abha	Light green	Light green	Light green	Light green	Absent	Present	Absent	Present
Arka Saurabh	Green	Green	Green	Green	Absent	Absent	Absent	Absent
Arka Alok	Green	Green	Green	Green	Absent	Absent	Absent	Absent
Akshaya	Light green	Light green	Light green	Light green	Absent	Present	Absent	Present
Anagha	Green	Green	Green	Green	Absent	Absent	Absent	Absent

Table 54: Mature fruit skin colour and fruit surface of of screened tomato genotypes

Genotypes	Mature fruit skin colour				Fruit surface			
	Summer evaluation		Rainy season evaluation		Summer evaluation		Rainy season evaluation	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	Orange	Orange	Orange	Orange	Smooth	Smooth	Smooth	Smooth
EC-151568	Yellow and red	Yellow and red	Yellow and red	Yellow and red	Corrugated	Corrugated	Corrugated	Corrugated
EC-157568	Red	Red	Red	Red	Corrugated	Corrugated	Corrugated	Corrugated
EC-160885	Red	Red	Red	Red	Smooth	Smooth	Smooth	Smooth
EC-163605	Red	Red	Red	Red	Smooth	Smooth	Smooth	Smooth
EC-164263	Yellow and red	Tangerine	Yellow and red	Tangerine	Smooth	Smooth	Smooth	Smooth
EC-164563	Red	Yellow and red	Red	Yellow and red	Corrugated	Corrugated	Corrugated	Corrugated
EC-164670	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Smooth	Smooth	Smooth	Smooth
EC-165395	Pink	Pink	Pink	Pink	Corrugated	Corrugated	Corrugated	Corrugated
EC-165690	Pink	Pink	Pink	Pink	Corrugated	Corrugated	Corrugated	Corrugated
EC-165700	Yellow and red	Yellow and red	Yellow and red	Yellow and red	Corrugated	Corrugated	Corrugated	Corrugated
EC-249514	Yellow and red	Yellow	Yellow and red	Yellow	Smooth	Smooth	Smooth	Smooth
EC-521067 B	Red	Yellow and red	Red	Yellow and red	Smooth	Smooth	Smooth	Smooth
EC-528368	Red	Red	Red	Red	Smooth	Smooth	Smooth	Smooth
EC-538153	Red	Tangerine and red	Red	Tangerine and red	Smooth	Smooth	Smooth	Smooth
EC-620376	Red	Red	Red	Red	Smooth	Smooth	Smooth	Smooth
EC-620378	Tangerine and red	Tangerine	Tangerine and red	Tangerine	Smooth	Smooth	Smooth	Smooth
EC-620382	Red	Orange	Red	Orange	Corrugated	Corrugated	Corrugated	Corrugated

Table 54: Continued

Genotypes	Mature fruit skin colour				Fruit surface			
	Summer evaluation		Rainy season evaluation		Summer evaluation		Rainy season evaluation	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-620387	Red	Red	Red	Red	Smooth	Smooth	Smooth	Smooth
EC-620389	Yellow and red	Yellow	Yellow and red	Yellow	Corrugated	Corrugated	Corrugated	Corrugated
EC-620395	Orange	Orange	Orange	Orange	Smooth	Smooth	Smooth	Smooth
EC-620401	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Corrugated	Corrugated	Corrugated	Corrugated
EC-620406	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Yellow, tangerine and red	Corrugated	Corrugated	Corrugated	Corrugated
EC-620410	Crimson	Crimson	Crimson	Crimson	Corrugated	Corrugated	Corrugated	Corrugated
EC-620417	Tangerine and red	Tangerine and red	Tangerine and red	Tangerine and red	Smooth	Smooth	Smooth	Smooth
EC-620427	Yellow and red	Yellow and red	Yellow and red	Yellow and red	Smooth	Smooth	Smooth	Smooth
EC-620429	Tangerine and red	Tangerine and red	Tangerine and red	Tangerine and red	Smooth	Smooth	Smooth	Smooth
EC-631369	Red	Red	Red	Red	Corrugated	Corrugated	Corrugated	Corrugated
EC-631379	Red	Red	Red	Red	Corrugated	Corrugated	Corrugated	Corrugated
Pusa Ruby	Yellow and red	Yellow and red	Yellow and red	Yellow and red	Smooth	Smooth	Smooth	Smooth
Arka Abha	Red	Yellow and red	Red	Yellow and red	Corrugated	Corrugated	Corrugated	Corrugated
Arka Saurabh	Tangerine and red	Tangerine and red	Tangerine and red	Tangerine and red	Corrugated	Corrugated	Corrugated	Corrugated
Arka Alok	Red	Red	Red	Red	Corrugated	Corrugated	Corrugated	Corrugated
Akshaya	Red	Red	Red	Red	Corrugated	Corrugated	Corrugated	Corrugated
Anagha	Yellow and red	Yellow and red	Yellow and red	Yellow and red	Smooth	Smooth	Smooth	Smooth

Table 55: Blossom end fruit shape of of screened tomato genotypes

Genotypes	Blossom end fruit shape			
	Summer season		Rainy season	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	Flat	Flat	Flat	Flat
EC-151568	Flat	Flat	Flat	Flat
EC-157568	Flat	Flat	Flat	Flat
EC-160885	Flat	Flat	Flat	Flat
EC-163605	Flat	Flat	Flat	Flat
EC-164263	Flat	Flat	Flat	Flat
EC-164563	Indented	Indented	Indented	Indented
EC-164670	Flat	Flat	Flat	Flat
EC-165395	Flat	Flat	Flat	Flat
EC-165690	Flat	Flat	Flat	Flat
EC-165700	Flat	Flat	Flat	Flat
EC-249514	Flat	Flat	Flat	Flat
EC-521067 B	Flat	Flat	Flat	Flat
EC-528368	Flat	Flat	Flat	Flat
EC-538153	Pointed	Pointed	Pointed	Pointed
EC-620376	Flat	Flat	Flat	Flat
EC-620378	Pointed	Pointed	Pointed	Pointed
EC-620382	Indented	Indented	Indented	Indented
EC-620387	Flat	Flat	Flat	Flat
EC-620389	Flat	Flat	Flat	Flat
EC-620395	Pointed	Pointed	Pointed	Pointed
EC-620401	Flat	Flat	Flat	Flat
EC-620406	Flat	Flat	Flat	Flat
EC-620410	Indented	Indented	Indented	Indented
EC-620417	Pointed	Pointed	Pointed	Pointed
EC-620427	Flat	Flat	Flat	Flat
EC-620429	Flat	Flat	Flat	Flat
EC-631369	Flat	Flat	Flat	Flat
EC-631379	Flat	Flat	Flat	Flat
Pusa Ruby	Pointed	Pointed	Pointed	Pointed
Arka Abha	Flat	Flat	Flat	Flat
Arka Saurabh	Pointed	Pointed	Pointed	Pointed
Arka Alok	Flat	Flat	Flat	Flat
Akshaya	Flat	Flat	Flat	Flat
Anagha	Flat	Flat	Flat	Flat

4.1.3 Identification of hotset genotypes

Tomato (*Solanum lycopersicum*) is an important horticultural crop of the family Solanaceae. The cultivation of this crop in tropical region inevitability results in plants being exposed to higher and widely varying diurnal temperature , light and relative humidity changes for successive days or even weeks. This stress especially in the reproductive phase can greatly hamper the fruit set. In this session the reproductive traits were correlated with each other. To describe the natural variation for environmental stress conditions and to detect correlation between traits, seven reproductive traits were analyzed in tomato genotypes (from Table 56 to Table 61). For this study only summer evaluation crop is considered.

The traits studied were pollen viability, fruit set per cent, flowers with exerted stigma, length of the style, anther length, number of flowers per cluster and number of fruits per cluster during the summer evaluation of the genotypes. These reproductive characters were observed for three different stage of flowering *viz:* early, mid and late stage of flowering. The correlation analysis of these characters was worked to select the most important characters determining the hotset nature in tomato.

4.1.3.1 Correlation of reproductive traits for polyhouse grown plant

The reproductive characters were recorded in the early, mid and late stages of the flowering. Under polyhouse condition in the summer season the early stage flowering was observed from standard week number 10 and 11. The mid stage of flowering was observed for the period between standard weeks 11 and 15. The late stage of flowering was from standard week number 15, 16 and 17.

4.1.3.1.1 Correlation of reproductive characters in early stage of flowering under polyhouse

Under polyhouse condition, flowers with exerted stigma exhibited moderately strong significant negative correlation with pollen viability and furit set per cent (-0.04* and -0.54*). Correlation between flowers with exerted stigma

Plate 6: Fruits of 35 tomato genotypes evaluated

EC-620387

EC-620389

EC-620395

EC-620401

EC-620406

EC-620410

EC-620417

EC-620427

EC-620429

EC-631369

EC-631379

Pusa Ruby

Arka Abha

Arka Saurabh

Arka Alok

Akshava

Anagha

Plate 6: Continued

and length of the style and anther length was weak negative and significant (-0.34*). Pollen viability exhibited moderately strong significant positive correlation with fruit set per cent (0.43*). Very strong positive significant correlation was observed between length of the style and anther length (0.95*). Number of flowers per cluster exhibited moderately strong significant positive correlation with number of fruits per cluster (0.48*) (Table 56 and Plate 7).

Table 56: Correlation matrix of reproductive characters in early stage of flowering under polyhouse

	Flowers with exerted stigma	**Pollen viability**	**Fruit set per cent**	**Length of the style**	**Anther length**	**Number of flowers / cluster**	**No of fruits / cluster**
Flowers with exerted stigma	1	r = -0.4* p = 0.04	r = -0.54* p = 0.001	r = -0.34* p = 0.04	r = -0.34* p = 0.05	r = 0.15 p = 0.38	r = 0.22 p = 0.2
Pollen viability		1	r = 0.43* p =0.01	r = 0.17 p =0.32	r = 0.19 p =0.26	r = 0.01 p =0.96	r = 0.28 p = 0.1
Fruit set per cent			1	r = 0.23 p = 0.18	r = 0.13 p = 0.47	r = -0.04 p = 0.82	r = 0.29 p =0.09
Length of the style				1	r = 0.95* p = 0.0	r = -0.11 p = 0.53	r = 0.03 p = 0.84
Anther length					1	r = -0.04 p = 0.83	r = 0.15 p = 0.41
No of flowers /cluster						1	r = 0.48* p = 0.003
No of fruits / cluster							1

The variation of weather parameters over this period (Annexure 1) was also recorded. The air temperature varied from 32.2°C to 32.5°C at 9 00 am and from 36.4ºC to 37.6°C at 2 00 pm. The soil temperature varied from 30.2°C to 30.5°C at 9 00 am and from 32.6ºC and 34.5°C at 2 00pm. The relative humidity variation was between 74.2% and 74.5% at 9 00 am and between 47.5% and 49.5% at 2 00 pm. The light varied between 382 µmol/m^2/sec and 447 µmol/m^2/sec.

4.1.3.1.2 Correlation of reproductive characters in mid stage of flowering under polyhouse

The correlation between flowers with exerted stigma and pollen viability was moderately strong negative and significant (-0.52*). Length of the style and anther length exhibited very strong positive significant correlation (0.98*). Moderately strong positive significant correlation was observed between number of flowers per cluster and number of fruits per cluster (0.43*) (Table 57 and Plate 8).

Table 57: Correlation matrix of reproductive characters in mid stage of flowering under polyhouse

	Flowers with exerted stigma	Pollen viability	Fruit set per cent	Length of the style	Anther length	Number of flowers /cluster	No of fruits /cluster
Flowers with exerted stigma	1	r = -0.52* p = 0.001	r = -0.27 p = 0.11	r = -0.02 p = 0.92	r = -0.05 p = 0.76	r = 0.17 p = 0.32	r = 0.09 p = 0.62
Pollen viability		1	r = 0.31* p =0.05	r = 0.23 p =0.18	r = 0.16 p =0.36	r = -0.06 p =0.74	r = -0.09 p = 0.61
Fruit set per cent			1	r = 0.01 p = 0.97	r = 0.04 p = 0.82	r = -0.2 p = 0.24	r = 0.27 p =0.11
Length of the style				1	r = 0.98* p = 0.0	r = -0.16 p = 0.74	r = 0.02 p = 0.92
Anther length					1	r = -0.12 p = 0.51	r = 0.14 p = 0.43
No of flowers / cluster						1	r = 0.43* p = 0.01
No of fruits / cluster							1

The weather parameters over this period varied as given in the Annexure I. The air temperature was in the range between 30.8°C and 32.5°C at 9 00 am and from 34.5°C and 37.5°C at 2 00 pm. The soil temperature varied from 28.7°C to 30.5°C at 9 00 am and from 30.2°C to 33.5°C at 2 00 pm. The variation of RH over this period was from 73.5% to 79.2% at 9 00 am and from 45.2% to 49.2% at 2 00 pm. The light variation recorded was from 347µmol/m^2/sec to 457µmol/m^2/sec.

4.1.3.1.3 Correlation of reproductive characters in late stage of flowering under polyhouse

Flowers with exerted stigma exhibited strong negative significant correlation with pollen viability (-0.75*). There observed strong positive significant correlation between pollen viability and fruit set per cent (0.69*). Correlation between fruit set per cent and number of fruits per cluster was moderately strong positive and significant (0.48*). Very strong positive significant correlation was observed between length of the style and anther length (0.98*). Number of fruits per cluster exhibited strong positive significant correlation with number of flowers per cluster (0.75*) (Table 58 and Plate 9).

The variation in the air temperature was in the range between 31.8°C and 32.8°C at 9.00 am and from 37.0°C to 37.6°C at 2 00 pm. The soil temperature varied from 29.8°C to 30.8°C at 9 00 am and from 31.8°C to 34.3°C at 2 00 pm. The variation in the RH was from 73.5% to 74.5% at 9 00 am and between 46.3% and 47.5% at 2 00pm. Light variation was between 387 µmol/m^2/sec and 454 µmol/m^2/sec (Appendix 1).

Under polyhouse moderately strong, positive and significant correlation was observed between pollen viability and fruit set per cent and fruit set per cent with number of fruits per cluster during early, mid and late stage of flowering. Flowers with exerted stigma exhibited negative significant correlation with pollen viability during early, mid and late stage of flowering and with fruit set per cent at the early stage of flowering.

4.1.3.2 Correlation of reproductive traits for rainshelter grown plant

The observations on reproductive traits were taken in the early stage of flowering (standard week number 9 and 10), mid stage of flowering (standard week number 10,11, 12, 13 and 14) and late stage of flowering (standard week number 14,15 and 16).

Table 58: Correlation matrix of reproductive characters in late stage of flowering under polyhouse

	Flowers with exerted stigma	Pollen viability	Fruit set per cent	Length of the style	Anther length	Number of flowers / cluster	No of fruits / cluster
Flowers with exerted stigma	1	r = -0.75* p = 0.01	r = -0.61 p = 0.1	r = -0.22 p = 0.19	r = -0.21 p = 0.23	r = 0.07 p = 0.69	r = -0.07 p = 0.68
Pollen viability		1	r = 0.69* p =0.05	r = 0.24 p =0.15	r = 0.22 p =0.26	r = -0.03 p =0.85	r = 0.18 p = 0.3
Fruit set per cent			1	r = 0.15 p = 0.39	r = 0.17 p = 0.34	r = 0.18 p = 0.31	r = 0.48* p =0.004
Length of the style				1	r = 0.98* p = 0.0	r = -0.17 p = 0.34	r = -0.03 p = 0.85
Anther length					1	r = -0.12 p = 0.51	r = 0.12 p = 0.92
No of flowers / cluster						1	r = 0.75* p = 0.02
No of fruits / cluster							1

4.1.3.2.1 Correlation of reproductive characters in early stage of flowering inside rainshelter

Flowers with exerted stigma exhibited weak negative significant correlation with fruit set per cent (-0.31*) and moderately strong negative significant correlation with number of fruits per cluster (-0.4*). Pollen viability exhibited weak positive significant correlation with fruit set per cent (0.34*). Number of fruits per cluster exhibited strong positive significant correlation with fruit set per cent (0.6*) and number of flowers per cluster (0.65*). Very strong positive significant correlation was observed between length of the style and anther length (0.98*) (Table 59 and Plate 10).

The weather parameters recorded over the period is given in the Annexure 1. The air temperature varied from 33.2°C to 34.7°C at 9 00 am and from 39.8°C to 40.7°C at 2 00 pm. The soil temperature varied from 30.5°C to 30.8°C at 9 00 am and from 35.1°C and 36.0°C at 2 00 pm. The RH variation was in the range between 63.5% and 65.7% at 9 00 am and between 59.8% and 61.2% at 2 00 pm.

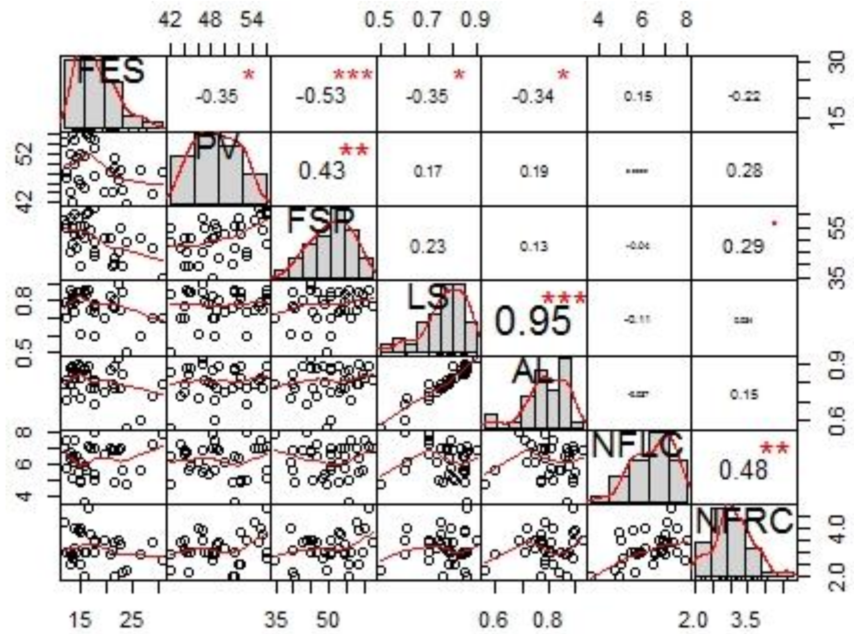


Plate 7: Correlation matrix and scatter plot of polyhouse plants in the early stage of flowering

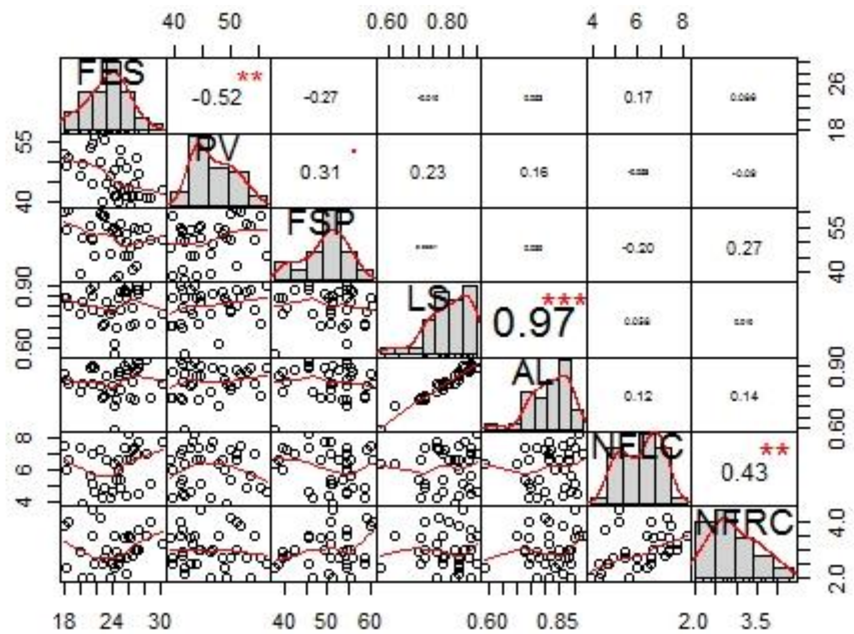


Plate 8: Correlation matrix and scatter plot of polyhouse plants in the mid stage of flowering

The light recorded was in the range between 743 μmol/m^2/sec and 886 μmol/m^2/sec.

Table 59: Correlation matrix of reproductive characters in early stage of flowering inside rainshelter

	Flowers with exerted stigma	Pollen viability	Fruit set per cent	Length of the style	Anther length	Number of flowers / cluster	No of fruits / cluster
Flowers with exerted stigma	1	r = -0.23 p = 0.18	r = -0.31* p = 0.05	r = -0.01 p = 0.97	r = -0.04 p = 0.83	r = -0.17 p = 0.34	r = -0.4* p = 0.03
Pollen viability		1	r = 0.34* p =0.05	r = - 0.15 p =0.38	r = -0.15 p =0.40	r = 0.06 p =0.75	r = 0.17 p = 0.33
Fruit set per cent			1	r = -0.10 p = 0.55	r = -0.08 p = 0.62	r = 0.04 p = 0.81	r = 0.6* p =0.0004
Length of the style				1	r = 0.98* p = 0.0	r = 0.21 p = 0.22	r = 0.15 p = 0.39
Anther length					1	r = 0.24 p = 0.16	r = 0.21 p = 0.23
No of flowers / cluster						1	r = 0.65* p = 0.03
No of fruits / cluster							1

4.1.3.2.2 Correlation of reproductive characters in mid stage of flowering inside rainshelter

Flowers with exerted stigma exhibited moderately strong, negative significant correlation with fruit set per cent. Correlation of pollen viability with fruit set per cent was strong positive and significant (0.6*) and with number of fruits per cluster was weak positive and significant (0.34*). Number of fruits per cluster exhibited moderately strong positive significant correlation with fruit set per cent (0.53*) and strong positive significant correlation with number of flowers per cluster (0.75*). Very strong positive significant correlation was observed between length of the style and anther length (0.99*) (Table 60 and Plate 11).

The weather parameters are depicted in Annexure I. The air temperature varied from 31.3°C to 34.7°C at 9 00 am and from 37.8°C and 40.7°C at 2 00 pm. The soil temperature was observed in the range between 29.2°C and 30.8°C at 9 00 am and between 33.5°C and 36.2°C at 2 00 pm. The variation of RH observed was in the range between 65.7% and 76.2% at 9 00 am and between 56.7% and 59.8% at 2 00 pm. The light recorded was between 679 µmol/m^2/sec and 823 µmol/m^2/sec.

Table 60: Correlation matrix of reproductive characters in mid stage of flowering inside rainshelter

	Flowers with exerted stigma	Pollen viability	Fruit set per cent	Length of the style	Anther length	Number of flowers / cluster	No of fruits / cluster
Flowers with exerted stigma	1	r = -0.26 p = 0.13	r = -0.49* p = 0.003	r = 0.12 p = 0.4	r = 0.12 p = 0.5	r = 0.03 p = 0.88	r = -0.26 p = 0.12
Pollen viability		1	r = 0.6* p =0.0002	r = - 0.08 p =0.66	r = -0.12 p =0.5	r = 0.18 p =0.32	r = 0.34* p = 0.05
Fruit set per cent			1	r = -0.24 p = 0.16	r = -0.27 p = 0.12	r = 0.21 p = 0.22	r = 0.53* p =0.001
Length of the style				1	r = 0.99* p = 0.0	r = 0.23 p = 0.18	r = 0.09 p = 0.63
Anther length					1	r = 0.26 p = 0.14	r = 0.11 p = 0.54
No of flowers / cluster						1	r = 0.75* p = 0.02
No of fruits / cluster							1

4.1.3.2.3 Correlation of reproductive characters in late stage of flowering inside rainshelter

Flowers with exerted stigma exhibited moderately strong negative significant correlation with pollen viability (-0.42*) and fruit set per cent (-0.56*). Pollen viability exhibited weak significant positive correlation with fruit set per cent (0.32*). Fruit set per cent exhibited moderately strong positive significant correlation with number of fruits per cluster (0.45*). Strong positive significant correlation was observed between number of fruits per cluster and number of flowers per cluster (0.76*). Length of the style and anther length exhibited very strong positive significant correlation (0.98*) (Table 61 and Plate 12).

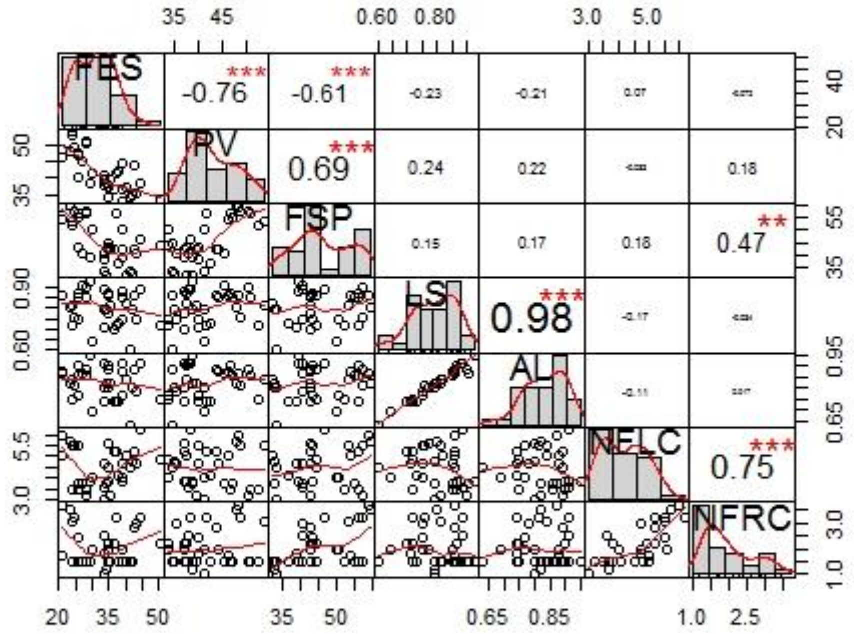


Plate 9: Correlation matrix and scatter plot of polyhouse plants in the late stage of flowering

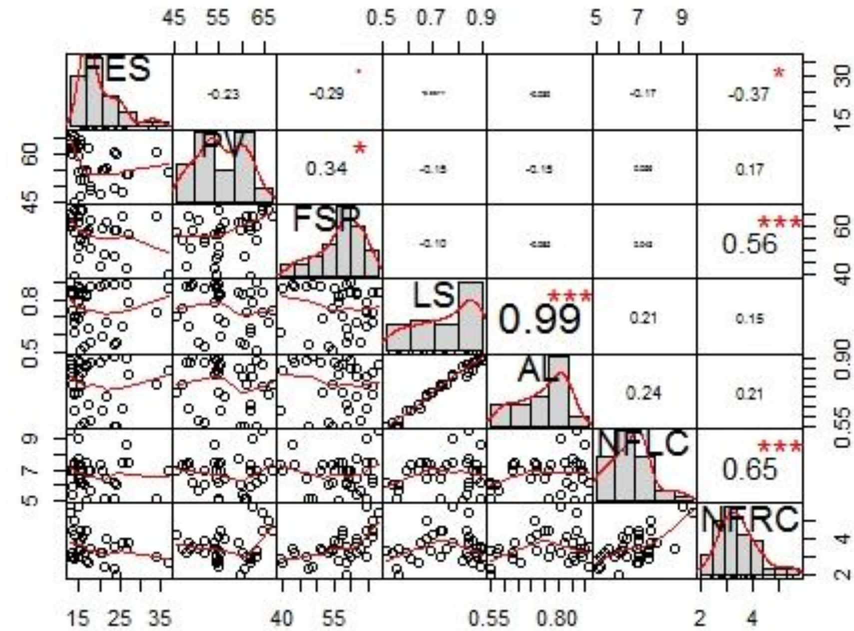


Plate 10: Correlation matrix and scatter plot of rainshelter plants in the early stage of flowering

Table 61: Correlation matrix of reproductive characters in late stage of flowering inside rainshelter

	Flowers with exerted stigma	Pollen viability	Fruit set per cent	Length of the style	Anther length	Number of flowers / cluster	No of fruits / cluster
Flowers with exerted stigma	1	r = -0.42* p = 0.02	r = -0.56* p = 0.001	r = -0.02 p = 0.93	r = 0.01 p = 0.94	r = 0.07 p = 0.67	r = -0.1 p = 0.57
Pollen viability		1	r = 0.32* p =0.05	r = - 0.09 p =0.62	r = -0.05 p =0.77	r = 0.18 p =0.32	r = 0.12 p = 0.5
Fruit set per cent			1	r = -0.08 p = 0.65	r = -0.08 p = 0.66	r = 0.05 p = 0.77	r = 0.45* p =0.01
Length of the style				1	r = 0.98* p = 0.0	r = 0.14 p = 0.42	r = 0.1 p = 0.58
Anther length					1	r = 0.19 p = 0.27	r = 0.14 p = 0.44
No of flowers / cluster						1	r = 0.76* p = 0.02
No of fruits / cluster							1

The weather parameters over this period are depicted in Annexure I. The air temperature was in the range between 32.8°C and 34.3ºC at 9 00 am and between 40.2ºC and 41.2°C at 2 00 pm. The soil temperature recorded the values between 30.4°C and 30.5°C at 9 00 am and between 35.4°C and 36.8°C at 2 00 pm. The RH variation observed was between 68.5% and 69.2% at 9 00 am and between 56.7% and 60.3% at 2 00 pm. The light measured recorded values between 726 µmol/m^2/sec and 871 µmol/m^2/sec.

Inside rainshelter the correlation of pollen viability with fruit set per cent was strong positive and significant at the mid stage of flowering and weak, positive and significant during early and late stage of flowering. Fruit set per cent exhibited moderately strong, significant and positive correlation with number of fruits per cluster.

Hence, the reproductive traits that could determine the performance of a genotype in a stressed environment are pollen viability, fruit set per cent and flowers with exerted stigma. Since, there observed negative relationship of flowers with exerted stigma with fruit set per cent and pollen viability in both structures, the pollen viability and fruit set per cent were considered while selecting the hotset genotypes.

As evident from the above results, for the genetic improvement of hotset types the selection is made on the basis of pollen viability and fruit set per cent. In Figure 1 the higher ranges of pollen viability and fruit set per cent were observed for the genotypes EC-164263 (58.6% and 60.3%), EC-620387 (59.0% and 62.2%), EC-620401 (60.6% and 59.5%), EC-620406 (58.9% and 62.8%), EC-620410 (59.6% and 63.6%), EC-620417 (56.4% and 58.5%), EC-631369 (56.1% and 56.1%) and EC-631379 (53.9% and 60.0%) in the early stage of flowering under polyhouse condition. In the mid stage of flowering the genotypes EC-620387 (54.9% and 57.3%), EC-620389 (59.5% and 60.1%), EC-620401 (56.9% and 62.6%), EC-620406 (57.0% and 63.4%), EC-620410 (56.7% and 64.3%), EC-631369 (53.1% and 54.4%) and EC-631379 (57.5% and 58.6%) recorded higher values of pollen viability and fruit set per cent (Figure 2). In the late stage of flowering the genotypes EC-620387 (52.2% and 60.8%), EC-620395 (47.9% and 53.6%), EC-620401 (49.4% and 61.5%), EC-620406 (49.7% and 61.0%), EC-620410 (49.8% and 60.5%), EC-620417 (51.7% and 57.4%), EC-631369 (52.8% and 58.5%) and EC-631379 (49.4% and 58.5%) maintained high pollen viability and fruit set per cent (Figure 3). Hence, the genotypes EC-620387, EC-620401, EC-620406, EC-620410, EC-631369 and EC-631379 could maintain the higher values of pollen viability and fruit set per cent in all the three stages of the crop, irrespective of the weather parameters.

Inside rainshelter in the early stage of flowering the genotypes EC-165395 (64.0% and 63.1%), EC-165690 (63.0% and 60.4%), EC-620387 (64.5% and 60.1%), EC-620401 (62.1% and 66.0%), EC-620406 (63.5% and 65.3%), EC-620410 (62.4% and 64.0%), EC-620417 (59.5% and 59.6%), EC-631369 (61.6% and 60.6%) and EC-631379 (60.6% and 59.4%) recorded higher ranges of pollen viability and fruit set per cent (Figure 4). In the mid stage of flowering the genotypes EC-165395 (61.9% and 61.6%), EC-165690 (64.0% and 61.8%), EC-

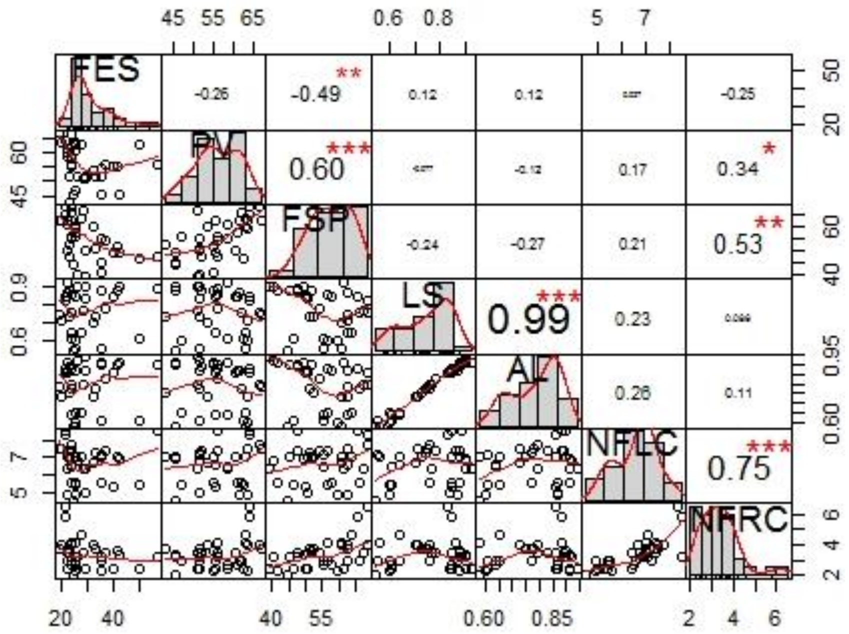


Plate 11: Correlation matrix and scatter plot of rainshelter plants in the mid stage of flowering

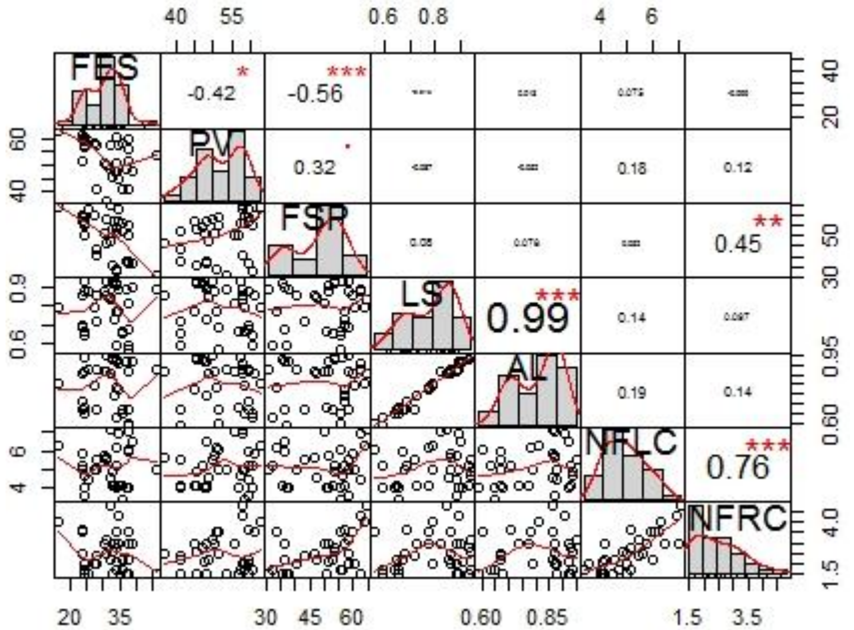


Plate 12: Correlation matrix and scatter plot of rainshelter plants in the late stage of flowering

528368 (58.9% and 43.7%), EC-620376 (62.8% and 55.5%) EC-620387 (58.2% and 59.7%), EC-620401 (61.1% and 61.9%), EC-620406 (59.6% and 65.5%), EC-620410 (62.4% and 63.3%), EC-620417 (59.3% and 58.2%), EC-631369 (59.4% and 58.2%) and EC-631379 (62.1% and 60.0%) recorded higher ranges of pollen viability and fruit set per cent (Figure 5). In the late stage of flowering the higher ranges of pollen viability and fruit set per cent were recorded for the genotypes EC-165395 (56.3% and 58.0%), EC-165690 (57.5% and 58.4%), EC-165700 (53.9% and 51.3%), EC-620387 (56.6% and 57.9%), EC-620389 (56.7% and 55.0%), EC-620401 (55.1% and 59.0%), EC-620406 (56.0% and 59.5%), EC-620410 (56.4% and 61.4%), EC-620417 (57.5% and 55.0%) and EC-631369 (57.2% and 57.5%) (Figure 6). Hence, the genotypes EC-165395, EC-165690, EC-620387, EC-620401, EC-620406, EC-620410, EC-620417, EC-631369 and EC-631379 could maintain higher ranges of pollen viability and fruit set per cent in all the three stage of flowering inside rainshelter irrespective of the weather parameters recorded.

The maximum temperature recorded during the crop period under poyhouse was 37.6°C and inside rainshelter was 41.3ºC. The genotypes EC-620387, EC-620401, EC-620406, EC-620410, EC-631369 and EC-631379 could perform well under both the structures. This implies that the performance of these genotypes was not influenced by the structure or the variations in the weather parameters. So these genotypes could be considered as hotset genotypes.

4.1.4 GENETIC PARAMETERS

The phenotypic and genotypic variance, genotypic coefficient of variation and phenotypic coefficient of variation, heritability and genetic advance as per cent mean were studied for summer crop in both the structures. The results are given in Table 62, 63, 64 and 65 and Figure 7 and 8

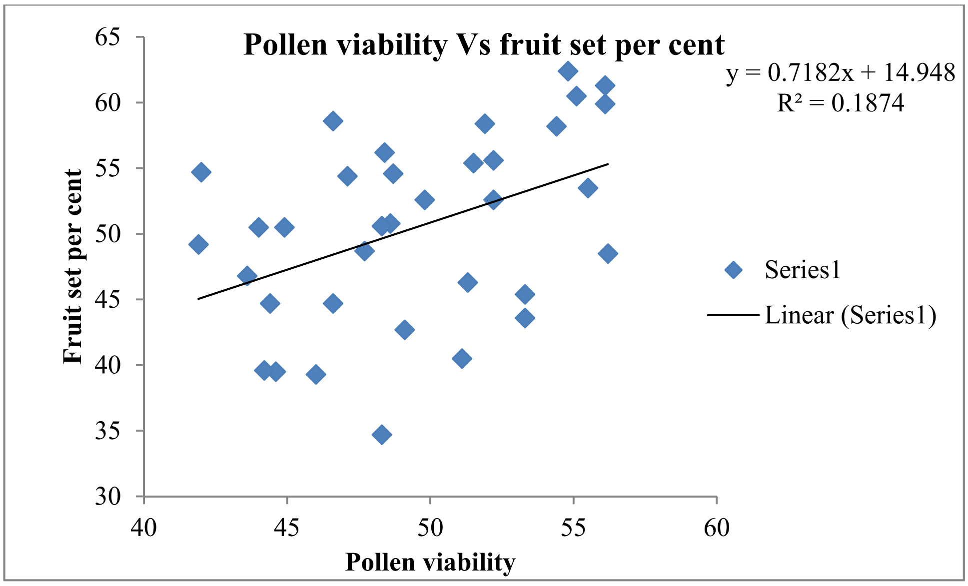


Figure 1: Scatter plot of pollen viability Vs fruit set per cent of polyhouse plants in the early stage of flowering

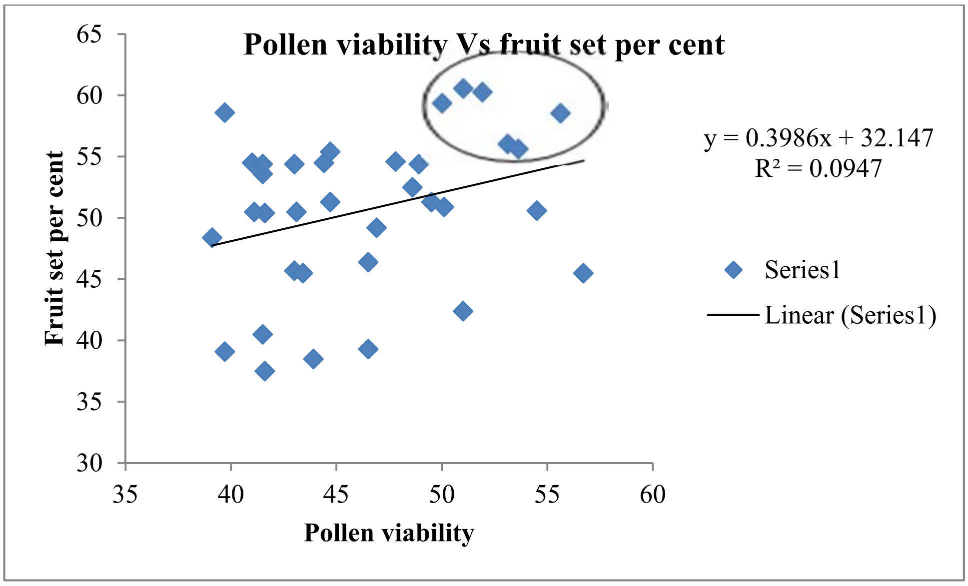


Figure 2: Scatter plot of pollen viability Vs fruit set per cent of polyhouse plants in the mid stage of flowering

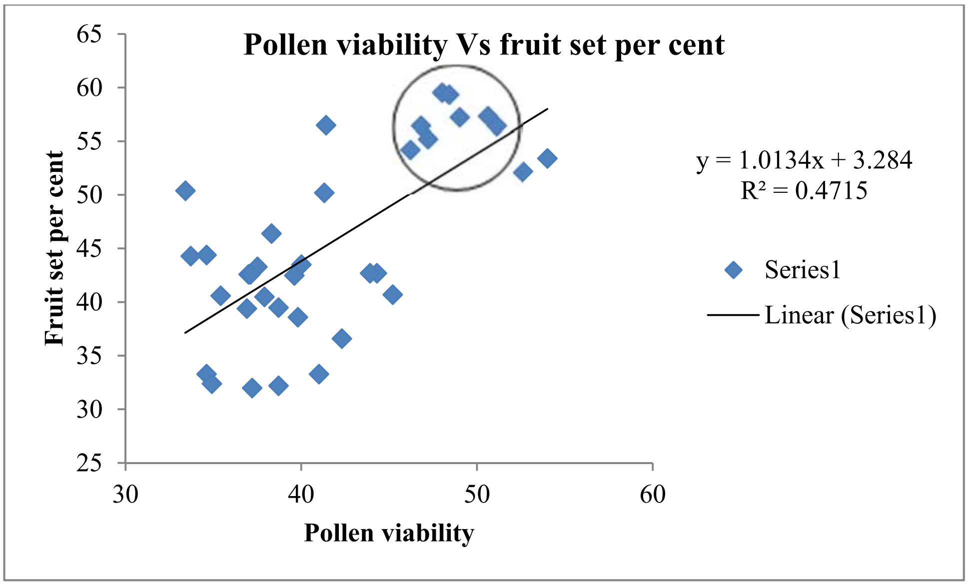


Figure 3: Scatter plot of pollen viability Vs fruit set per cent of polyhouse plants in the late stage of flowering

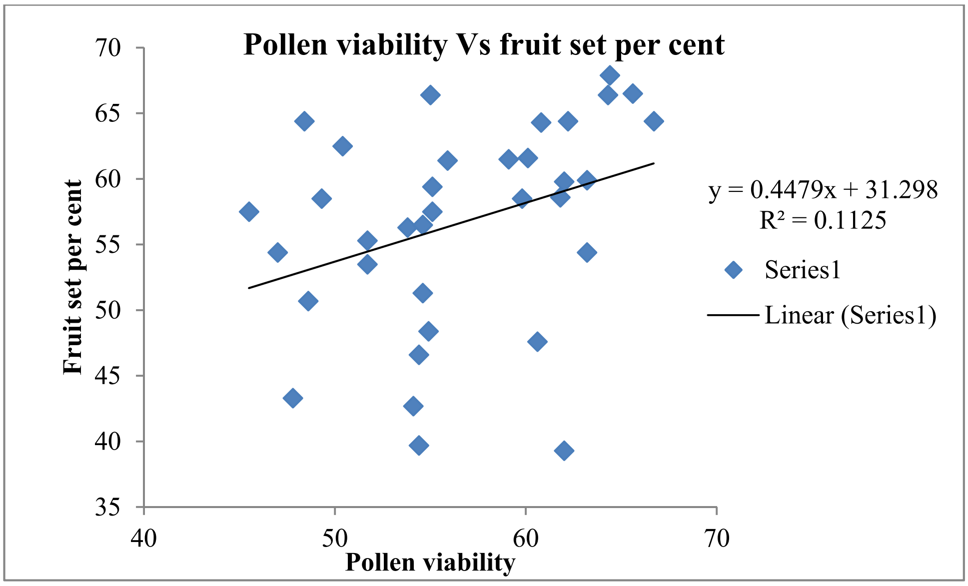


Figure 4: Scatter plot of pollen viability Vs fruit set per cent of rainshelter plants in the early stage of flowering

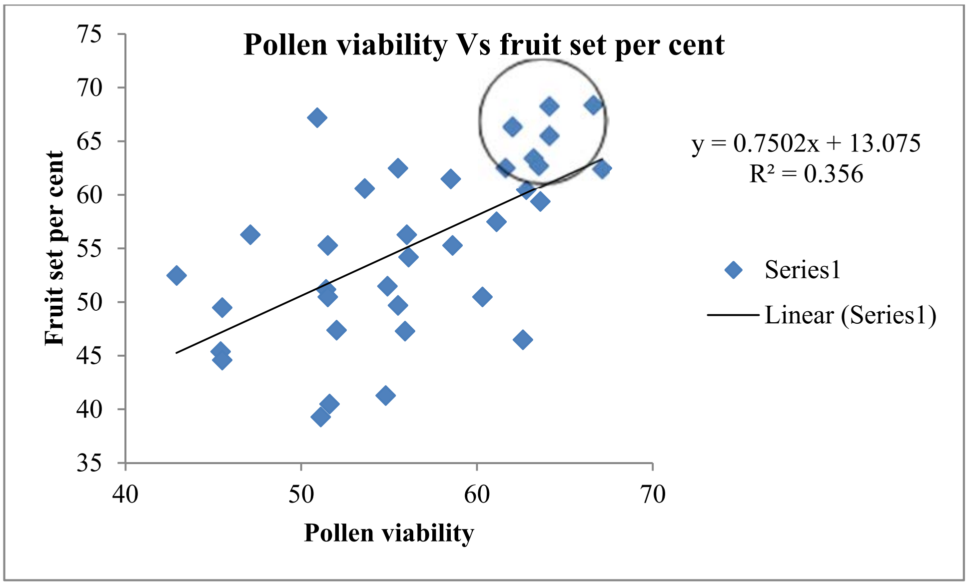


Figure 5: Scatter plot of pollen viability Vs fruit set per cent of rainshelter plants in the mid stage of flowering

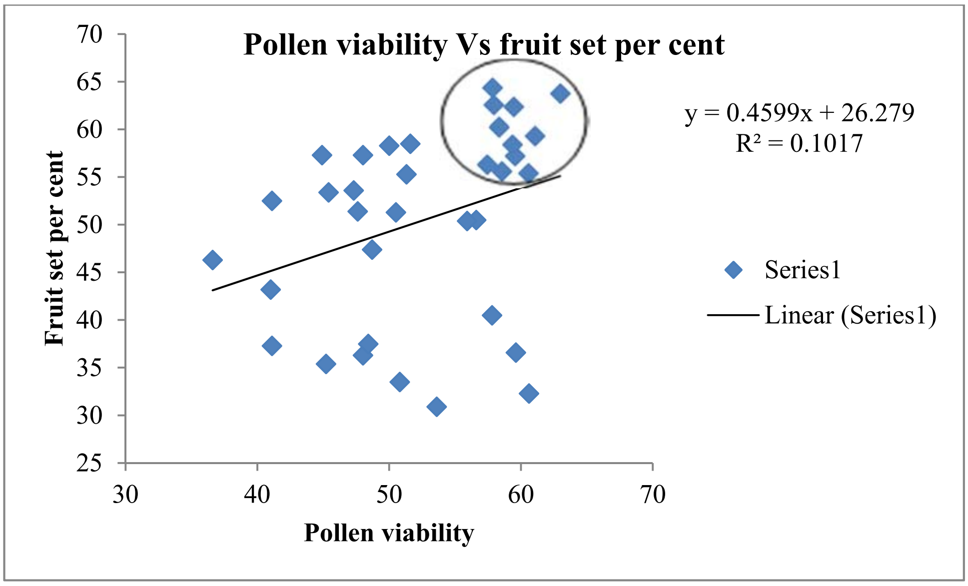


Figure 6: Scatter plot of pollen viability Vs fruit set per cent of rainshelter plants in the late stage of flowering

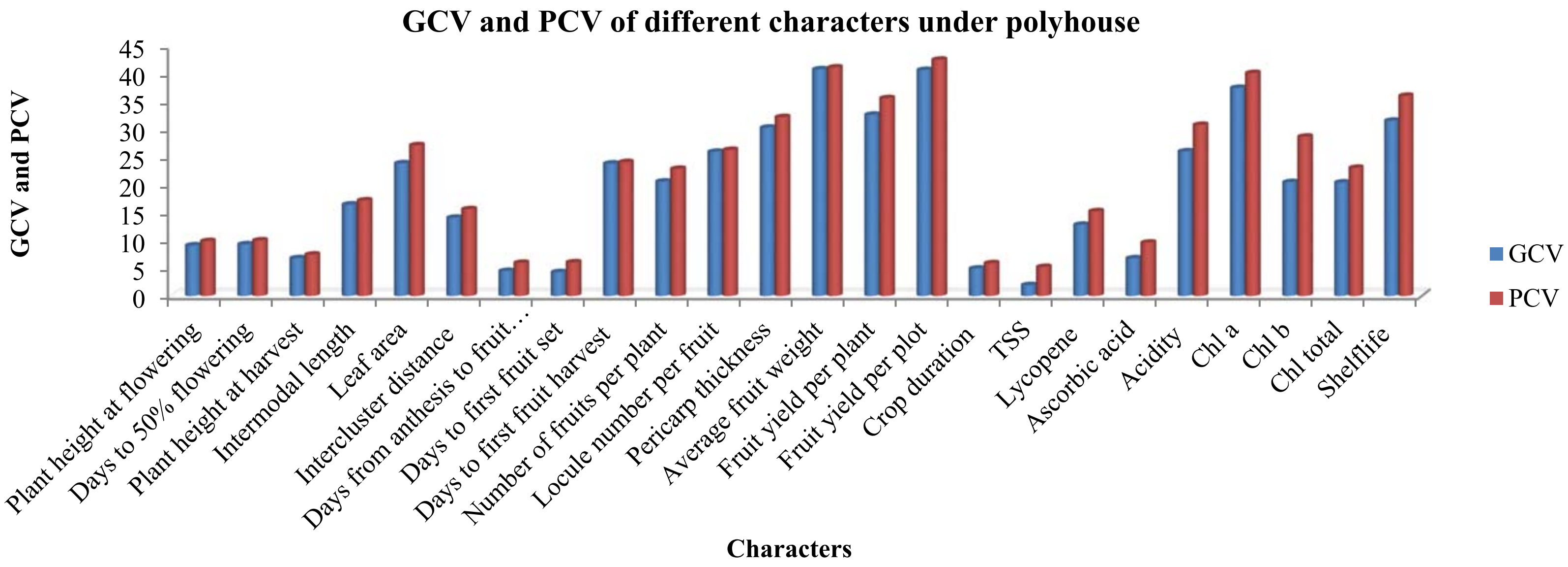


Figure 7: Genotypic and phenotypic coefficient of variation for different characters under polyhouse

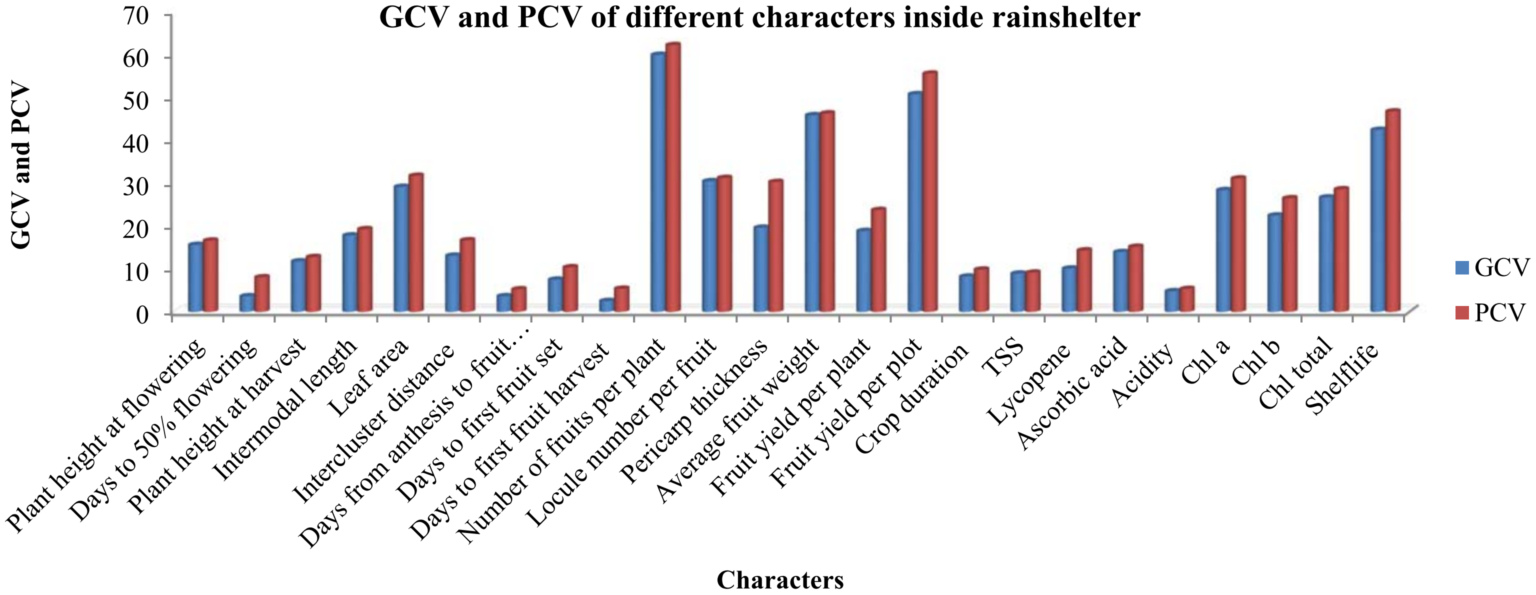


Figure 8: Genotypic and phenotypic coefficient of variation for different characters under polyhouse

4.1.4.1 Variance

Under polyhouse, the high phenotypic and genotypic variance were observed for the characters *viz.* plant height at flowering, days to 50% flowering, plant height at harvest, leaf area, days to first fruit harvest, average fruit weight, fruit yield per plant and crop duration. A close association was observed between phenotypic and genotypic variance. In the case of reproductive traits, flowers with exerted stigma, pollen viability and fruit set per cent recorded higher values for phenotypic and genotypic variance. In the reproductive traits also, a close association was observed between phenotypic and genotypic variance.

Inside rainshelter, plant height at flowering, plant height at harvest, leaf area, number of fruits per plant, average fruit weight, fruit yield per plant and crop duration recorded high values for phenotypic and genotypic variance. A close association was observed between phenotypic and genotypic variance, except for days to first fruit harvest. In the reproductive traits, flowers with exerted stigma, pollen viability at mid and late stage of flowering and fruit set per cent recorded higher ranges for phenotypic and genotypic variance. A close association was observed between phenotypic and genotypic variance.

4.1.4.2 Coefficient of variation

Under polyhouse condition, high GCV and PCV values were observed for leaf area (23.9, 27.1), days to first fruit harvest (23.8, 24.1), number of fruits per plant (20.6, 22.9), locule number (26.0, 26.3), pericarp thickness (30.3, 32.2), average fruit weight (40.8, 41.1), fruit yield per plant (32.6, 35.6), fruit yield per plot (40.9, 42.5), acidity (26.0, 30.8), chlorophyll a (37.5, 40.1),chlorophyll b (20.5, 28.7), total chlorophyll (20.4, 23.1) and shelf life (31.6, 36.0). Among reproductive traits, flowers with exerted stigma in the early stage of flowering (22.1, 35.9), number of flowers per cluster in the mid stage of flowering (21.9, 22.7), number of fruits per cluster during early (28.2, 36.0), mid (34.6, 39.2), late (36.7, 42.8) stage of flowering and fruit set per cent at early stage of flowering (20.2, 21.2) exhibited high GCV and PCV (Table 62 and 63).

Inside rain shelter, the high GCV and PCV ranges were observed for leaf area (29.2, 31.8), number of fruits per plant (59.9, 62.2), locule number (30.5, 31.3), average fruit weight (45.8, 46.2), fruit yield per plot (50.7, 55.5), chlorophyll a (28.4, 31.2), chlorophyll b (22.5, 26.5), total chlorophyll (26.7, 28.6) and shelf life (42.4, 46.7). In the reproductive traits, flowers with exerted stigma early (40.2, 52.4), mid (30.8, 39.1) and late (22.3, 30.4) stage of flowering, the number of flowers per cluster in the late stage of flowering (21.3, 27.0), the number of fruits per cluster in the early (35.1, 36.9), mid (36.0, 38.3) and late (39.0, 42.1) stage of flowering expressed high GCV and PCV (Table 64 and 65).

Under polyhouse, moderate levels of GCV and PCV ranges were observed for internodal length (16.5, 17.2), intercluster distance (14.1, 15.6) and lycopene (12.8, 15.2). In the reproductive traits, pollen viability at late stage of flowering (14.2, 17.7), number of flowers per cluster in the early stage of flowering (14.0, 18.5) and fruit set per cent in the mid stage of flowering (18.1, 19.4) exhibited moderate GCV and PCV.

Inside rainshelter moderate GCV and PCV was observed for the characters plant height at flowering (15.6, 16.6), plant height at harvest (11.8, 12.8), internodal length (17.9, 19.3), intercluster distance (13.1, 16.7), lycopene (10.1, 14.4) and ascorbic acid (14.0, 15.2). In the reproductive traits, pollen viability at late (15.0, 18.9) stage of flowering, length of the style at early (15.9, 16.5), mid (18.3, 19.6) and late (14.4, 14.9) stage of flowering, anther length in the early (15.4, 16.0), mid (16.5, 17.8) and late (16.2,17.5) stage of flowering, number of flowers per cluster in the early stage of flowering (16.6, 18.5) and fruit set per cent in the early (14.9, 15.9), mid (12.3, 13.3) and late (16.0, 19.1) stage of flowering exhibited moderate GCV and PCV.

Under polyhouse, low GCV and PCV ranges were observed for plant height at flowering (9.1, 9.9), days to 50% flowering (9.3, 10.0), plant height at harvest (6.8, 7.5), days form anthesis to fruit maturity (4.5, 6.0), days to first fruit set (4.3, 6.1), crop duration (4.9, 5.9), TSS (2.0, 5.2) and ascorbic acid (6.8, 9.6). In the reproductive traits low GCV and PCV was observed for pollen viability at the early (7.2, 9.7) and mid (7.3, 9.6) stage of flowering and anther length at the late (8.6, 9.4) stage of flowering.

Table 62: Estimation of genetic parameters for tomato genotypes under polyhouse

Character	Phenotypic variance	Genotypic variance	GCV	PCV	Heritability	GA (%)
Plant height at flowering	58.5	49.5	9.1	9.9	85.2	2.5
Days to 50% flowering	27.5	23.9	9.3	10.0	86.8	3.7
Plant height at harvest	58.0	49.4	6.8	7.5	85.1	1.9
Internodal length	3.4	3.1	16.5	17.2	91.5	18.4
Leaf area	583.3	452.7	23.9	27.1	77.5	2.0
Intercluster distance	3.2	2.6	14.1	15.6	81.3	16.3
Days from anthesis to fruit maturity	7.4	4.2	4.5	6.0	75.5	3.4
Days to first fruit set	7.8	3.9	4.3	6.1	50.1	3.2
Days to first fruit harvest	461.4	451.6	23.8	24.1	97.9	2.3
Number of fruits /plant	10.6	8.6	20.6	22.9	81.1	3.0
Locule number / fruit	1.2	1.2	26.0	26.3	**97.5**	**49.1**
Pericarp thickness	0.03	0.03	30.3	32.2	**97.1**	**116.0**
Average fruit weight	522.5	514.5	40.8	41.1	98.5	3.7
Fruit yield / plant	516.9	481.8	32.6	35.6	93.5	0.3
Fruit yield / plot	3.9	3.6	40.9	42.5	**91.5**	**43.1**
Crop duration	44.9	31.6	4.9	5.9	70.4	1.5
TSS	0.09	0.01	2.0	5.2	14.1	13.3
Lycopene	2.4	1.7	12.8	15.2	70.7	17.0
Ascorbic acid	3.6	1.8	6.8	9.6	49.9	7.4
Acidity	0.004	0.003	26.0	30.8	**71.4**	**908.1**
Chl a	3.6	1.2	37.5	40.1	32.6	42.5
Chl b	2.9	1.1	20.5	28.7	36.7	39.5
Chl total	5.4	3.3	20.4	23.1	**60.9**	**36.8**
Shelflife	4.6	3.5	31.6	36.0	**76.6**	**30.5**

Table 63: Estimation of genetic parameters for tomato genotypes under polyhouse for reproductive traits

Character	Stage of flowering	Phenotypic variance	Genotypic variance	GCV	PCV	Heritability	GA (%)
Flowers with exerted stigma	Early	39.4	15.5	22.1	35.9	39.4	7.3
	Mid	50.5	17.4	17.2	29.3	34.5	4.9
	Late	61.3	39.2	18.0	22.5	**64.0**	**47.5**
Pollen viability	Early	41.7	23.4	7.2	9.7	56.0	2.3
	Mid	43.3	25.3	7.3	9.6	58.5	2.3
	Late	97.3	63.0	14.2	17.7	64.7	3.0
Length of the style	Early	0.01	0.01	9.8	10.8	**71.4**	**22.4**
	Mid	0.01	0.01	9.7	11.2	**85.7**	**22.4**
	Late	0.01	0.01	7.5	11.2	**85.2**	**22.3**
Anther length	Early	0.01	0.01	9.6	10.4	**85.7**	**23.7**
	Mid	0.01	0.01	8.7	10.2	**71.4**	**21.3**
	Late	0.01	0.01	8.6	9.4	**83.3**	**22.9**
No. of flowers / cluster	Early	1.4	0.8	14.0	18.5	56.8	24.4
	Mid	2.0	1.9	21.9	22.7	**92.5**	**31.8**
	Late	1.2	0.6	18.5	25.4	53.1	34.8
No. of fruits / cluster	Early	1.9	1.3	28.2	36.0	**71.0**	**46.1**
	Mid	2.0	1.5	34.6	39.2	**78.2**	**51.0**
	Late	1.2	0.9	36.7	42.8	**73.6**	**69.1**
Fruit set per cent	Early	98.9	89.6	20.2	21.2	**90.7**	**41.9**
	Mid	101.6	88.4	18.1	19.4	**87.0**	**37.0**
	Late	122.9	115.6	19.6	20.2	**94.3**	**36.5**

Inside rainshelter, the low GCV and PCV ranges were recorded for days from anthesis to fruit maturity (3.7, 5.3), days to first fruit harvest (2.5, 5.4), crop duration (8.2, 9.9) and TSS (8.9, 9.2). In the reproductive traits only pollen viability at early stage recorded low GCV and PCV (4.1, 5.2).

4.1.4.3 Heritability and genetic advance

Under polyhouse, high heritability was observed for plant height at flowering (85.2), days to 50% flowering (86.8), plant height at harvest (85.1), internodal length (91.5), leaf area (77.5), intercluster distance (81.3), days from anthesis to fruit maturity (75.5), days to first fruit harvest (97.9), number of fruits per plant (81.1), locule number per fruit (97.5), pericarp thickness (97.1), average fruit weight (98.5), fruit yield per plant (93.5), fruit yiled per plot (91.5), crop duration (70.4), lycopene (70.7), acidity (71.4) and shelf life (76.6). The characters days to first fruit set (50.1), ascorbic acid (49.9), chlorophyll a (32.6), chlorophyll b (36.7) and total chlorophyll (60.9) exhibited moderate heritability. The heritability was very low only for TSS (14.1).

In the case of reproductive traits, high heritability was observed for flowers with exerted stigma in the late stage of flowering (64.0), pollen viability in the late stage of flowering (64.7), length of the style in early (71.4), mid (85.7), and late (85.2) stage of flowering, anther length in early (85.7), mid (71.4), and late (83.3), stage of flowering, number of flowers per cluster in the mid stage of flowering (92.5), number of fruits per cluster in the early (71.0), mid (78.2), and late (73.6) stage of flowering and fruit set per cent in the early (90.7), mid (87.0) and late (94.3) stage of flowering. Moderate heritability was observed for flowers with exerted stigma during early (39.4) and mid (34.5) stage of flowering, pollen viability during early (56.0) and mid (58.5) stage of flowering and number of flowers per cluster during the early (56.8) and late (53.1) stage of flowering.

Inside rainshelter, high heritability was observed for plant height at flowering (88.3), plant height at harvest (85.0), internodal length (85.5), leaf area (84.3), intercluster distance (61.5), number of fruits per plant (92.8), locule number per fruit (95.2), average fruit weight (98.2), fruit yield per plant (63.0), fruit yield per plot (83.4), crop duration (69.8), TSS (95.4), ascorbic acid (84.6), acidity (81.0), chlorophyll a (70.3), chlorophyll b (78.6), total chlorophyll (88.3) and shelf life (82.4). Moderate heritability was recorded for days from anthesis to fruit maturity (52.0), days to first fruit set (52.3), pericarp thickness (41.9) and lycopene (49.8). The traits, days to 50% flowering (20.4) and days to first fruit harvest (22.0) recorded low heritability.

In the case of reproductive traits, high heritability was observed for flowers with exerted stigma in the mid stage of flowering (62.1), pollen viability in three stages of flowering (62.0, 68.8 and 62.5), length of the style in three stages of

Table 64: Estimation of genetic parameters for tomato genotypes inside rainshelter

Character	Phenotypic variance	Genotypic variance	GCV	PCV	Heritability	GA (%)
Plant height at flowering	98.2	86.7	15.6	16.6	88.3	3.3
Days to 50% flowering	10.6	2.2	3.6	8.1	20.4	2.3
Plant height at harvest	93.0	79.1	11.8	12.8	85.0	2.5
Internodal length	2.5	2.2	17.9	19.3	**85.5**	**23.2**
Leaf area	316.4	266.8	29.2	31.8	84.3	3.3
Intercluster distance	3.1	1.9	13.1	16.7	61.5	15.4
Days from anthesis to fruit maturity	5.0	2.6	3.7	5.3	52.0	3.2
Days to first fruit set	15.5	8.1	7.5	10.4	52.3	4.0
Days to first fruit harvest	20.1	4.4	2.5	5.4	22.0	1.2
Number of fruits per plant	177.3	164.6	59.9	62.2	**92.8**	**92.9**
Locule number per fruit	1.3	1.2	30.5	31.3	**95.2**	**56.0**
Pericarp thickness	0.0	0.0	19.7	30.4	41.9	2.3
Average fruit weight	668.8	656.5	45.8	46.2	**98.2**	**36.5**
Fruit yield per plant	494.1	311.5	18.9	23.8	63.0	17.5
Fruit yield per plot	10.6	8.9	50.7	55.5	**83.4**	**32.1**
Crop duration	115.9	80.9	8.2	9.9	69.8	15.8
TSS	0.3	0.3	8.9	9.2	**95.4**	**34.7**
Lycopene	2.0	1.0	10.1	14.4	49.8	14.8
Ascorbic acid	10.8	9.1	14.0	15.2	84.6	8.8
Acidity	0.02	0.0	4.8	5.4	**81.0**	**140.3**
Chl a	1.5	1.0	28.4	31.2	**70.3**	**46.7**
Chl b	1.9	1.1	22.5	26.5	**78.6**	**52.3**
Chl total	3.3	2.9	26.7	28.6	**88.3**	**58.7**
Shelflife	8.0	6.6	42.4	46.7	**82.4**	**30.9**

Table 65: Estimation of genetic parameters for tomato genotypes inside rainshelter for reproductive traits

Character	Stage of flowering	Phenotypic variance	Genotypic variance	GCV	PCV	Heritability	GA (%)
Flowers with excerted stigma	Early	178.9	105.3	40.2	52.4	58.9	6.2
	Mid	139.0	86.3	30.8	39.1	62.1	5.4
	Late	101.3	54.6	22.3	30.4	53.9	4.5
Pollen viability	Early	13.2	8.2	4.1	5.2	62.0	2.4
	Mid	64.5	44.4	9.7	11.7	68.8	2.5
	Late	119.6	74.7	15.0	18.9	62.5	2.8
Length of the style	Early	0.02	0.01	15.9	16.5	**93.3**	**26.8**
	Mid	0.02	0.01	18.3	19.6	**93.3**	**24.8**
	Late	0.01	0.01	14.4	14.9	**92.9**	**25.0**
Anther length	Early	0.02	0.01	15.4	16.0	**93.3**	**26.0**
	Mid	0.01	0.01	16.5	17.8	**92.9**	**25.3**
	Late	0.01	0.01	16.2	17.5	**92.9**	**24.8**
Number of flowers per cluster	Early	1.5	1.2	16.6	18.5	**79.9**	**28.0**
	Mid	1.8	1.2	17.5	21.5	**66.8**	**26.8**
	Late	1.8	1.1	21.3	27.0	**62.3**	**33.2**
Number of fruit per cluster	Early	2.6	2.4	35.1	36.9	**90.7**	**45.0**
	Mid	2.6	2.3	36.0	38.3	**88.3**	**46.4**
	Late	1.7	1.4	39.0	42.1	**85.6**	**62.2**
Fruit set per cent	Early	73.3	68.2	14.9	15.9	**93.1**	**37.1**
	Mid	54.6	46.4	12.3	13.3	**85.0**	**34.4**
	Late	89.6	62.5	16.0	19.1	**69.8**	**34.8**

flowering (93.3, 93.3 and 92.9), anther length in three stages of flowering (93.3, 92.9 and 92.9), number of fruits per cluster in three stages of flowering (79.9, 66.8 and 62.3), number of fruits per cluster in three stage of flowering (90.7, 88.3 and 85.6) and fruit set per cent in three stages of flowering (93.1, 85.0 and 69.8). Moderate level of heritability was observed for flowers with exerted stigma in the early (58.9) and late (53.9) stage of flowering. High heritability was recorded for reproductive traits both under polyhouse and inside rainshelter.

Under polyhouse condition the high genetic advance was observed for the traits locule number per fruit (49.1), pericarp thickness (116.0), yield per plot (43.1), acidity (908.1), chlorophyll a (42.5), chlorophyll b (39.5), total chlorophyll (36.8) and shelf life (30.5). Genetic advance was moderate for internodal length (18.4), intercluster distance (16.3), TSS (13.3) and lycopene (17.0). Low genetic advance was observed for plant height at flowering (2.5), days to 50% flowering (3.7), plant height at harvest (1.9), leaf area (2.0), days from anthesis to fruit maturity (3,4), days to first fruit set (3.2), days to first fruit harvest (2.3), number of fruits per plant (3.0), average fruit weight (3.7), fruit yield per plant (0.3), crop duration (1.5) and ascorbic acid (7.4). High heritability combined with high genetic advance was observed for locule number per fruit, pericrap thickness, yield per plot, acidity, total chlorophyll and shelf life.

In reproductive traits, high genetic advance was observed for flowers with exerted stigma in the late stage of flowering (47.5), length of the style during early (22.4), mid (22.4), late (22.3) stage of flowering, anther length at early (23.7), mid (21.3), late (22.9) stage of flowering, number of flowers per cluster at early (24.4), mid (31.8), late (34.8) stage of flowering, number of fruits per plant at early (46.1), mid (51.0), late (69.1) stage of flowering and fruit set per cent at early (41.9), mid (37.0) and late (36.5) stage of flowering. Low levels of genetic advance was observed for exerted stigma at early (7.3) and mid (4.9) stage of flowering and pollen viability in three stages of flowering (2.3, 2.3 and 3.0). High heritability combined with high genetic advance was observed for flowers with exerted stigma at late stage of flowering, length of the style in three stages of flowering, anther length in three stages of flowering, number of flowers per cluster in the mid stage of flowering, number of fruits per cluster in three stages of flowering and fruit set per cent in three stages of flowering.

Inside rainshelter, high genetic advance was observed for internodal length (23.2), number of fruits per plant (92.9), locule number per fruit (56.0), average fruit weight (36.5), yield per plot (32.1), TSS (34.7), acidity (140.3), chlorophyll a (46.7), chlorophyll b (52.3), total chlorophyll (58.7) and shelf life (30.9). The moderate genetic advance was observed for intercluster distance (15.4), yield per plant (17.5), crop duration (15.8) and lycopene (14.8). The genetic advance was low for plant height at flowering (3.3), days to 50% flowering (2.3), plant height at harvest (2.5), leaf area (3.3), days from anthesis to fruit maturity (3.2), days to first fruit set (4.0), days to first fruit harvest (1.2), pericarp thickness (2.3) and ascorbic acid (8.8). High heritability combined with high genetic advance was observed for internodal length, number of fruits per plant, locule number per fruit, average fruit weight, yield per plot, TSS, acidity, chlorophyll a, b and total and shelf life.

In the reproductive traits, high genetic advance was observed for length of the style (26.8, 24.8 and 25.0), anther length (26.0, 25.3 and 24.8), number of flowers per cluster (28.0, 26.8 and 33.2), number of fruits per cluster (45.0, 46.4 and 62.2) and fruit set per cent (37.1, 34.4 and 34.8) in early, mid and late stage of flowering. High heritability combined with high genetic advance was also observed in the above said traits. Low range for genetic advance was observed for flowers with exerted stigma (6.2, 5.4 and 4.5) and pollen viability (2.4, 2.5 and 2.8) in early, mid and late stage of flowering.

4.1.4 MULTIVARIATE ANALYSIS (D^2 STATISTICS)

Since, the difference among the genotypes were highly significant, with respect to the characters studied, to estimate the genetic divergence the D^2 value between each pair of genotypes were estimated. Following "Tocher clustering method", the genotypes were grouped into different clusters separately for polyhouse and rainshelter.

4.1.4.1 Multivariate analysis (D^2 statistics) for Polyhouse plants

Under polyhoues condition, thirty five genotypes were grouped into seven clusters depending on their genetic divergence (Table 66). Cluster III contained largest number of genotypes (14), followed by Cluster IV (8). Cluster VII contains only one genotype.

Table 66: Details of 35 genotypes included in different clusters under polyhouse

Cluster	No of genotypes / cluster	Genotypes included
I	3	EC-145057, EC-151568 and Pusa Ruby
II	3	EC-620427, Arka Saurabh and Arka Abha
III	14	EC-163605, EC-164263, EC-620395, Anagha, Akshaya, EC-620378, Arka Alok, EC-164563, EC-249514, EC-620382, EC-620389, EC-165395, EC-165690 and EC-160885
IV	8	EC-620401, EC-631369, EC-538153, EC-620406, EC-620417, EC-620410, EC-631379 and EC-620387
V	3	EC-528368, EC-620376 and EC-165700
VI	3	EC-164670, EC-521067 B and EC-157568
VII	1	EC-620429

The intra-cluster divergence ranged from 0.0 to 123.96, the least being for Cluster VII including only EC-620429. Cluster IV had the highest intra-cluster divergence including EC-620401, EC-631369, EC-538153, EC-620406, EC-620417, EC-620410, EC-631379 and EC-620387. The inter-cluster distance was maximum between Cluster IV and Cluster V (2506.24), followed by Cluster II and Cluster IV (1678.56) and Cluster IV and Cluster VII (1353.79). The least inter-cluster distance was between Cluster I and Cluster VII (55.27) (Table 67).

Table 67: Intra and inter-cluster distance (D^2) of 35 tomato genotypes under polyhouse

Clusters	I	II	III	IV	V	VI	VII
I	30.00	105.6	402.65	1250.01	358.61	196.50	55.27
II		49.04	657.20	1678.56	188.28	336.64	100.99
III			111.03	385.85	1273.42	254.96	435.46
IV				123.96	2506.24	722.81	1353.79
V					26.23	634.28	414.44
VI						48.66	321.28
VII							0.00

Diagonal elements: Intra-cluster value

Off diagonal elements: Inter-cluster value

The cluster mean of 35 genotypes (Table 68) showed that the mean value of the clusters were different in magnitude for all the characters. Comparatively, higher inter-cluster values were observed between the clusters. The average fruit weight, yield per plant, pollen viability and fruit set per cent were maximum for the Cluster IV, with minimum stigma exertion, including EC-620401, EC-631369, EC-538153, EC-620406, EC-620417, EC-620410, EC-631379 and EC-620387. All traits together indicate the presence of hotset genotypes in the cluster IV. The cluster also recorded highest intra-cluster divergence, indicating the heterogenous nature of the cluster. Number of fruits per cluster was maximum for Cluster IV and Cluster V. Cluster V also recorded maximum number of fruits per plant and minimum average fruit weight and yield per plant. The intra-cluster divergence was only 26.23, indicating the homogenous nature of the cluster with small fruits. Pericarp thickness was maximum for Cluster VII with only one genotype, EC-620429. The cluster was in the second position for average yield per plant.

Table 68: Cluster means for 9 characters in 35 genotypes of tomato under polyhouse

Character	Clusters						
	I	II	III	IV	V	VI	VII
Flowers with exerted stigma	29.0	28.4	24.9	20.8	25.5	30.4	30.4
Pollen viability	39.8	42.2	45.3	51.9	46.1	40.9	46.4
Days to first fruit set	46.0	45.4	46.2	46.5	45.7	46.0	45.9
Number of fruits per cluster	2.4	2.7	2.7	3.0	3.0	2.7	2.9
Fruit set per cent	41.4	46.0	48.3	56.0	45.5	46.9	47.5
Average fruit weight	36.7	61.6	51.7	74.6	8.2	37.3	68.6
Pericarp thickness	0.4	0.72	0.54	0.74	0.28	0.55	0.89
Number of fruits per plant	12.3	14.2	13.7	16.4	20.9	14.6	15.5
Yield per plant	399.7	842.6	672.8	1054.0	134.5	464.7	986.1

4.1.4.2 Multivariate analysis (D^2 statistics) for rainshelter plants

The rainshelter grown genotypes were grouped into five clusters depending on their genetic divergence (Table 69). Cluster II included maximum number of genotypes (15), followed by Cluster I (14). Cluster V had only one genotype.

Table 69: Details of 35 genotypes included in different clusters inside rainshelter

Cluster	No of genotypes / cluster	Genotypes included
I	14	EC-165395, EC-165690, EC-145057, EC-157568, EC-163605, EC-160885, EC-164563, EC-163605, EC-164670, EC-165700, EC-528368, Pusa Ruby, EC-620376 and EC-521067 B
II	15	EC-249514, EC-164263, EC-620378, EC-620389, EC-620395, EC-620417, EC-620401, EC-620406, EC-620410, EC-620387, Arka Saurabh, Arka Alok, EC-631369, EC-631379 and Anagha
III	2	EC-620429 and EC-620382
IV	3	Arka Abha, Akshaya and EC-538153
V	1	EC-620427

The intra-cluster divergence ranged from 0.0 to 400.63. Cluster IV, containing Arka Abha, Akshaya and EC-538153 recorded maximum intra-cluster value (400.63). Cluster I containing 14 genotypes *viz:* EC-165395, EC-165690, EC-145057, EC-157568, EC-163605, EC-160885, EC-164563, EC-163605, EC-164670, EC-165700, EC-528368, Pusa Ruby, EC-620376 and EC-521067 B, followed (372.06) (Table 70).

The inter-cluster divergence ranged between 937.87 (between Cluster III and Cluster V) and 3758.17 (between Cluster II and Cluster V).

Table 70: Intra and inter-cluster distance (D^2) of 35 tomato genotypes inside rainshelter

Clusters	I	II	III	IV	V
I	372.06	1114.07	3242.22	2796.87	3326.62
II		277.44	3059.18	1212.69	3758.17
III			33.18	1584.2	937.87
IV				400.63	985.62
V					0.00

Diagonal elements: Intra-cluster value

Off diagonal elements: Inter-cluster value

The cluster mean value of the clusters (Table 71) was different in magnitude for all the characters. Inside rainshelter also inter-cluster distance was observed to be more, indicating divergence between clusters. The Cluster II with 15 genotypes included most of the hotset types as the cluster members were characterised with minimum stigma exertion and maximum pollen viability and fruit set per cent. Cluster II also exhibited maximum average fruit weight and yield per plant. Cluster II exhibited higher inter-cluster distance than intra-cluster distance, indicating the homogenous and heterogeneous nature within and between the clusters. Days to first fruit set was minimum for Cluster III, followed by Cluster IV. Cluster I exhibited maximum number of fruits, but the same cluster recorded minimum average fruit weight and yield per plant, indicating the predominance of small fruited type genotypes. This is also evident from the high inter-cluster distance between Cluster I and other clusters. Cluster III exhibited maximum pericarp thickness. Cluster III had only two genotypes and recorded low intra-cluster distance, indicating the homogenous nature of the cluster. Intra-cluster distance of Cluster III was lowest with Cluster V, indicating the similarity of the Cluster III with Cluster V.

Table 71: Cluster means for 9 characters in 35 genotypes of tomatoinside rainshelter

Character	Clusters				
	I	II	III	IV	V
Flowers with exerted stigma	27.3	23.7	29.3	28.1	40.8
Pollen viability	53.3	57.0	52.5	56.2	52.7
Days to first fruit set	38.5	38.4	34.5	34.8	35.1
Number of fruits per cluster	3.3	3.0	3.5	3.1	3.2
Fruit set per cent	51.3	57.8	50.5	56.8	42.1
Average fruit weight	34.4	76.2	72.6	69.1	65.4
Pericarp thickness	0.47	0.63	0.76	0.64	0.68
Number of fruits per plant	30.0	18.6	17.6	19.9	24
Yield per plant	744.5	1218.6	1115.2	1178.1	1208.1

4.1.4.3 Selection of the parents

Under polyhouse condition parents were selected from Cluster II, III, IV and VII. Cluster I, V and VI were very low in average fruit weight and yield per plant, thus not considered for parents selection. The three lines EC-620401, EC-620406 and EC-620410 were from Cluster IV, which exhibited hotset characters of high pollen viability, fruit set per cent and low stigma exertion with high average fruit weight and yield per plant. Testers were selected from Cluster II, III and VII based on their mean value for days to first fruit set and pericarp thickness, with average fruit weight and satisfactory levels of yield, along with divergence with Cluster IV. Cluster IV exhibited maximum inter-cluster distance with Cluster II. Cluster II exhibited minimum days for first fruit set and comparatively higher ranges for average fruit weight and yield per plant. Hence, two testers were selected for Cluster II *viz*: EC-620427 and Arka Abha. Cluster VII recorded maximum pericarp thickness and second position for average fruit weight and yield per plant. Thus the only genotype in Cluster VII, EC-620429, was taken as a tester. Maximum number of genotypes was included in cluster III with satisfactory levels of average fruit weight and yield per plant. Hence the remaining tester was selected from Cluster III.

In the clustering pattern of rainshelter, the selected parents were spread in four clusters, three lines selected were from Cluster II, and four testers selected were from Cluster III, IV and V. Cluster I mostly contained small fruited genotypes as evident from minimum average fruit weight and yield per plant and thus, not considered for parental selection. Cluster II with 15 members recorded highest average for pollen viability and fruit set per cent. Same cluster also recorded minimum stigma exertion, indicating the presence of hotset types. Maximum number of genotypes was also present in Cluster II, offering the scope for wide selection. Hence, three lines were selected from Cluster II with highest average fruit weight and yield per plant. Cluster II exhibited maximum inter-cluster distance with Cluster V. Cluster V was second in yield per plant and had satisfactory value for average fruit weight. So the only genotype in Cluster V was selected as a tester. Cluster III had only two genotypes and minimum intra-cluster distance. Cluster III exhibited maximum pericarp thickness and second position in average fruit weight. Cluster III also maintained high inter-cluster distance with Cluster II. So both the genotypes in Cluster III were taken as testers. The remaining one tester was taken from Cluster IV as Cluster IV exhibited satisfactory levels of inter-cluster distance with Cluster II and possess comparatively good range for average fruit weight and yield per plant. The testers selected were also been confirmed with bacterial wilt resistance in 4.2.

4.5 SELECTION INDEX

Construction of selection indices would give the most appropriate weight age to the phenotypic values of two or more characters to be used simultaneously for the selection. Even though there are many methods for the calculation of selection indices, discriminate function is widely used by the researchers. In the present investigation selection indices were formulated to identify the hot set genotypes with superior yield attributes. Hence, in the present study selection index computation was based on five characters *viz:* pollen viability, fruit set per cent, flowers with exerted stigma, number of fruits per plant and average fruit weight. Selection indices were calculated separately for two structures.

4.5.1 Selection index for polyhouse plants

The index value for each genotype was determined using the formula, Index I= pollen viability * (20.947) + flowers with exerted stigma * (-17.4643) + fruit set per cent * (15.5329) + number of fruits per plant * (19.8919) + average fruit weight *(13.0799). They were ranked according to the scores. The scores obtained for the genotypes based on the selection index are given in Table 72. The genotype, EC-620410, with score 3325.1 was ranked one, followed by EC-620401 (3299.2) and EC-620406 (3291.2). The genotype, EC-620376, obtained the least score (1844.9).

4.1.5.2 Selection index for rainshelter plants

The index value for each genotype was determined using the formula, Index I= pollen viability * (11.6523) + flowers with exerted stigma * (-7.8126) + fruit set per cent * (5.1733) + number of fruits per plant * (8.8525) + average fruit weight *(12.7431). They were ranked according to the scores. The scores obtained for the genotypes based on the selection index are given in Table 73. The genotype, EC-620410, with score 2230.7 was ranked one, followed by EC-538153 (2192.3) and EC-620401 (2175.3). The genotype, EC-151568, obtained the least score (1071.9).

Table 72: Selection index ranking of genotypes under polyhouse

Genotype	Means					Index I= pollen viability * (20.947) + flowers with exerted stigma * (-17.4643)+fruit set per cent * (15.5329)+ number of fruits per plant * (19.8919) + average fruit weight *(13.0799)	Rank according to index
	Pollen viability	Flowers with exerted stigma	Fruit set per cent	No of fruits per plant	Average fruit weight		
EC-620410	55.4	18.2	62.9	21.5	82.5	3325.1	1
EC-620401	55.6	16.9	61.2	20.4	82	3299.2	2
EC-620406	55.2	18.3	62.4	21.9	80.2	3291.2	3
EC-620417	54.4	19.0	57.6	19.9	82	3170.6	4
EC-620387	55.4	22.3	60.1	13.5	90.8	3159.5	5
EC-631369	54.0	19.8	56.3	19.9	81.7	3125.4	6
EC-164263	57.4	20.5	57.7	18.9	73	3071.3	7
EC-538153	56.0	18.7	47.7	15.9	84.1	3003.0	8
EC-620389	56.7	21.2	56.4	15.3	69.5	2907.5	9
EC-631379	53.6	21.1	59.0	13.6	66.4	2810.8	10
EC-620395	48.3	18.4	54.2	16.2	70	2771.2	11
Akshaya	48.8	26.1	56.9	17.7	59.7	2583.1	12
Anagha	47.1	25.0	52.1	14.1	67.7	2525.4	13
EC-620382	45.7	31.0	46.9	20.5	67	2428.0	14
Arka Saurabh	47.2	23.7	46.6	13.3	63.8	2397.3	15
Arka Alok	47.0	25.9	46.5	15.3	62.3	2373.8	16
Arka Abha	44.3	29.8	47.3	16.9	68.4	2373.0	17
EC-620429	45.4	31.2	47.5	15.9	69.5	2368.6	18
EC-620378	47.8	19.2	43.5	15	55.6	2367.2	19
EC-620427	43.7	30.4	42.9	15.1	66.3	2218.2	20
EC-164563	47.2	27.6	48.4	15.2	49.2	2204.5	21

Table 72: Continued

Genotype	Means					Index I= pollen viability * (20.947) + flowers with exerted stigma * (-17.4643)+fruit set per cent * (15.5329)+ number of fruits per plant * (19.8919) + average fruit weight *(13.0799)	Rank according to index
	Pollen viability	Flowers with exerted stigma	Fruit set per cent	No of fruits per plant	Average fruit weight		
EC-249514	44.7	24.1	46.2	15.5	47	2156.1	22
EC-164670	48.2	24.4	47.0	15	34.4	2062.0	23
EC-160885	50.4	23.6	43.7	12.6	37.3	2061.0	24
EC-165700	52.9	21.3	48.5	21.8	7.8	2023.3	25
EC-521067 B	44.7	27.4	48.2	16.1	36.9	2009.6	26
Pusa Ruby	44.6	30.1	49.1	16.6	38.6	2006.3	27
EC-157568	46.8	28.2	46.9	14.5	35.5	1968.4	28
EC-165690	48.4	23.8	46.2	15.1	25.1	1944.3	29
EC-528368	47.4	24.6	52.3	21.8	7.2	1903.3	30
EC-151568	47.4	27.0	38.7	14.2	37.6	1896.2	31
EC-165395	46.8	24.3	48.4	14.3	23.2	1895.0	32
EC-145057	43.3	26.4	41.5	14.7	35.8	1851.4	33
EC-163605	44.5	24.6	39.2	15.5	32.7	1846.7	34
EC-620376	50.9	24.2	46.9	17.9	8.9	1844.9	35

Table 73: Selection index ranking of genotypes inside rainshelter

Genotype	Means					Index I= pollen viability * (11.6523) + flowers with exerted stigma * (-7.8126)+fruit set per cent * (5.1733)+ number of fruits per plant * (8.8525) + average fruit weight *(12.7431)	Rank according to index
	Pollen viability	Flowers with exerted stigma	Fruit set per cent	No of fruits per plant	Average fruit weight		
EC-620410	60.4	16.9	62.9	22.5	89.0	2230.7	1
EC-538153	59.9	20.6	53.3	19.3	94.8	2192.3	2
EC-620401	59.4	18.1	62.3	23.3	86	2175.3	3
EC-620406	59.7	20.3	63.4	21.7	84.3	2131.8	4
EC-620395	52.8	20.8	58.4	19.7	91.8	2099.9	5
EC-620387	59.8	19.8	59.2	14.8	83.6	2044.2	6
EC-620417	58.8	17.8	57.6	19.9	72.2	1940.2	7
EC-164263	59.8	18.8	55.7	21.5	68.9	1906.6	8
EC-620389	58.9	22.4	57.6	18.6	71.1	1879.9	9
EC-631369	59.4	21.4	58.8	20.8	64.8	1838.6	10
EC-165690	61.5	24.4	60.2	69.5	25.8	1781.2	11
EC-631379	59.4	23.8	58.7	14.1	64.4	1755.6	12
EC-165395	60.7	21.4	60.9	66.6	23.5	1744.8	13
Anagha	50.0	23.5	56.9	15.6	71.3	1740.1	14
Akshaya	52.5	25.1	57.0	21.7	64.9	1729.5	15
EC-620429	52.8	28.4	43.5	17.6	70.2	1669.0	16
Arka Saurabh	51.1	25.5	47.1	14	70.1	1657.1	17
Arka Abha	50.9	32.5	49.9	17.6	67.4	1612.6	18
EC-620427	50.4	34.2	51.4	16.9	67.7	1598.5	19
Arka Alok	49.0	28.2	41.7	16.4	69.3	1594.9	20

Table 73: Continued

Genotype	Means					Index I= pollen viability * (11.6523) + flowers with exerted stigma * (-7.8126)+fruit set per cent * (5.1733)+ number of fruits per plant * (8.8525) + average fruit weight *(12.7431)	Rank according to index
	Pollen viability	Flowers with exerted stigma	Fruit set per cent	No of fruits per plant	Average fruit weight		
EC-620378	51.3	22.2	52.3	19.6	55.4	1574.3	21
EC-620382	52.0	37.8	43.5	23.3	64.6	1564.5	22
EC-164563	52.4	24.6	52.2	17.4	51.3	1496.4	23
EC-249514	48.9	28.5	50.5	17.1	49.2	1386.6	24
EC-164670	51.8	25.1	47.9	20.6	39.2	1337.2	25
EC-521067 B	48.6	24.9	52.4	17.9	40.9	1322.6	26
EC-620376	60.4	26.7	48.0	44.7	12.3	1296.2	27
EC-163605	51.6	32.0	46.8	16.6	37.6	1219.9	28
EC-145057	47.9	24.0	42.5	16.4	33.6	1163.2	29
Pusa Ruby	46.4	29.6	45.3	17.3	36	1155.9	30
EC-528368	57.7	25.7	45.4	30.9	12.8	1143.6	31
EC-157568	47.2	31.1	49.1	15.9	34.4	1140.4	32
EC-165700	58.2	29.2	47.3	37	8.2	1126.8	33
EC-160885	52.2	40.4	36.7	12.6	38.5	1084.7	34
EC-151568	46.9	30.0	39.5	11.9	35.3	1071.9	35

4.1.5.3 Selection of hotset types

Hence, the genotypes EC-164263, EC-538153, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369, which secured ranks within ten under both the structures, could be considered as hotset high yielding genotypes among the thirty five screened genotypes. Thus, the lines selected, *viz:* EC-620401, EC-620406 and EC-620410, were also confirmed with high yield potential (Plate 13).

4.2 EXPERIMENT II: SCREENING FOR BACTERIAL WILT

4.2.1: Screening of tomato genotypes

The 35 tomato genotypes, 29 NBPGR accessions, Pusa Ruby, Arka Abha, Arka Saurabh, Arka Alok, Akshaya and Anagha, along with KAU released known resistant sources Sakthi and Mukthi were artificially screened for wilt incidence. Data was taken as the per cent disease incidence for all the genotypes. Days taken for wilting and per cent disease incidence are given in the Table 74.

The observations were taken from the third day of inoculation. There was significant difference among the genotypes for the days taken for wilting. The days was in the range between 5.0 and 13.5. The resistant genotypes did not wilt, hence, recorded nil. The longest time (13.5 days) was taken by Sakthi. It was followed by EC-157568 (12.5 days), followed by EC-521067 B (12.0 days). The earliest to wilt was genotypes EC-151568 and Pusa Ruby (5.0 days), followed by EC-160885, EC-164670 and EC-620417 (6.5 days) (Plates from 14 to 18).

According to the reaction scores (3.2.2), the genotypes were divided into five categories. The plants showing symptoms were confirmed with ooze test. The two genotypes, EC-145057 and Pusa Ruby, were highly susceptible (> 70-100%). Eighteen genotypes, EC-151568, EC-157568, EC-160885, EC-163605, EC-164263, EC-164563, EC-164670, EC-249514, EC-521067 B, EC-528368, EC-538153, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410,

Table 74: Evaluation of tomato genotypes for bacterial wilt incidence and per cent disease incidence

Sl No.	Genotype	No. of days taken for wilting	Per cent disease incidence*	Reaction
1	EC-145057	7.5	85.0 (73.0)	HS
2	EC-151568	5.0	45.0 (42.1)	S
3	EC-157568	12.5	65.0 (53.8)	S
4	EC-160885	6.5	35.0 (36.2)	S
5	EC-163605	8.5	35.0 (36.2)	S
6	EC-164263	7.5	35.0(36.2)	S
7	EC-164563	9.5	65.0 (53.9)	S
8	EC-164670	6.5	40.0 (39.2)	S
9	EC-165395	Nil	0.0 (0.9)	R
10	EC-165690	8.5	20.0 (20.1)	MS
11	EC-165700	Nil	0.0 (0.9)	R
12	EC-249514	11.5	45.0 (42.1)	S
13	EC-521067 B	12.0	50.0 (45.0)	S
14	EC-528368	10.5	35.0 (36.2)	S
15	EC-538153	8.5	65.0 (53.8)	S
16	EC-620376	Nil	0.0 (0.9)	R
17	EC-620378	Nil	0.0 (0.9)	R
18	EC-620382	Nil	0.0 (0.91)	R
19	EC-620387	8.5	40.0 (39.1)	S
20	EC-620389	9.5	45.0 (42.1)	S
21	EC-620395	7.5	10.0 (13.7)	MR
22	EC-620401	10.5	35.0 (36.2)	S
23	EC-620406	8.5	45.0 (42.1)	S
24	EC-620410	8.5	65.0 (53.8)	S
25	EC-620417	6.5	20.0 (20.1)	MS
26	EC-620427	Nil	0.0 (0.9)	R
27	EC-620429	Nil	0.0 (0.9)	R
28	EC-631369	7.5	50.0 (45.0)	S
29	EC-631379	11.5	15.0 (17.1)	MR
30	Pusa Ruby	5.0	100.0 (89.1)	HS
31	Arka Abha	Nil	0.0 (0.9)	R
32	Arka Saurabh	7.5	40.0 (39.2)	S
33	Arka Alok	9.5	25.0 (23.0)	MS
34	Akshay	Nil	0.0 (0.9)	R
35	Anagha	Nil	0.0 (0.9)	R
36	Sakthi	13.5	15.0 (17.1)	MR
37	Mukthi	Nil	0.0 (0.9)	R
CD (0.05)		0.9	16.9	
CV		8.2	10.4	

EC-620401: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

EC-620406 : The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

EC-620410: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

Plate 13: Genotypes selected as lines

Plate 14: Collection of bacterial suspension and preparation of sick filed

Plate 15: Root trimming, Dipping in bacterial suspension and Replanting in the sick protrays

Plate 16: Susceptible genotypes start wilting

Plate 17: Susceptible genotypes wilted and resistant genotypes non wilted

Plate 18: Confirmation of susceptible genotypes in the ooze test

EC-631369 and Arka Saurabh were included in the category susceptible (>30-70%). The moderate susceptibility (>20-30%) was exhibited by three genotypes, EC-620417 and Arka Alok. The genotypes EC-620395, EC-631379 and KAU released variety Sakthi were moderately resistant (> 10-20%).

The disease index was figured for each genotype on seventh day of inoculation (Table 75). EC-620382 (0.20) and Arka Abha (0.20) were categorized as highly resistant. Nine genotypes *viz:* EC-165395 (0.24), EC-165700 (0.25), EC-521067 B (0.25), EC-620376 (0.30), EC-620378 (0.28), EC-620427 (0.21), EC-620429 (0.23), Akshay (0.21), Anagha (0.28) were resistant. Pusa Ruby was the only extremely susceptible genotype with disease index 1.0.

Table 75: **Classification of genotypes based disease index from artificial inoculation**

Disease index	Reaction	No. of genotypes	Genotypes with their individual disease index
0.00 - 0.2	Highly resistant	2	EC-620382 (0.20), Arka Abha (0.20)
0.21 - 0.3	Resistant	10	EC-165395 (0.24),EC-165700 (0.25), EC-521067 B (0.25), EC-620376 (0.30), EC-620378 (0.28), EC-620427 (0.21), EC-620429 (0.23), Akshay (0.21), Anagha (0.28), Sakthi (0.28)
0.31 - 0.4	Moderately resistant	4	EC-164563 (0.33), EC-164670 (0.36), EC-538153 (0.39), Mukthi (0.36)
0.41 - 0.5	Moderately susceptible	5	EC-160885 (0.44), EC-164263 (0.42), EC-620389 (0.44),EC-620395 (0.45), Arka Saurabh (0.44),
0.51 - 0.6	Susceptible	7	EC-151568 (0.53), EC-165690 (0.57), EC-528368 (0.54), EC-631379 (0.59), EC-163605 (0.56), EC-620417 (0.57), Arka Alok (0.51)
0.61 - 0.9	Highly susceptible	8	EC-145057 (0.85), EC-157568 (0.65), EC-249514 (0.71), EC-620387 (0.80), EC-620401 (0.77), EC-620406 (0.85) EC-620410 (0.88), EC-631369 (0.76)
0.91 - 1.0	Extremely susceptible	1	Pusa Ruby (1.0)

In this study twelve genotypes, EC-165395, EC-165700, EC-521067 B, EC-620376, EC-620378, EC-620382, EC-620427, EC-620429, Arka Abha and KAU released varieties Akshaya, Anagha, and Sakthi were observed to be resistant (< 10%) to bacterial wilt. These genotypes were also evaluated in the field and observations recorded on per cent incidence of bacterial wilt. Also they were evaluated for yield characteristics in the field. From the results, it was concluded that the resistant genotypes from the NBPGR accessions are suggested to have the potential to be used in the breeding experiments for bacterial wilt resistance. Hence, for the line x tester analysis, the genotypes EC-620382, EC-620427, EC-620429 and Arka Abha were decided as testers with stable bacterial wilt resistance, satisfying average fruit weight and genetic divergence with lines (Plate 19).

4.3 EXPERIMENT III: PRODUCTION OF F_1 HYBRIDS

Three lines *viz*: EC-620401 (1), EC-620406 (2) and EC-620410 (3), and four testers *viz*: EC-620382 (4), EC-620427 (5), EC-620429 (6) and Arka Abha (7) were crossed to get twelve combinations of hybrids (Table 76 and Plates 20 - 22).

Table 76: Cross combination and seed recovery of crossed fruits

Sl. No.	Cross combinations	Code number	Number of flowers hybridized	Number of crossed fruits harvested	Total fruit weight of freshly harvested crossed fruits (g)	Seed recovery (g)
1	EC-620401 x EC-620382	1 x 4	43	10	646	2.8
2	EC-620401 x EC-620427	1 x 5	37	11	823	3.7
3	EC-620401 x EC-620429	1 x 6	32	8	587	2.5
4	EC-620401 x Arka Abha	1 x 7	28	10	687	3.2
5	EC-620406 x EC-620382	2 x 4	35	10	726	3.5
6	EC-620406 x EC-620427	2 x 5	32	9	625	2.7
7	EC-620406 x EC-620429	2 x 6	35	8	536	2.5
8	EC-620406 x Arka Abha	2 x 7	27	10	647	3.2
9	EC-620410 x EC-620382	3 x 4	33	12	823	3.4
10	EC-620410 x EC-620427	3 x 5	32	8	563	2.5
11	EC-620410 x EC-620429	3 x 6	38	10	650	2.8
12	EC-620410 x Arka Abha	3 x 7	29	10	738	3.4

EC-620382: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

EC-620427: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

Plate 19: Genotypes selected as testers

EC-620429: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

EC-620429: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

Plate 19: Continued

4.3.1 Fruit harvesting and seed processing

Fruits were harvested 35 – 40 days after pollination. The harvested fruits were cut with sharp knife, and the pulp with seed was extracted and kept for fermentation one day. The fermented pulp was washed 8-10 times with clean water and the seeds obtained were sun dried for one day and shade dried for 3-4 days. Then these seeds were stored in air tight zip-lock polythene covers.

4.4 EXPERIMENT IV: F_1 HYBRIDS EVALUATION

Twelve hybrids along with seven parents, 3lines (1, 2 and 3), 4 testers (4, 5, 6 and 7), and two checks, one check hybrid (Abhilash) and one check variety (Akshaya), were evaluated from March to August 2019. The results are briefed below.

4.4.1 Analysis of variance

Under polyhouse condition analysis of variance revealed significant differences among the genotypes, parents, parents vs. crosses and crosses for all characters. Among the lines, significant difference was observed for all characters except for plant height at harvest, intercluster distance, crop duration, shelf life, number of fruits per plant, pericarp thickness and lycopene. Among the testers significant difference was observed for all characters except for plant height at flowering, days to 50% flowering, days to first fruit harvest and TSS (Tables 77).

Among the reproductive traits significant differences was found among the genotypes, parents, parents vs. crosses and crosses for all characters. Among the lines significant difference was observed for all characters except length of the style and number of flowers per cluster in the mid and late stage of flowering, number of fruits per cluster in the mid stage of flowering and fruit set per cent in the early stage of flowering. Among the testers, the significant difference was observed for traits except number of flowers per cluster in the early and mid stage of flowering and number of fruits per cluster in the early stage of flowering (Tables 78).

Inside rainshelter, analysis of variance revealed significant differences among the genotypes, parents and parents vs. crosses for all characters. Crosses were significantly different except for internodal length, leaf area, locule number per fruit and chlorophyll a. Lines were significantly different except for leaf area, days to first fruit set, days from anthesis to fruit maturity, pericarp thickness, TSS and ascorbic acid. Testers showed significant difference except for plant height at flowering, intercluster distance, days to first fruit set, locule number per fruit, TSS and ascorbic acid (Tables 79).

Among the reproductive traits significant difference was not observed for all characters studied for genotypes, parents and parents vs. crosses. Crosses were significantly different except for pollen viability at early stage of flowering. Lines showed significant difference except for flowers with exerted stigma at early stage of flowering, number of flowers per cluster at early stage of flowering and number of fruits per cluster in the early and mid stage of flowering. Testers showed significant difference for all characters except for flowers with exerted stigma during early stage of flowering, number of flowers per cluster in early and mid stage of flowering and number of fruits per cluster in early, mid and late stage of flowering (Tables 80).

So ample variability was observed for the characters studied among the material used.

4.4.2 Mean performance of the hybrids, parents and checks

The mean performance of parents, F_1 hybrids and checks and the heterosis percentages of F_1 hybrids over mid parent, better parent and standard check hybrid for different characters are presented in tables from Table 80 to Table 116. The magnitude of heterosis, estimated as per cent increase or decrease of F_1 value over mid-parent (RH), better parent (HB) and standard check hybrid (SH). The salient findings of the experiment are discussed below.

Plate 20: Plants kept covered after hybridisation

Plate 21: Fruit set after artificial pollination

Plate 22: Seed extraction from hybridized fruits

Table 77: Line x Tester (ANOVA) summary various traits for polyhouse plants

Source of variation	Df	Plant height at flowering	DT 50% flowering	Plant height at harvest	Internod al length	Leaf area	Intercluster distance	DTF frit set	DFAT fruit maturity	DTF fruit harvest	Crop duration	No of fruits /plant	Locule no/fruit
Replications	1	23.03	1.17	0.12	0.34	53.79	2.53	21.0	9.91	9.62	18.80	55.78*	0.08
Treatments	19	37.41*	19.43*	32.25*	2.54*	79.52*	8.95*	17.77*	5.34*	23.68*	14.70*	9.52*	0.96*
Parents	7	42.07*	17.17*	41.34*	1.05*	76.24*	3.54*	16.12*	7.21*	25.76*	14.3*	2.11*	0.93*
Parents vs. Crosses	1	1.93*	1.91*	1.01*	0.03*	2.0*	4.16*	0.12*	3.82*	10.34*	6.81*	130.34*	0.76*
Crosses	11	37.67*	22.47*	29.32*	0.03*	88.65*	12.83*	20.44*	4.29*	23.57*	15.68*	3.25*	0.99*
Lines	2	96.15*	22.63*	76.74	0.41*	182.17*	20.44	23.22*	2.06*	36.55*	2.51	0.41	1.63*
Testers	3	19.0	19.71	23.89*	5.4*	99.94*	14.79*	13.82*	1.57*	24.34	48.8*	8.47*	1.69*
Lines X Testers	6	27.51*	23.79*	16.22*	3.97*	51.8*	9.31*	22.82*	6.39*	18.86*	3.51*	1.59*	0.43*
Error	21	16.86	8.218	20.78	0.42	70.4	0.93	10.87	4.08	14.69	10.75	4.71	0.43
Total	41	1087.85	542.98	1049.22	57.41	3042.93	192.08	587.0	196.98	767.89	524.01	335.51	27.36

Table 77: Continued

Source of variation	Df	Pericarp thickness	Avg. Fruit weight	Yld/ plant	Yld/plot	TSS	Lycopene	Ascorbic acid	Acidity	chl.a	chl.b	chl. total	Shelflife
Replications	1	0.003	4.34	99056.57	0.76	0.07	0.07	4.79	0.0004	0.001	0.05	0.05*	0.019
Treatments	19	0.01*	250.95*	152235.37*	5.29*	0.06*	4.29*	14.71*	0.001*	0.05*	0.03*	0.12*	2.16*
Parents	7	0.01*	216.49*	31144.36*	0.65*	0.06*	2.32*	6.65*	0.0008*	0.05*	0.01*	0.08*	1.2*
Parents vs. Crosses	1	0.01*	2552.4*	2316902.2*	73.87*	0.14*	32.23*	9.03*	0.004*	0.001*	0.01*	0.32*	0.08*
Crosses	11	0.02*	63.66*	32505.39*	2.01*	0.05*	3.00*	20.36*	0.0009*	0.05*	0.05*	0.13*	2.96*
Lines	2	0.004	58.30*	40459.69*	2.86*	0.09*	4.09	2.98*	0.00003*	0.04*	0.02*	0.1*	7.52*
Testers	3	0.03*	73.32*	55768.42 *	3.59*	0.2	4.34*	34.15*	0.0005*	0.1*	0.1*	0.20*	2.44*
Lines X Testers	6	0.01*	60.61*	18222. 44*	0.93*	0.05*	1.97*	19.26*	0.001*	0.03*	0.03*	0.11*	1.71*
Error	21	0.01	86.28	59793.70	1.97	0.08	1.46	3.68	0.0004	0.04	0.03	0.09	2.24
Total	41	0.41	6584.30	4247196.33	142.60	2.85	112.11	361.60	0.03	1.71	1.31	4.27	88.21

Table 78: Line x Tester (ANOVA) summary of reproductive traits for polyhouse plants

Source of variation	**Df**	**Pollen viability**			**Length of the style**			**Anther length**		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Replications	1	0.06	0.64	1.34	0.001	0.001	0.0002	0.0002	0.001	1.19
Treatments	19	10.26*	17.76*	19.14*	0.003*	0.002*	0.003*	0.002*	0.002*	0.002*
Parents	7	3.74*	8.01*	5.75*	0.002*	0.002*	0.003*	0.002*	0.003*	0.002*
Parents vs. Crosses	1	139.13*	246.40*	304.27*	0.001*	0.001*	0.001*	0.001*	0.0002*	0.003*
Crosses	11	2.69*	3.17*	1.738*	0.003*	0.002*	0.002*	0.003*	0.002*	0.003*
Lines	2	2.26*	4.18*	1.366*	0.001*	0.001	0.003	0.001*	0.001*	0.002*
Testers	3	3.55*	4.79*	4.05*	0.004*	0.002*	0.004*	0.004*	0.002*	0.005*
Lines X Testers	6	2.4*	2.03*	0.71*	0.003*	0.003*	0.002*	0.002*	0.002*	0.002*
Error	21	6.34	9.04	9.4	0.001	0.001	0.002	0.001	0.001	0.005
Total	41	28.02	527.83	562.31	0.08	0.07	0.07	0.07	0.06	0.005

Table 78: Continued

Source of variation	**Df**	**Flowers with exerted stigma**			**No. of flowers / cluster**			**No. of fruits / cluster**			**Fruit set per cent**		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Replications	1	10.40	75.47	0.20	0.01	0.31*	0.64*	0.12	0.095	0.26	0.53	1.34	5.65
Treatments	19	9.14*	11.91*	14.25*	0.93*	0.96*	0.92*	0.36*	0.45*	0.22*	10.42*	14.28*	14.07*
Parents	7	8.16*	10.18*	18.14*	0.72*	1.41*	0.68*	0.38*	0.59*	0.12*	3.86*	6.85*	10.99*
Parents vs. Crosses	1	38.50*	34.36*	40.52*	0.471*	5.26*	5.64*	1.0*	2.87*	1.94*	96.38*	90.36*	65.36*
Crosses	11	7.1*	10.97*	9.39*	1.11*	0.29*	0.64*	0.29*	0.14*	0.13*	6.77*	12.09*	11.36*
Lines	2	0.13*	3.89 *	20.32*	3.95*	0.14	1.10	0.87*	0.003	0.15*	3.59	3.58*	15.83*
Testers	3	5.67*	4.61*	8.46*	0.82	0.23	0.86	0.22	0.37*	0.19*	3.76*	11.69*	10.41*
Lines X Testers	6	10.14*	16.51*	6.21*	0.31*	0.37*	0.38*	0.14*	0.07	0.10*	9.34*	15.12*	10.34*
Error	21	10.87	23.83	16.95	0.05	0.02	0.11	0.05	0.03	0.07	9.59	10.73	14.09
Total	41	412.39	802.24	627.0	18.83	19.01	20.31	7.99	9.22	5.93	399.72	497.87	568.98

Table 79: Line x Tester (ANOVA) summary various traits for rainshelter plants

Source of variation	Df	Plant height at flowering	DT 50% flowering	Plant height at harvest	Internodal length	Leaf area	Intercluster distance	DTF fruit set	DFAT fruit maturity	DTF fruit harvest	Crop duration	No of fruits /cluster	Locule no/fruit
Replications	1	9.10	17.23	37.96	2.22	110.97	2.19	8.51	7.23	2.15	0.17	4.75	0.93
Treatments	19	42.93*	34.33*	45.719*	3.12*	63.81*	8.02*	19.38*	5.51*	22.75*	28.89*	7.15*	1.00*
Parents	7	31.62*	30.98*	74.06*	1.47*	83.62*	3.87*	18.28*	8.81*	25.03*	9.44*	7.0	0.6*
Parents vs. Crosses	1	4.754*	0.320*	0.1*	0.26*	26.15*	0.004*	0.96*	9.17*	7.48*	43.94*	36.16*	0.0002*
Crosses	11	53.58*	39.56*	31.84*	4.43	54.63	11.38*	21.76*	3.08*	22.69*	39.9*	4.61*	1.35
Lines	2	176.13*	21.61*	47.56*	0.46*	95.4	22.46*	31.08	0.86	38.31*	12.99*	3.64*	3.53*
Testers	3	25.55	37.08*	15.87*	5.2*	37.11*	16.61	7.88	3.21*	11.54*	115.3*	7.46*	0.71
Lines X Testers	6	26.75*	46.78*	34.58*	5.35*	49.80*	5.07*	25.59*	3.75*	23.06*	11.16*	3.51*	0.95*
Error	21	12.49	3.76	25.7	0.27	66.80	0.41	5.12	4.33	13.64	4.64	3.51	0.61
Total	41	1086.94	67.19	0.015	2726.26	646.55	87.92	748.6	0.016	484.65	202.90	214.33	0.33

Table 79: Continued

Source of variation	Df	Pericarp thickness	Avg. Fruit weight	Yld/ plant	Yld/plot	TSS	Lycopene	Ascorbic acid	Acidity	chl.a	chl.b	chl. total	shelflife
Replications	1	0.021	4.87	3476.93	0.20	0.05	0.17	6.40*	0.0009	0.004	0.001	0.008	0.80
Treatments	19	0.03*	254.89*	163532.41*	3.9*	0.01*1	4.24***	20.7***	0.001*	0.04*	0.04*	0.14*	2.4*
Parents	7	0.02*	139.22*	26343.75*	0.2*	0.009*	2.26*	7.49*	0.0005*	0.017*	0.01*	0.10*	1.53*
Parents vs. Crosses	1	0.03*	2938.67*	2388458.87*	54.64*	0.004*	51.12*	35.73**	0.004*	0.01*	0.05*	0.39*	0.31*
Crosses	11	0.04*	84.52*	48568.25*	1.63*	0.008*	1.24*	27.73*	0.001*	0.05	0.05*	0.14*	3.14*
Lines	2	0.01	52.62*	4791.1*	0.33*	0.01	0.03*	17.44	0.0003*	0.04*	0.02*	0.20*	6.53*
Testers	3	0.09*	165.86*	69580.79*	2.45*	0.017	3.79*	35.7	0.0004*	0.09*	0.09*	0.17*	2.41*
Lines X Testers	6	0.02*	54.48*	52654.36*	1.66*	0.003*	0.37*	27.18***	0.002*	0.04*	0.05*	0.11*	2.38*
Error	21	0.02	43.06	15265.42	0.46	0.021	0.98	3.30	0.001	0.03	0.03	0.08	1.98
Total	41	0.91	5752.03	3431166.61	83.86	0.64	101.37	468.9	0.04	1.4	1.32	4.41	720.72

Table 80: Line x Tester (ANOVA) summary of reproductive traits for rainshelter plants

Source of variation	Df	Pollen viability			Length of the style			Anther length		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Replications	1	4.15	23.02	4.02	0.002	0.0009	0.001	0.002	0.009	0.0004
Treatments	19	9.44*	14.27*	16.96*	0.004*	0.004*	0.004*	0.004*	0.003*	0.003*
Parents	7	7.6*	11.24*	6.28*	0.007*	0.004*	0.005*	0.006*	0.003*	0.004*
Parents vs. Crosses	1	84.04*	135.06*	200.9*	0.002*	0.0009*	0.005*	0.0007*	0.001*	0.001*
Crosses	11	3.83	5.23*	7.03*	0.002*	0.003*	0.004*	0.002*	0.003*	0.003*
Lines	2	8.43*	1.64*	12.67*	0.003*	0.0008*	0.007*	0.001*	0.008*	0.006*
Testers	3	5.22*	4.39*	4.0917*	0.005*	0.006*	0.004*	0.005*	0.005*	0.003*
Lines X Testers	6	1.61	6.84*	6.62*	0.001*	0.003*	0.003*	0.001*	0.003*	0.001*
Error	21	7.9	7.87	7.06	0.0003	0.0004	0.0003	0.0004	0.003	0.0002
Total	41	349.35	459.48	474.37	0.09	0.076	0.09	0.081	0.006	0.06

Table 80: Continued

Source of variation	Df	Flowers with exerted stigma			No. of flowers / cluster			No. of fruits / cluster			Fruit set per cent		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Replications	1	87.73	56.47	0.1	0.06	0.44*	0.13	0.02	0.1	0.05	0.004	0.6	16.1
Treatments	19	13.15*	20.7*	15.4*	0.8*	0.77*	1.24*	0.03*	0.43*	0.27*	9.92*	9.49*	8.37*
Parents	7	23.0*	40.73*	21.98*	0.61*	0.45*	0.31*	0.03*	0.16*	0.15*	8.44*	9.03*	9.16*
Parents vs. Crosses	1	15.33*	12.89*	27.96*	0.11*	3.08*	9.83*	0.08*	2.08*	2.54*	26.24*	5.87*	20.56*
Crosses	11	6.68*	8.65*	10.07*	0.98*	0.76*	1.06*	0.04*	0.46*	0.15*	9.37*	10.10*	6.76*
Lines	2	2.88	0.23*	8.203*	0.69	1.19*	3.66*	0.02	0.34	0.15*	9.65*	21.2*	22.26*
Testers	3	8.05	13.39*	6.12*	0.54	0.35	0.30	0.04	0.12	0.09*	6.08*	12.82*	7.08*
Lines X Testers	6	7.29*	9.09*	12.66*	1.30*	0.83*	0.57*	0.05*	0.66*	0.17	10.93*	5.04*	1.44*
Error	21	10.19	11.32	11.28	0.07	0.03	0.04	0.05	0.03	0.07	11.56	12.18	13.87
Total	41	551.57	687.48	529.51	16.61	15.74	24.53	0.08	8.96	6.75	2.04	436.64	466.53

4.4.2.1 Quantitative characters

4.4.2.1.1 Vegetative characters

The traits studied were plant height at flowering, internodal length, plant height at harvest, leaf area and crop duration (Table 81 – 85, respectively)

4.4.2.1.1.1 Plant height at flowering (cm)

Under polyhouse, among the hybrids plant height at flowering was highest for 3 x 7 (67.15 cm) which was higher than both the checks (54.15 cm for Akshaya and 54.7 cm for Abhilash). Among the parents 6 (EC-620429) recorded highest plant height at flowering (66.45 cm). Inside rainshelter also the same hybrid 3 x 7 recorded highest plant height at flowering (57.65 cm) which was higher than both the checks and parents. Among the parents the highest plant height was recorded for 6 (56.3 cm).

Under poyhouse, the RH was in the range between -11.8% (1 x 6) and 11.7% (3 x 7). Only one hybrid, 3 x 7, recorded significant positive RH. The HB was in the range between -19.1% (1 x 6) and 7.1% (3 x 7). The SH observed ranged between -3.2% (1 x 7) and 22.77% (3 x 7) among which Eight hybrids recorded significant positive SH. Inside rainshelter, the RH ranged between -23.97% (1 x 6) and 10.76% (3 x 7). Significant positive heterosis was recorded for two hyrids, 3 x 7 (10.76%) and 2 x 7 (4.24%). HB was in the range between -26.2% (1 x 6) and 6.27% (3 x 7). Only one hybrid, 3 x 7 recorded significant positive HB (6.27%). Nine hybrids recorded significant positive SH, highest being 3 x 7 (26.7%).

4.4.2.1.1.2 Internodal length (cm)

Under polyhouse condition, among the parents the internodal length was highest for 6 (EC-620429), 10.45 cm. Among the hybrids 3 x 7 recorded highest intermodal length (11.0 cm). The intermodal length for the checks was 8.8 cm for Akshaya and 8.05 cm for Abhilash. Inside rainshelter among the parents 6 (EC-620429) recorded highest internodal length (9.95 cm). Among the hybrid 3 x 7 recorded highest internodal length (10.6 cm) which was higher than parents and checks

Under polyhouse, RH was in the range between -23.76% (1 x 7) and 29.41% (3 x 5). The HB was observed between -30.14% (1 x 7) and 24.29% (3 x 5). SH ranged between -18.63% (2 x 6) and 36.65% (3 x 7). Inside rainshelter, three hybrids recorded significant positive RH, highest being recorded for 3 x5 (40.82%). Significant HB was observed for two hybrids, 30.78% (3 x 5) and 20.05% (2 x 4). Eight hybrids recorded significant positive SH, highest being observed for 3 x 7 (44.22%).

Table 81: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for plant height at flowering

Parents / hybrids / checks	**Plant height at flowering (cm)**		**Per cent heterosis**					
	Polyhouse	**Rainshelter**	**Polyhouse**			**Rainshelter**		
			RH	**HB**	**SH**	**RH**	**HB**	**SH**
1	62.55	53.0						
2	61.65	52.80						
3	62.70	54.25						
4	64.20	54.50						
5	62.85	54.60						
6	66.45	56.30						
7	57.50	49.85						
1 x 4	56.85	44.35	-4.9*	-11.5*	3.93	-17.49*	-18.62*	-2.53
1 x 5	62.20	53.15	5.2	-1.03	**13.71***	-1.21	-2.66	**16.81***
1 x 6	53.75	41.55	-11.8*	-19.1*	-1.74	-23.97*	-26.2*	-8.68*
1 x 7	52.95	44.45	-6.2*	-15.4*	-3.2	-13.56*	-16.13*	-2.31
2 x 4	62.0	49.85	-1.5*	-3.4	**13.35***	-7.08*	-8.53*	**9.56***
2 x 5	62.80	54.60	0.9	-0.08	**14.81***	1.68	3.41	**20.0***
2 x 6	64.0	56.75	-0.1*	-3.7	**17.0***	4.03	0.8	**24.73***
2 x 7	56.8	53.50	-4.7*	-7.87*	3.84	**4.24***	1.33	**17.58***
3 x 4	60.55	53.65	-4.6	-5.69*	**10.7***	-1.3	-1.56	**17.91***
3 x 5	63.80	54.0	1.6	1.51	**16.64***	-0.78	-1.1	**18.68***
3 x 6	60.95	51.88	-5.6*	-8.28*	**11.43***	-6.15*	-7.86*	**14.01***
3 x 7	67.15	57.65	**11.7***	**7.1***	**22.77***	**10.76***	**6.27***	**26.7***
Akshaya	54.15	46.95						
Abhilash	54.70	45.40						
CD (0.05)	7.24	7.52						
CV	6.95	6.99						

Table 82: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for internodal length

Parents / hybrids / checks	Internodal length (cm)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	8.75	8.30						
2	8.40	7.75						
3	8.15	6.95						
4	9.05	8.46						
5	8.85	8.11						
6	10.45	9.95						
7	8.70	8.20						
1 x 4	8.25	7.75	-15.38*	-21.05*	2.48	-15.78*	-22.11*	**5.44***
1 x 5	10.10	9.15	4.66	-3.35	**25.47***	1.36	-8.04*	**24.49***
1 x 6	8.45	7.70	-11.98*	-19.14*	4.97	-15.62*	-22.61*	**4.76***
1 x 7	7.30	6.60	-23.76*	-30.14*	-9.32*	-27.27*	-33.67*	-10.20*
2 x 4	10.60	10.15	**21.49***	**17.13***	**31.68***	**25.27***	**20.05***	**38.1***
2 x 5	9.20	8.10	6.67*	3.96	**14.29***	2.18	-0.06	**10.20***
2 x 6	6.55	5.60	-23.62*	-25.14*	-18.63*	-30.22*	-32.53*	-23.81*
2 x 7	8.65	7.86	-9.66*	-0.58	7.45*	-1.51	-4.21*	6.87*
3 x 4	7.15	6.10	-16.86*	-20.99*	-11.18*	-20.81*	-27.85*	-17.0*
3 x 5	8.95	8.36	**29.41***	**24.29***	**11.18***	**40.82***	**30.78***	**13.67***
3 x 6	8.80	8.00	4.14	0.57	**9.32***	4.92	-3.61	**8.84***
3 x 7	11.00	10.60	6.23	2.87	**36.65***	**10.3***	1.89	**44.22***
Akshaya	8.80	8.35						
Abhilash	8.05	7.35						
CD (0.05)	1.35	1.02						
CV	7.36	6.04						

4.4.2.1.1.3 Plant height at harvest (cm)

Under polyhouse, among the parents plant height at harvest was highest for 5 (EC-620427), 80.4 cm. Among the hybrids 3 x 7 recorded highest value (82.4 cm), which was higher that both the checks (71.05 cm for Akshaya and 69.6 cm for Abhilash). Inside rainshelter among the parents 4 (EC-620382) recorded highest value (75.38 cm). Among the hybrids 3 x 7 recorded maximum value (72.60 cm).

Under polyhouse only one hybrid recorded significant and positive RH, 3 x 7 (9.25%). The same hybrid recorded significant positive HB also (4.97%). All hybrids recorded positive standard heterosis, ten being significant. The highest was observed for the hybrid 3 x 7 (18.39%). Inside the rainshelter, none of the hybrids exhibited significant positive RH and HB. All hybrids, except one (1 x 7), recorded positive significant SH, highest being recorded for 3 x 7 (21.71%).

Table 83: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for plant height at harvest

Parents / hybrids / checks	Plant height at harvest (cm)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	80.10	69.24						
2	79.45	67.25						
3	78.50	74.10						
4	77.65	75.38						
5	80.40	73.20						
6	79.50	73.56						
7	72.35	66.45						
1 x 4	73.95	71.92	-7.85*	-8.02*	**6.25***	-0.54	-4.59	**20.57***
1 x 5	79.10	68.90	-0.88	-1.25	**13.65***	-3.25	-5.87*	**15.51***
1 x 6	70.85	65.72	-10.17*	-11.55*	1.8	-7.96*	-10.67*	**10.17***
1 x 7	70.35	58.10	-7.71	-12.17*	1.08	-14.36*	-16.08*	-2.6
2 x 4	76.45	66.44	-4.35*	-4.91*	**9.84***	-6.84*	-11.87*	**11.38***
2 x 5	79.40	70.29	-0.09*	-0.13	**14.08***	0.09	-3.98	**17.84***
2 x 6	79.05	72.09	0.64*	-0.50	**13.58***	2.39	-2.01	**20.85***
2 x 7	73.85	68.49	-2.7	-7.05*	**6.11***	2.45	1.84	**14.82***
3 x 4	77.75	69.85	-2.14	-3.3	**11.71***	-6.54*	-7.34*	**17.10***
3 x 5	80.90	70.60	2.41	1.76	**16.24***	-4.14	-4.72	**18.36***
3 x 6	77.85	70.77	-0.29*	-0.83	**11.85***	-4.15	-4.50	**18.63***
3 x 7	82.40	72.60	**9.25***	**4.97***	**18.39***	3.31	-2.02	**21.71***
Akshaya	71.05	61.35						
Abhilash	69.60	59.65						
CD (0.05)	5.36	6.03						
CV	6.08	7.52						

4.4.2.1.1.4 Leaf area (mm^2)

The cross, 2 x 5, recorded maximum leaf area (62.45 mm^2), under polyhouse, which was higher than both the checks (58.85 mm^2 for Akshaya and 57.8 mm^2 for Abhilash). Among parents 5 (EC-620427) recorded highest value (57.4 mm^2). Inside rainshelter, 2 x 7 recorded highest value (41.24 mm^2). The checks recorded higher values (48.42 mm^2 for Akshaya and 42.29 mm^2 for Abhilash). Among the parents 1 (EC-620401) recorded the highest value, 37.69 mm^2.

Under polyhouse, ten hybrids recorded significant positive RH. The hybrid 3 x 4 recorded the highest value (48.93%). Positive significant HB was observed only for 2 x 7 (14.85%) and none exhibited positive significant SH. Inside rainshelter, four hybrids recorded positive significant RH, highest value observed for 3 x 5 (62.9%). Two hybrids recorded positive and significant HB, 3 x 5 (59.98%) and 2 x 7 (16.6%). None exhibited positive significant SH.

Table 84: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for leaf area

Parents / hybrids / checks	Leaf area (mm^2)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	47.10	37.69						
2	53.20	31.84						
3	40.85	24.63						
4	54.50	34.13						
5	57.40	25.54						
6	54.60	31.62						
7	51.05	35.37						
1 x 4	47.59	27.50	9.22	-12.69*	-17.67*	-23.41*	-27.03*	-34.97*
1 x 5	52.80	26.64	**31.58***	-8.01	-8.65	-15.75	-29.32*	-37.02*
1 x 6	41.85	28.59	3.05	-23.35*	-27.6*	-17.5	-24.13*	-32.4*
1 x 7	52.60	30.45	**19.31***	3.04	-9.0	-16.63	-19.2*	-28.0*
2 x 4	54.60	26.63	**29.43***	0.18	-5.54	-19.26*	-21.96*	-37.03*
2 x 5	62.45	36.03	**22.78***	8.8	8.05	**25.58***	13.16	-14.80*
2 x 6	54.75	28.50	**26.25***	0.28	-5.28	-10.18	-10.49	-32.61*
2 x 7	61.10	41.24	**34.20***	**14.85***	5.71	**22.71***	**16.6***	-2.5
3 x 4	59.50	35.59	**48.93***	9.17	2.94	**21.16***	4.29	-15.84*
3 x 5	59.15	40.86	**44.12***	3.05	2.34	**62.90***	**59.98***	-3.31
3 x 6	48.00	33.08	**29.91***	-12.09*	-16.96*	17.63	4.62	-21.78*
3 x 7	44.700	30.44	**32.97***	-12.44*	-22.66*	1.48	-13.93	-28.02*
Akshaya	58.85	48.42						
Abhilash	57.80	42.29						
CD (0.05)	7.20	5.84						
CV	16.2	12.34						

4.7.2.1.1.5 Crop duration (no. of days)

Under polyhouse, among the hybrids 1 x 6 recorded maximum days (148.55 days), this was higher than one check (147.4 days for Akshaya and 150.6 days for Abhilash). Among the parents, 7 (Arka Abha) recorded highest value (148.65 days). Inside rainshelter, the hybrid 2 x 5 recorded maximum crop duration (144.21 days). Among the parents 7 (Arka Abha) recorded the longest duration (143.85 days).

Under polyhouse, RH was in the range between -3.02% (2 x 7) and 1.99% (1 x 6) and HB was in the range between -4.86% (2 x 4) and 1.78 (1 x 6). Positive significant SH was not observed for crop duration under polyhouse. Inside rainshelter, three hybrids recorded significant and positive RH and HB. The highest was recorded for 1 x 5 (2.32% and 1.6% respectively). The SH was in the range between -7.22% (2 x 4) and 2.53% (2 x 5). Six hybrids recorded positive significant SH.

Table 85: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for crop duration

Parents / hybrids / checks	Crop duration (no. of days)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	145.35	141.50						
2	148.1	142.65						
3	147.75	141.40						
4	141.6	138.85						
5	144.65	139.50						
6	145.95	142.15						
7	148.65	143.85						
1 x 4	141.2	133.25	-1.59	-2.86*	-6.24*	-4.94*	-5.83*	-5.26*
1 x 5	147.1	143.77	1.45	1.20	-2.32*	**2.32***	**1.60***	**2.22***
1 x 6	148.55	143.95	**1.99***	**1.78***	-1.36	**1.5***	**1.27***	**2.35***
1 x 7	148.0	138.69	0.68	-0.44	-1.73*	-2.8*	-3.59*	-1.4*
2 x 4	140.9	130.50	-2.73*	-4.86*	-6.44*	-7.28*	-8.52*	-7.22*
2 x 5	147.8	144.21	0.97	-0.20	-1.86*	**2.22***	**1.09***	**2.53***
2 x 6	148.25	142.55	0.83	0.10	-1.56*	0.11	0.07	**1.35***
2 x 7	143.9	138.04	-3.02*	-3.2*	-4.45*	-3.64*	-4.04*	-1.86*
3 x 4	143.2	137.95	-1.02	-3.08*	-4.91*	-1.55*	-2.44*	-1.92*
3 x 5	146.5	141.65	0.21	-0.85	-2.72*	0.85	0.18	0.71
3 x 6	148.05	143.05	0.82	0.20	-1.69*	0.9	0.63	**1.71***
3 x 7	146.85	142.80	-0.91	-1.21	-2.49*	0.12	-0.73	**1.53***
Akshaya	147.4	143.35						
Abhilash	150.6	140.65						
CD (0.05)	3.23	4.48						
CV	2.25	1.52						

4.4.2.1.2 Flowering characters

The traits studied were days to 50% flowering (Table 86), intercluster distance (Table 87), flowers with exerted stigma (Table 88), pollen viability (Table 89), length of the style (Table 90) anther length (Table 91), number of flowers per cluster (Table 92) and days to first fruit set (Table 93)

4.4.2.1.2.1 Days to 50% flowering

Under polyhouse condition, the cross 1 x 7 recorded earliest flowering (38.5 days). Among the parents, 6 (EC-620429) recorded earliest flowering (39.0 days). The check hybrid Abhilash recorded only 36.5 days for 50% flowering. Inside rainshelter, the same cross 1 x 7 recorded earliest flowering (32.0 days), followed by 2 x 5 (32.5 days). Among the parents 6 (EC-620429) recorded earliest flowering (31.5 days). Abhilash recorded 33.5 days.

Under polyhouse three hybrids recorded significant negative RH, highest being recorded for 1 x 7 (-18.95%). Significant negative HB was recorded for two hybrids, 1 x 7 (-18.95%) and 2 x 5 (-10.0%). Significant negative SH was not observed for days to 50% flowering under polyhouse. Inside rainshelter, the RH ranged between -46.75% (2 x 4) and 20.81% (2 x 6). The HB ranged between -24.71% (1 x 7) and 42.86% (2 x 6). Four hybrids (2 x 4, 1 x 7, 2 x 5and 1 x 5) recorded significant RH and three hybrids (1 x 7, 2 x 5 and 1 x 5) recorded significant HB. Two hybrids recorded significant negative SH, 1 x 7 (-4.48%) and 2 x 5 (-2.99%).

4.7.2.1.2.2 Intercluster distance (cm)

Under polyhouse and inside rainshelter, the hybrid 1 x 7 recorded minimum intercluster distance (6.95 cm and 5.65 cm, respectively). Among parents 4 (EC-620382) recorded minimum intercluster distance (8.15 cm and 7.7 cm, respectively). Akshaya recorded 8.45 cm under poly house and 7.7 cm inside rainshelter.

Under polyhouse, six hybrids recorded significant negative RH in the range between -45.16% (1 x 6) and 43.26% (2 x 5). Four hybrids exhibited significant negative HB, highest being recorded for 1 x 6 (-42.51%). Five hybrids recorded significant and negative SH, highest for 1 x 7 (-42.05%), followed by 1 x 6 (-38.97%). Inside rainshelter, three hybrids recorded significant and negative RH, 1 x 6 (-38.13%), 1 x 7 (-33.65%) and 3 x 4 (-17.12%). Two hybrids, 1 x 6 (-37.45%) and 1 x 7 (-25.67%) recorded significant and negative HB. Five hybrids recorded significant negative SH, highest being recorded for 1 x 7 (-38.77%), followed by 1 x 6 (-37.45%).

Table 86: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for days to 50% flowering

Parents / hybrids / checks	**Days to 50% flowering (no. of days)**		**Per cent heterosis**					
	Polyhouse	**Rainshelter**	**Polyhouse**			**Rainshelter**		
			RH	**HB**	**SH**	**RH**	**HB**	**SH**
1	47.50	42.50						
2	46.50	43.0						
3	48.0	42.0						
4	44.0	41.50						
5	45.0	42.0						
6	39.0	31.50						
7	47.50	43.0						
1 x 4	45.50	40.50	-0.55	3.41	24.66*	-3.57	-2.41	20.9*
1 x 5	44.0	40.0	**-4.87***	-2.22	20.55*	**-5.33***	**-4.76***	19.40*
1 x 6	48.0	44.55	10.98*	23.08*	31.51*	20.41*	41.43*	32.99*
1 x 7	38.50	32.0	**-18.95***	**-18.95***	5.48	**-25.15***	**-24.71***	**-4.48***
2 x 4	48.50	45.0	7.18*	10.23*	32.88*	**-46.75***	8.43*	34.33*
2 x 5	40.50	32.50	**-11.48***	**-10.0***	10.96*	**-23.53***	**-22.62***	**-2.99***
2 x 6	47.50	45.0	11.11*	21.8*	30.14*	20.81*	42.86*	34.39*
2 x 7	49.0	43.0	4.26*	5.38*	34.25*	19.38*	2.38	28.36*
3 x 4	49.0	43.50	6.52*	11.36*	34.25*	4.19*	4.82*	29.85*
3 x 5	47.50	43.0	2.15	5.56*	30.14*	2.38	2.38	28.36*
3 x 6	46.0	40.50	5.75*	17.95*	26.03*	10.20*	28.57*	20.9*
3 x 7	46.50	43.0	-2.62	-2.11	27.4*	1.18	2.38	28.36*
Akshaya	45.0	42.0						
Abhilash	36.50	33.50						
CD (0.05)	6.09	4.09						
CV	6.39	4.77						

Table 87: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for intercluster distance

Parents / hybrids / checks	Intercluster distance (cm)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	11.60	11.35						
2	9.35	8.25						
3	12.00	11.15						
4	8.15	7.70						
5	9.95	9.55						
6	11.35	10.35						
7	9.35	8.60						
1 x 4	9.45	7.35	**-22.84***	**-4.55***	**-24.62***	-4.30	15.95*	**-16.74***
1 x 5	12.35	10.75	2.87	12.57*	10.26*	14.62*	24.12*	8.81*
1 x 6	7.10	5.95	**-45.16***	**-42.51***	**-38.97***	**-38.13***	**-37.45***	**-37.45***
1 x 7	6.95	5.65	**-43.36***	**-34.30***	**-42.05***	**-33.65***	**-25.67***	**-38.77***
2 x 4	11.00	9.90	24.14*	28.57*	1.54	25.71*	34.97*	-3.08
2 x 5	13.20	12.75	43.26*	54.55*	30.77*	36.79*	41.18*	16.30*
2 x 6	13.90	11.25	20.97*	36.36*	15.39*	34.30*	48.66*	22.47*
2 x 7	8.85	7.65	**-9.2***	**-7.27***	**-21.54***	-5.35	-5.35	**-22.03***
3 x 4	8.35	7.80	**-17.24***	1.3	**-20.0***	**-17.12***	2.45	**-26.43***
3 x 5	12.95	11.85	14.49*	24.08*	21.54*	18.0	30.15*	14.1*
3 x 6	12.80	10.10	**-6.05***	-2.42	3.59*	9.64*	12.78*	12.78*
3 x 7	12.80	11.30	14.43*	31.4*	15.9*	19.91*	37.0*	12.78*
Akshaya	8.45	7.70						
Abhilash	11.35	9.75						
CD (0.05)	1.55	0.99						
CV	7.05	5.05						

4.4.2.1.2.3Flowers with exerted stigma (%)

4.4.2.1.2.3.1 Early stage of flowering

Under polyhouse condition among the hybrids 3 x 7 recorded minimum flowers with exerted stigma (18.1%), followed by 1 x 4 (18.2%), both were lower than the check hybrid (24.6%). Inside rainshelter, 1 x 4 recorded minimum flowers with exerted stigma (15.7%). The check hybrid recorded 20.5%.

Under polyhouse, significant negative RH and HB were not observed. All hybrids recorded negative SH, eight being significant (3 x 7) being highest (-26.4%). Inside rainshelter, only one hybrid recorded significant negative RH, 2 x 5 (-12.3%). Significant negative HB was not observed for this trait. Five hybrids recorded significant negative SH, highest being recorded for 1 x 4 (-23.7%).

4.7.2.1.2.3.2 Mid stage of flowering

Under polyhouse condition 1 x 4 recorded minimum flowers with exerted stigma (17.4%). The check hybrid Abhilash and 3 (EC-620410) recorded 27.0% and 16.5% respectively. Inside the rainshelter, 2 x 4 recorded minimum flowers with exerted stigma (15.4%). The checks and parents recorded higher values (22.9% for Abhilash and 23.8% for Akshaya).

Under polyhouse, significant negative RH and HB were not observed. All hybrids recorded negative SH and ten among them were significant 1 x 4 (-35.4%), being highest. Inside rainshelter, RH ranged between -26.8% (2 x 4) and 21.5% (2 x 7). Only one hybrid recorded significant negative HB, 2 x 4 (-19.2%). All hybrids recorded negative SH, and eight among them were significant, highest being observed for 2 x 4 (-32.6%).

4.7.2.1.2.3.3 Late stage of flowering

Under polyhouse condition the hybrid, 2 x 7 (19.1%) recorded minimum value, which was lower than checks, Abhilash recorded (27.7%) and Akshaya (25.9%). Inside rainshelter, 3 x 6 recorded minimum flowers with exerted stigma (19.1%), lower than checks, Abhilash (25.7%) and for Akshaya (26.7%).

Under polyhouse, significant negative RH and HB were not observed. All hybrids exhibited negative SH and eight among them were significant 2 x 7 being highest (-30.9%). Inside the rainshelter, significant and negative RH and HB were not observed for flowers with exerted stigma. Nine hybrids recorded significant and negative SH. The highest was recorded for the hybrid 3 x 6 (- 25.5%), followed by 2 x 4 (-22.1%).

Table 88: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for flowers with exerted stigma

Parents / hybrids / checks	Flowers with exerted stigma (%)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	21.0	12.5	19.3	16.0	24.5	20.3																		
2	15.6	18.4	20.6	19.1	20.3	18.1																		
3	18.5	16.1	16.5	16.6	16.6	19.7																		
4	34.7	35.5	38.5	35.5	32.6	40.7																		
5	32.5	42.7	33.8	40.5	38.5	36.7																		
6	32.5	37.5	36.4	40.5	33.6	38.5																		
7	35.5	39.7	35.5	40.2	32.6	38.5																		
1 x 4	18.2	15.7	17.4	19.1	22.4	22.7	-7.2	0.3	**-26.2***	-5.3	25.2*	**-23.7***	-13.5	-9.6	**-35.4***	-2.2	19.4*	**-16.4***	4.2	21.1*	**-19.0***	0.7	11.8*	**-11.5***
1 x 5	20.3	21.9	23.8	21.5	26.6	25.0	-5.6	-3.3	**-17.5***	20.7*	74.8*	6.6	18.0*	23.4*	-11.9	-0.2	34.1*	-6.2	9.6	10.6	-3.8	10.4	23.2*	-2.5
1 x 6	21.2	19.6	23.0	18.1	24.1	22.0	6.3	12.5*	**-14.0***	22.5*	56.8*	-4.4	7.8	19.2	**-14.8***	**-15.5***	13.1	**-20.8***	-2.3	-1.6	**-12.9***	13.0*	18.0*	**-14.2***
1 x 7	23.6	17.5	21.5	19.4	21.5	20.5	14.7*	17.1*	-4.1	12.2	40.1*	**-14.6***	1.9	11.7	**-20.2***	19.4*	21.1*	**-15.1***	-9.2	-12.3	**-22.2***	12.6*	27.4*	**-20.3***
2 x 4	20.1	17.3	23.4	15.4	22.8	20.0	19.2*	28.9*	**-18.5***	-11.3	-6.0	**-15.9***	12.5	13.6	**-13.2***	**-26.8***	**-19.2***	**-32.6***	17.4*	23.0*	**-17.7***	-6.7	10.8	**-22.1***
2 x 5	21.1	18.5	23.1	20.5	23.8	24.1	12.4*	35.7*	**-14.2***	**-12.3***	0.6	**-10.0***	10.82	11.9	**-14.5***	-11.0	7.6	**-10.3***	7.2	17.3*	**-14.1***	12.0*	33.5*	-6.0
2 x 6	19.5	20.6	19.5	19.9	22.7	27.3	13.5*	25.4*	**-20.7***	8.9	12.3	0.5	-11.3	-5.3	**-27.6***	**-13.5***	4.2	**-13.1***	0.7	12.1	**-17.9***	48.8*	51.3*	6.4

Table 88: Continued

Parents / hybrids / checks	Flowers with exerted stigma (%)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 7	22.6	20.8	23.4	21.6	19.1	22.7	26.6*	45.3*	-8.1	12.0	13.1*	1.2	7.5	13.6	**-13.2***	21.5*	13.4*	-5.5	-11.4	-5.7	**-30.9***	33.1*	25.8*	**-11.5***
3 x 4	20.1	20.6	23.0	21.1	26.7	21.6	10.0	11.1*	**-18.3***	12.1*	27.6*	0.2	22.6*	39.5*	**-14.8***	6.4	27.1*	-7.7	52.5*	61.3*	-3.4	-2.8	9.9	**-15.8***
3 x 5	22.2	20.5	22.0	21.9	24.0	22.3	9.5	20.1*	**-10.0***	2.8	27.0*	-0.2	17.2	33.4*	**-18.6***	0.2	31.6*	-4.4	18.2*	45.0*	**-13.2***	-0.3	13.2*	**-13.3***
3 x 6	23.8	20.2	26.3	16.2	25.0	19.1	27.5*	28.7*	-3.5	13.5*	25.5*	-1.5	32.2*	59.9*	-2.4	**-25.7***	-2.7	**-29.3***	20.8*	51.1*	-9.6	-0.3	2.4	**-25.5***
3 x 7	18.1	18.2	19.9	19.6	25.4	23.1	-6.2	-1.9	**-26.4***	4.6	13.0	**-11.2***	0.8	20.7	**-26.4***	18.4*	18.9*	**-14.2***	28.7*	53.2*	-8.3	29.1*	43.6*	**-10.1***
Akshaya	21.9	18.4	21.5	23.8	25.9	26.7																		
Abhilash	24.6	20.5	27.0	22.9	27.7	25.7																		
CD (0.05)	4.9	4.8	5.5	6.4	8.3	4.6																		
CV	14.8	16.8	18.9	15.4	16.6	13.5																		

*PH – polyhouse; RS – rainshelter

4.4.2.1.2.4 Pollen viability (%)

4.4.2.1.2.4.1 Early stage of flowering

Under polyhouse condition, 2 x 4 and 3 x 6 recorded highest value (56.6%). Inside rainshelter, 3 x 7 recorded maximum pollen viability (66.7%).

Under polyhouse, all hybrids recorded significant RH and four among them were positive, highest for 2 x 5 (1.5%). Significant and positive HB was not observed for this trait. All hybrids recorded significant SH and two among them were positive, 2 x 7 (9.3%) and 2 x 4 (9.0%). Inside rainshelter, significant and positive RH and HB were observed only for two hybrids, 3 x 7 (9.9% and 9.5%, respectively) and 3 x 5 (8.1% and 7.1%, respectively). Three hybrids recorded significant and positive SH, 3 x 7 (9.3%), 3 x 5 (7.0%) and 2 x 5 (2.7%).

4.4.2.1.2.4.2 Mid stage of flowering

The hybrid 2 x 4 (59.7%) recorded highest pollen viability under polyhouse.Inside rainshelter, 3 x 5 (68.1%) recorded the highest.

Under polyhouse, three hybrids recorded significant and positive RH, 2 x 4 (2.0%), 3 x 6 (1.8%) and 3 x 4 (1.6%). Significant and positive HB and SH were not observed. Inside rainshelter, three hybrids recorded significant and positive RH, HB and SH, 3 x 5 (16.1%, 11.5% and 15.8%, respectively), 3 x 7 (9.8%, 7.1% and 11.3%, respectively) and 2 x 5 (9.6%, 3.5% and 11.2%, respectively).

4.7.2.1.2.4.3 Late stage of flowering

Under polyhouse, 1 x 7 and 2 x 4 recorded the highest value (51.7%). Inside rainshelter, 3 x 5 recorded highest value (64.3%).

Under polyhouse, significant positive RH, HB and SH were not observed. Inside rainshelter, four hybrids recorded significant and positive RH, highest for 3 x 7 (11.2%). HB was significant and positive for four hybrids, highest for 2 x 5 (9.8%), followed by 3 x 5 (7.9%). The highest positive and significant SH was recorded for 3 x 5 (12.8%) and 3 x 7 (12.2%).

Table 89: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for pollen viability

Parents / hybrids / checks	Pollen viability (%) Early stage of flowering PH	Early stage of flowering RS	Mid stage of flowering PH	Mid stage of flowering RS	Late stage of flowering PH	Late stage of flowering RS	Per cent heterosis: Early stage of flowering, Polyhouse RH	Early Polyhouse HB	Early Polyhouse SH	Early Rainshelter RH	Early Rainshelter HB	Early Rainshelter SH	Mid stage of flowering, Polyhouse RH	Mid Polyhouse HB	Mid Polyhouse SH	Mid Rainshelter RH	Mid Rainshelter HB	Mid Rainshelter SH	Late stage of flowering, Polyhouse RH	Late Polyhouse HB	Late Polyhouse SH	Late Rainshelter RH	Late Rainshelter HB	Late Rainshelter SH
1	61.7	65.0	59.7	62.9	54.2	58.6																		
2	59.1	62.2	60.4	63.2	56.3	57.2																		
3	57.5	60.9	56.1	61.1	52.0	59.6																		
4	46.7	52.1	48.5	50.5	38.4	44.6																		
5	43.1	49.9	46.5	46.2	34.2	42.5																		
6	45.2	48.2	44.5	49.2	41.0	45.3																		
7	43.0	49.6	45.4	48.1	44.0	45.4																		
1 x 4	53.9	56.5	54.6	53.8	50.2	56.8	-7.8*	-12.7*	-15.3*	-9.4*	-13.1*	-7.4*	-2.9*	-8.6*	-6.9*	-12.1*	-14.6*	-8.5*	-11.1*	-13.8*	-9.6*	-0.4	-3.1*	-0.26
1 x 5	54.0	57.1	52.4	59.3	49.6	60.3	-6.0*	-12.6*	-15.2*	-8.6*	-12.2*	-6.5*	-9.8*	-12.2*	-10.6*	-0.5	-5.8*	0.9	-13.4*	-14.9*	-10.7*	**4.7***	**2.8***	**5.8***
1 x 6	55.6	58.7	54.1	57.4	49.6	50.5	-5.0*	-10.0*	-12.7*	-5.4*	-9.7*	-3.8*	-5.3*	-9.4*	-7.8*	-6.0*	-8.8*	-2.4*	-13.2*	-14.9*	-10.7*	-11.4*	-13.9*	-11.4*
1 x 7	56.5	59.2	53.2	58.9	51.7	53.4	-1.6*	-8.5*	-11.2*	-5.7*	-8.9*	-3.0*	-7.5*	-10.8*	-9.2*	-2.7*	-6.4*	0.3	-9.5*	-11.2*	-6.9*	-6.3*	-8.9	-6.2*
2 x 4	56.6	61.0	59.7	56.5	51.7	50.4	-0.8*	-5.8*	**9.0***	-0.04	-2.0	-0.1	**2.0***	-8.1*	1.9	-7.8*	-10.5*	-3.8*	-6.9*	-8.2*	-6.9*	-10.5*	-11.9*	-11.6*

Table 89: Continued

Parents / hybrids / checks	Pollen viability (%)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 5	55.8	62.7	53.2	65.4	49.7	62.8	**1.5***	-7.1*	-12.3*	2.7	0.7	**2.7***	-8.9*	-11.9*	-9.2*	**9.6***	**3.5***	**11.2***	-11.7*	-11.7*	-10.5*	**10.5***	**9.8***	**10.2***
2 x 6	56.5	59.8	54.5	58.1	50.5	54.4	-1.1*	-5.9*	-11.2*	-1.4	-3.9*	-2.0*	-5.1*	-9.7*	-7.0*	-5.1*	-8.1*	-1.2	-10.0*	-10.2*	-9.0*	-3.3*	-4.9*	-4.6*
2 x 7	55.2	58.8	59.5	56.0	51.4	51.0	-1.6*	-8.2*	**9.3***	-4.2*	-5.5*	-3.6*	-3.8*	-7.7*	1.5	-7.7*	-11.4*	-4.8*	-8.5*	-8.7*	-7.5*	-9.3*	-10.8*	-10.5*
3 x 4	56.4	59.2	54.8	56.5	51.6	53.5	**1.3***	-5.1*	-11.3*	-1.9	-2.8*	-3.0*	**1.6***	-10.3*	-6.6*	-6.2*	-7.5*	-3.8*	-9.3*	-12.6*	-7.1*	-7.0*	-10.2*	-6.1*
3 x 5	53.4	65.3	53.1	68.1	49.7	64.3	-3.4*	-10.2*	-16.0*	**8.1***	**7.1***	**7.0***	-5.6*	-13.0*	-9.4*	**16.1***	**11.5***	**15.8***	-13.8*	-15.9*	-10.5*	**10.8***	**7.9***	**12.8***
3 x 6	56.6	58.1	54.3	54.8	51.6	51.4	**1.4***	-4.9*	-11.1*	-3.2*	-4.6*	-4.6*	**1.8***	-11.1*	-7.3*	-8.8*	-10.2*	-6.7*	-10.3*	-12.5*	-7.0	-10.5*	-13.8*	-9.8*
3 x 7	55.4	66.7	57.7	65.4	51.5	63.9	**1.3***	-6.8*	-12.9*	**9.9***	**9.5***	**9.3***	-7.8*	-15.8*	-1.7*	**9.8***	**7.1***	**11.3***	-10.5*	-12.8*	-7.3*	**11.2***	**7.3***	**12.2***
Akshaya	54.2	55.5	56.1	55.6	50.4	50.3																		
Abhilash	58.6	61.0	56.6	58.8	55.6	57.0																		
CD (0.05)	3.1	4.5	5.34	3.8	5.3	3.5																		
CV	2.6	3.7	4.6	3.1	4.8	3.1																		

4.4.2.1.2.5 Length of the style (cm)

4.4.2.1.2.5.1 Early stage of flowering

Under polyhouse among the hybrids, 1 x 7 recorded minimum style length (0.62 cm). Inside rainshelter also 1 x 7 and 7 (Arka Abha) recorded the minimum style length among hybrids and parents (0.62 cm and 0.65 cm, respectively).

Under polyhouse, three hybrids recorded significant and negative RH, 1 x 7 (-11.4%), 2 x 7 (-4.4%) and 2 x 5 (-4.2%). Two hybrids recorded significant and negative HB, 1 x 7 (-6.8%) and 2 x 5 (-3.5%). None exhibited significant and negative SH. Inside rainshelter, three hybrids recorded significant and negative RH, 1 x 7 (-12.5%), 1 x 6 (-8.9%) and 1 x 5 (-8.7%). Significant and negative HB and SH were not observed for this trait.

4.4.2.1.2.5.2 Mid stage of flowering

Under polyhouse, 1 x 7 recorded minimum style length (0.63 cm). Inside rainshelter also 1 x 7 recorded the minimum style length (0.64 cm).

Under polyhouse, three hybrids recorded significant RH, highest for 1 x 7 (-11.0%). Four hybrids recorded significant HB, highest for 1 x 7 (-12.0%). Only one hybrid recorded significant and negative SH 1 x 7 (-4.6%). Inside rainshelter, three hybrids recorded significant and negative RH, 1 x 7 (-9.9%), 2 x 6 (-8.0%) and 3 x 6 (-7.8%). None exhibited significant negative HB and SH.

4.4.2.1.2.5.3 Late stage of flowering

Under polyhouse condition the hybrid 3 x 6 (0.63 cm) exhibited minimum style length. Inside rainshelter, 2 x 7 (0.63 cm) recorded minimum style length.

Under polyhouse, seven hybrids recorded significant negative RH. Highest negative RH and HB were recorded for 1 x 7 (-10.0% and -11.6%, respectively). Inside the rainshelter, five hybrids recorded significant negative RH, with highest value -16.4% (2 x 7). Three hybrids recorded significant negative SH, 2 x 7 (-6.1%), 1 x 5 and 2 x 6 (-3.0%).

Table 90: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for length of the style

Parents / hybrids / checks	Length of the style (cm)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	0.74	0.76	0.71	0.73	0.74	0.76																		
2	0.72	0.71	0.73	0.73	0.73	0.78																		
3	0.69	0.67	0.69	0.70	0.71	0.72																		
4	0.68	0.67	0.67	0.67	0.69	0.69																		
5	0.73	0.74	0.74	0.74	0.77	0.76																		
6	0.68	0.71	0.71	0.72	0.73	0.75																		
7	0.67	0.65	0.7	0.69	0.71	0.72																		
1 x 4	0.73	0.73	0.74	0.75	0.75	0.75	3.6	8.2*	15.0*	1.8	4.0	19.8*	6.5*	3.5*	12.2*	6.4	-2.1	14.6*	5.3*	2.0	14.5*	3.1	1.3	12.0*
1 x 5	0.72	0.68	0.74	0.71	0.73	0.65	-2.1	-1.4	12.6*	**-8.7***	9.9	12.4*	1.4	-0.7	12.2*	-3.1	2.7	9.2*	-2.7	**-4.6***	11.5*	**-14.9***	15.1	**-3.0***
1 x 6	0.69	0.67	0.69	0.68	0.69	0.71	-2.5	1.5	8.7*	**-8.9***	11.9	9.9*	-2.8	-2.8	5.3*	-6.2	6.9	4.6	**-5.5***	**-6.1***	5.3*	-5.7	5.3	6.8*
1 x 7	0.62	0.62	0.63	0.64	0.65	0.68	**-11.4***	**-6.8***	-2.4	**-12.5***	18.5*	1.7	**-11.0***	**-12.0***	**-4.6***	**-9.9***	12.3	-1.5	**-10.0***	**-11.6***	-0.8	**-7.5***	9.9	2.3*
2 x 4	0.72	0.72	0.71	0.7	0.68	0.68	2.9	5.9*	12.6*	4.7	-2.1	19.0*	1.8	-2.1	8.4*	-0.4	4.1	6.9	**-4.6***	**-6.9***	3.1*	**-7.53***	12.8	2.3*

Table 90: Continued

Parents / hybrids / checks	Length of the style (cm)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 5	0.69	0.72	0.69	0.76	0.70	0.73	**-4.2***	**-3.5***	8.7*	2.1	2.0	19.0*	**-6.5***	**-7.4***	4.6*	3.4	-2.7	16.2*	**-6.0***	**-8.5***	6.9*	-5.8	7.1	9.0*
2 x 6	0.70	0.67	0.7	0.67	0.69	0.65	0.4	2.9	10.2*	-5.0	5.0	10.7*	-3.1	**-4.1***	6.1*	**-8.0***	8.3	2.3*	**-5.5***	**-5.5***	4.6*	**-15.7***	17.3*	**-3.0***
2 x 7	0.66	0.66	0.68	0.67	0.65	0.63	**-4.4***	-0.8	3.9*	-2.6	6.4	9.1*	**-4.2***	**-6.2***	3.8*	-6.0	8.3	2.3*	**-9.4***	**-10.4***	-0.8	**-16.4***	19.9*	**-6.1***
3 x 4	0.68	0.72	0.72	0.75	0.75	0.77	0.0	0.7	7.1*	6.7	-6.7	18.2*	5.5	4.4*	9.2*	9.5*	-7.1	15.4*	7.1*	5.6*	14.5*	9.6*	-7.7	15.8*
3 x 5	0.76	0.73	0.72	0.70	0.73	0.72	7.81*	11.0*	19.7*	3.9	0.7	20.7*	1.1	-2.7	9.9*	-2.4	4.8	7.7*	-1.7	**-5.2***	10.7*	-2.4	5.2	8.3*
3 x 6	0.68	0.68	0.68	0.66	0.63	0.7	-1.1	-0.7	6.3*	-1.8	4.3	11.6*	-2.5	-4.2*	3.8*	**-7.8***	9.0	0.8	**-8.7***	**-9.7***	**-4.6***	-5.1	7.3	4.5*
3 x 7	0.72	0.71	0.74	0.74	0.73	0.73	6.7*	8.3*	13.4*	6.8	5.2	16.5*	7.3*	6.5*	13.0*	6.5	-5.7	13.9*	2.8	2.8	11.5*	2.1	-2.1	9.8*
Akshaya	0.66	0.6	0.65	0.6	0.65	0.64																		
Abhilash	0.64	0.61	0.66	0.65	0.66	0.67																		
CD (0.05)	0.05	0.04	0.07	0.03	0.06	0.04																		
CV	5.33	2.76	5.37	2.36	4.21	2.56																		

4.4.2.1.2.6 Anther length (cm)

4.4.2.1.2.6.1 Early stage of flowering

Under polyhouse, the hybrid 3 x 5 recorded maximum anther length (0.77 cm). Inside rainshelter, two hybrids 1 x 4 and 2 x 5 recorded maximum anther length (0.75 cm).

Under polyhouse, four hybrids exhibited significant positive RH, 3 x 7 being highest (5.7). Only one hybrid recorded significant positive HB, 3 x 7 (3.5%). Eight hybrids recorded significant positive SH. Inside rainshelter, significant positive RH and HB were not observed. All hybrids except 1 x 7 recorded significant positive SH.

4.4.2.1.2.6.2 Mid stage of flowering

Under polyhouse, two hybrids 1 x 4 and 3 x 7 recorded highest anther length (0.76 cm). Inside rainshelter, three hybrids 1 x 4, 2 x 5 and 3 x 4 (0.77 cm) recorded highest anther length similar to parent, 5 (EC-620427) (0.77 cm).

Under polyhouse, two hybrids exhibited significant positive RH, 3 x 7 (5.6%) and 1 x 4 (4.8%). One hybrid exhibited significant positive HB, 1 x 4 (10.2%). Six hybrids recorded significant positive SH. Inside rainshelter significant positive HB was not observed. Six hybrids recorded significant positive SH.

4.4.2.1.2.6.3 Late stage of flowering

Under polyhouse two hybrids 1 x 4 and 3 x 4 recorded maximum anther length (0.78 cm). Inside rainshelter, the hybrid 3 x 4 (0.79 cm) recorded longest anther.

Under polyhouse, four hybrids recorded significant positive RH, highest for 1 x 4 (43.5%). None showed significant positive HB. Two hybrids recorded significant positive SH, 1 x 4 and 3 x 4 (8.4%). Inside rainshelter, 3 x 4 exhibited significant positive RH (9.0%). None showed significant positive HB.

Table 91: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for anther length

Parents / hybrids / checks	Anther length (cm)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	0.75	0.77	0.76	0.75	0.77	0.77																		
2	0.74	0.75	0.72	0.75	0.77	0.80																		
3	0.72	0.7	0.73	0.73	0.74	0.74																		
4	0.69	0.7	0.69	0.70	0.72	0.72																		
5	0.76	0.76	0.77	0.77	0.75	0.78																		
6	0.71	0.74	0.74	0.74	0.77	0.76																		
7	0.69	0.68	0.72	0.70	0.73	0.73																		
1 x 4	0.76	0.75	0.76	0.77	0.78	0.76	**4.9***	0.7	**15.3***	2.7	-2.0	**18.1***	**4.8***	**10.2***	**11.0***	6.2	2.7	**11.6***	**43.5***	8.4	**8.4***	1.7	-1.0	**8.6***
1 x 5	0.73	0.72	0.74	0.73	0.75	0.75	-3.0	-3.3*	**11.5***	-6.2	-6.5	**12.6***	-3.3	-3.9*	**8.0***	-4.0	-5.2	**5.8***	**35.1***	0.7	4.9	-2.9	-3.2	**7.9***
1 x 6	0.70	0.70	0.71	0.71	0.71	0.74	-3.8*	-6.7*	6.9	-6.7	-8.5	**10.2***	-5.0*	-6.6*	3.7	-4.4	-5.3	2.9	**25.1***	-7.8	-0.7	-3.9	-3.3	**5.8***
1 x 7	0.64	0.64	0.65	0.67	0.68	0.70	-11.5*	-15.3*	-3.1	-12.1*	-17.0*	0.0	-11.9*	-14.5*	-5.1	-7.6*	-10.7	-2.9	**23.9***	-6.9	-5.6	-6.7*	-9.1*	0.7
2 x 4	0.75	0.74	0.73	0.72	0.71	0.70	**4.6***	1.4	**13.7***	2.4	-1.3	**16.5***	3.6	1.4	**6.6***	-1.4	-4.7	3.6	-4.1	-7.2	-0.7	-7.6*	-12.5*	0.7
2 x 5	0.73	0.75	0.73	0.77	0.74	0.74	-2.7	-4.0*	**10.7***	-0.7	-1.3	**18.1***	-2.7	-5.8*	5.8	1.3	2.7	**11.6***	-2.7	-3.9	2.8	-6.0*	-7.5	**6.5***

Table 91: Continued

Parents / hybrids / checks	Anther length (cm)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 6	0.72	0.69	0.72	0.69	0.71	0.70	0.0	-2.0	**9.9***	-7.0	-6.1	**8.7***	-1.0	-2.0	5.1	-7.1*	-8.0	0.0	-7.5	-7.8	-0.7	-10.3*	-12.5*	0.7
2 x 7	0.7	0.68	0.71	0.68	0.67	0.66	-2.1	-5.4*	6.1	-5.6	-10.0	**6.3***	-1.1	-1.4	3.7	-6.2	-9.3	-1.5	-10.1	-12.4*	-6.3*	-14.4*	-18.1*	-5.8*
3 x 4	0.71	0.73	0.73	0.77	0.78	0.79	1.1	-0.7	**8.4***	5.0	5.0	**15.0***	3.2	0.7	**6.6***	**7.7***	5.5	**11.6***	6.9	5.4	**8.4***	**9.0***	7.5	**13.7***
3 x 5	0.77	0.74	0.74	0.72	0.75	0.75	**4.8***	2.0	**17.6***	1.7	-2.6	**16.5***	-1.7	-4.6*	**7.3***	-4.0	-6.5	**4.4***	1.4	0.7	4.9	-0.7	-3.2	**7.9***
3 x 6	0.7	0.70	0.70	0.69	0.68	0.72	-2.1	-2.8	6.1	-2.1	-4.8	**10.2***	-4.1*	-4.8*	2.2	-6.5*	-6.8	-0.7	-9.6	-11.7*	-4.9	-4.4	-5.9	2.9
3 x 7	0.74	0.73	0.76	0.76	0.75	0.75	**5.7***	**3.5***	**13.0***	6.2	7.4	**15.0***	**5.6***	4.8*	**11.0***	6.3	4.1	**10.2***	2.1	1.4	4.2	1.7	1.4	**7.2***
Akshaya	0.69	0.63	0.67	0.65	0.68	0.66																		
Abhilash	0.66	0.64	0.69	0.69	0.72	0.7																		
CD (0.05)	0.07	0.04	0.04	0.03	0.05	0.03																		
CV	4.68	2.91	4.28	1.93	6.29	1.85																		

4.4.2.1.2.7 Number of flowers per cluster (No.)

4.4.2.1.2.7.1 Early stage of flowering

Under polyhouse condition the hybrid 1 x 6 recorded highest number of flowers per cluster (6.7). Inside rainshelter 3 x 5 recorded maximum number of flowers per cluster (7.6).

Under polyhouse, six hybrids recorded significant positive RH and HB, the highest value observed was 22.0% and 17.7% (1 x 6). Three hybrids exhibited significant positive SH. Inside rainshelter, 1 x 6 recorded highest positive significant RH and HB (18.7% and 12.9%).

4.4.2.1.2.7.2 Mid stage of flowering

Under polyhouse the hybrid 1 x 6 recorded maximum number of flowers per cluster (5.7). Inside rainshelter 3 x 7 recorded maximum number of flowers per cluster (7.5).

Under polyhouse, the RH was in the range between -20.2% (1 x 5) and 5.6% (3 x 7). The hybrid 1 x 6 recorded significant positive HB (5.6%). Four hybrids showed significant positive SH with highest value for 1 x 6 (7.6%). Inside rainshelter, RH was in the range between -19.9% (1 x 5) and 7.7% (3 x 4). None exhibited significant positive HB.

4.4.2.1.2.7.3 Late stage of flowering

Under polyhouse the hybrid 1 x 7 recorded maximum number of flowers per cluster (5.3). Inside rainshelter 3 x 7 recorded maximum number (6.7).

Under polyhouse, significant positive RH and HB were not observed. Two hybrids recorded significant positive SH, 1 x 7 (14.1%) and 3 x 4 (8.4%).Inside rainshelter, Two hybrids recorded significant positive RH, 3 x 4 (9.02%), and 2 x 5 (1.2%). None recorded positive significant HB. Four hybrids exhibited significant positive SH with highest value for 3 x 4 (13.7%).

Table 92: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for number of flowers per cluster

Parents / hybrids / checks	Number of flowers / cluster (no.)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	5.7	6.6	5.7	6.3	4.9	6.0																		
2	5.6	7.4	5.5	6.6	4.6	6.3																		
3	5.0	6.5	5.4	6.3	5.1	5.6																		
4	5.5	7.6	5.6	7.1	5.4	6.6																		
5	5.3	6.7	5.3	7.1	5.1	5.9																		
6	5.3	6.0	5.6	6.5	5.1	6.0																		
7	5.6	7.5	5.4	7.4	5.3	6.6																		
1 x 4	6.5	7.4	5.4	5.5	3.6	4.3	**17.1***	**15.0***	-0.76	**3.9***	-2.7*	**4.3***	-4.9*	-5.3*	1.9*	-17.6*	-22.5*	-30.9*	-30.4*	-33.7*	-22.8*	-32.5*	-35.6*	-24.1*
1 x 5	5.4	5.6	4.4	5.4	4.3	3.7	-0.9*	-4.4*	-17.6*	-16.2*	-16.5*	-21.3*	-20.2*	-23.0*	-17.1*	-19.9*	-24.6*	-40.7*	-14.1*	-15.8*	-7.6*	-38.7*	-39.2*	-34.8*
1 x 6	6.7	7.5	5.7	6.5	4.7	4.7	**22.0***	**17.7***	1.5	**18.7***	**12.9***	**5.7***	0.4	**5.6***	**7.6***	**1.2***	-0.8	-24.4*	-7.5*	-9.8*	1.1	-22.5*	-22.5*	-17.0*
1 x 7	6.5	7.4	5.4	6.7	5.3	5.5	**14.7***	**14.2***	-1.5	**4.6***	-1.3	**4.3***	-2.7*	-5.3*	**1.9***	-2.2*	-9.5*	-11.4*	4.0	0.0	**14.1***	-13.5*	-17.4*	-2.7*
2 x 4	5.6	6.2	5.2	6.3	4.5	5.5	**1.8***	0.9	-14.5*	-16.8*	-17.8*	-12.1*	-7.2*	-8.0*	-1.9*	-8.4*	-12.0*	-11.4**	-9.6*	-15.9*	-2.2	-15.2*	-17.4*	-2.7*
2 x 5	4.7	7.4	5.1	7.2	3.6	6.4	-13.9*	-16.2*	-29.0*	**5.0***	**10.5***	**4.3***	-5.1*	-7.3*	-2.9*	**4.9***	0.8	**3.3***	-25.4*	-28.7*	-21.7*	**1.2***	-1.6	**13.4***

Table 92: Continued

Parents / hybrids / checks	Number of flowers / cluster (no.)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	**RS**	**PH**	**RS**	**PH**	**RS**	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 6	4.7	5.6	4.7	5.3	4.3	5.1	0.0	-2.0	**9.9***	-7.0	-6.1	**8.7***	-1.0	-2.0	5.1	-7.1*	-8.0	0.0	-7.5	-7.8	-0.7	-10.3*	-12.5*	0.7
2 x 7	5.5	6.7	5.1	6.6	4.8	5.7	-2.1	-5.4*	6.1	-5.6	-10.0	**6.3***	-1.1	-1.4	3.7	-6.2	-9.3	-1.5	-10.1	-12.4*	-6.3*	-14.4*	-18.1*	-5.8*
3 x 4	5.5	7.3	5.6	6.6	5.1	5.5	1.1	-0.7	**8.4***	5.0	5.0	**15.0***	3.2	0.7	**6.6***	**7.7***	5.5	**11.6***	6.9	5.4	**8.4***	**9.0***	7.5	**13.7***
3 x 5	4.8	7.6	5.4	7.1	4.7	6.3	**4.8***	2.0	**17.6***	1.7	-2.6	**16.5***	-1.7	-4.6*	**7.3***	-4.0	-6.5	**4.4***	1.4	0.7	4.9	-0.7	-3.2	**7.9***
3 x 6	5.1	6.7	4.8	6.5	5.1	5.8	-2.1	-2.8	6.1	-2.1	-4.8	**10.2***	-4.1*	-4.8*	2.2	-6.5*	-6.8	-0.7	-9.6	-11.7*	-4.9	-4.4	-5.9	2.9
3 x 7	4.6	7.4	5.4	7.5	5.1	6.7	**5.7***	**3.5***	**13.0***	6.2	7.4	**15.0***	**5.6***	4.8*	**11.0***	6.3	4.1	**10.2***	2.1	1.4	4.2	1.7	1.4	**7.2***
Akshaya	6.6	6.5	5.2	6.1	4.8	5.5																		
Abhilash	6.6	7.1	5.3	6.2	4.6	5.6																		
CD (0.05)	0.49	0.37	0.3	0.4	0.6	0.4																		
CV	4.22	2.62	2.6	2.75	5.6	3.46																		

4.4.2.1.2.8 Days to first fruit set (No. of days)

The hybrid 1 x 7 took minimum days to set first fruit (46.50 days), which was earlier than check hybrid Abhilash (50.85 days) and other hybrids. Inside ranishelter, all genotypes set fruits early. Among the hybrids, 1 x 7 recorded minimum days to first fruit set (38.48 days).

Under polyhouse, three hybrids exhibited significant and negative RH, 1 x 7 (-13.44%), 2 x 5 (-9.07%) and 1 x 5 (-7.34%). The HB ranged between -12.59% (1 x 7) and 17.01% (1 x 6). Only one hybrid recorded significant negative SH, 1 x 7 (-7.75%). Inside rainshelter, three hybrids exhibited significant negative RH and HB, 1 x 7 (-18.3% and -17.43% respectively), 2 x 5 (-12.92% and -12.74% respectively) and 1 x 5 (-6.3% and -4.04%). Two hybrids recorded significant negative SH, 1 x 7 (-9.03%) and 2 x 5 (-1.36%).

Table 93: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for days to first fruit set

Parents / hybrids / checks	DTF fruit set (no. of days)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	54.65	46.60						
2	52.05	48.65						
3	54.25	47.50						
4	50.0	46.85						
5	51.0	48.85						
6	46.15	39.40						
7	53.60	47.60						
1 x 4	51.40	45.93	-1.77	2.8	9.71*	-1.71	-1.45	8.57*
1 x 5	52.75	44.72	**-7.34***	-4.02	12.59*	**-6.36***	**-4.03***	5.72*
1 x 6	54.0	47.27	7.14*	17.01*	15.26*	9.93*	19.98*	11.75*
1 x 7	46.50	38.48	**-13.44***	**-12.59***	**-7.75***	**-18.30***	**-17.43***	**-9.03***
2 x 4	52.80	48.67	3.48	5.60*	12.70*	1.92	3.87*	15.05*
2 x 5	53.50	42.45	**-9.07***	**-8.14***	14.19*	**-12.92***	**-12.74***	**-1.36***
2 x 6	52.60	48.95	7.13*	13.98*	12.27*	11.19*	24.24*	15.72*
2 x 7	57.0	49.61	7.90	9.51*	21.67*	3.08*	4.21*	17.27*
3 x 4	55.80	47.95	7.05*	11.60*	19.10*	1.64	2.35	13.36*
3 x 5	53.90	47.90	2.42	5.69*	15.05*	-0.57	0.84	13.24*
3 x 6	51.75	45.10	3.09*	12.13*	10.46*	3.8*	14.47*	6.62*
3 x 7	53.30	49.45	-1.16	-0.56	13.78*	4.0*	4.11*	16.90*
Akshaya	48.95	47.35						
Abhilash	50.85	42.30						
CD (0.05)	5.63	4.85						
CV	6.48	4.99						

4.4.2.1.3 Fruit characters and yield

The traits studied were days from anthesis to fruit maturity (Table 94), number of fruits per cluster (Table 95), fruit set per cent (Table 96), days to first fruit harvest (Table 97), number of fruits per plant (Table 98), locule number per fruit (Table 99), pericarp thickness (Table 100), average fruit weight (Table 101), yield per plant (Table 102) and yield per plot (Table 103).

4.4.2.1.3.1 Days from anthesis to fruit maturity (No. of days)

Under polyhouse condition the hybrid, 2 x 5 recorded minimum days from anthesis to fruit maturity (42.40 days). The hybrid 2 x 5 recorded minimum days (39.97 days). Under polyhouse, one hybrid exhibited significant negative RH and HB, 2 x 7 (-7.18% and -5.18%, respectively). Inside rainshelter, also the hybrid 2 x 7 exhibited significant negative RH and HB (-7.84% and -6.57% respectively).

Table 94: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for days from anthesis to fruit maturity

Parents / hybrids / checks	DF anthesis to fruit maturity (no. of days)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	44.75	40.20						
2	45.35	44.39						
3	41.40	38.94						
4	43.10	40.45						
5	42.0	38.20						
6	43.50	39.57						
7	47.3	43.20						
1 x 4	43.40	41.07	-1.2	0.7	1.28	1.85	2.16	4.69*
1 x 5	43.45	40.59	0.17	3.45*	1.40	3.53	6.24*	3.45
1 x 6	45.55	43.96	3.23*	4.71*	6.30*	10.22*	11.09*	12.06*
1 x 7	45.90	41.13	-0.27	2.57	7.12*	-1.37	2.31	4.84*
2 x 4	47.40	43.44	7.18*	9.98*	10.62*	2.4	7.39*	10.72*
2 x 5	42.40	39.97	-2.92	0.95	-1.05	-3.21	4.63*	1.89
2 x 6	43.65	41.41	-1.75	0.35	1.87	-1.36	4.65*	5.56*
2 x 7	43.00	40.36	**-7.18***	**-5.18***	0.35	**-7.84***	**-6.57***	2.88
3 x 4	44.50	40.90	5.33*	7.49*	3.85*	3.05	5.05*	4.26*
3 x 5	45.85	41.90	9.95*	10.75*	7.0*	8.64*	9.69*	6.81*
3 x 6	45.25	42.30	6.6*	9.30*	5.60*	7.76*	8.64*	7.83*
3 x 7	44.90	42.69	1.24	8.45*	4.78*	3.94	9.63*	8.81*
Akshaya	45.70	42.11						
Abhilash	42.85	39.23						
CD (0.05)	1.33	1.57						
CV	4.44	4.93						

4.4.2.1.3.2 Number of fruits per cluster (No.)

4.4.2.1.3.2.1 Early stage of flowering

Under polyhouse the hybrid, 1 x 6 recorded maximum number of fruits per cluster (3.8). Inside rainshelter, the hybrid 3 x 7 recorded maximum number of fruits per cluster (5.0).

Under polyhouse, two hybrids recorded significant and positive RH and HB, 1 x 6 (24.6% and 18.8% respectively) and 1 x 7 (10.6% and 6.3%). Only one hybrid, 1 x 6 recorded significant and positive SH (16.9%). Inside rainshelter, five hybrids recorded significant positive RH and HB, and ten hybrids recorded significant positive SH with range from -18.6% (1 x 5) to 43.5% (3 x 7).

4.4.2.1.3.2.2 Mid stage of flowering

Under polyhouse the hybrid, 3 x 4 exhibited maximum value (3.2). Inside rainshelter the hybrid 3 x 7 recorded maximum value (4.6).

Under polyhouse, significant positive RH, HB and SH were not observed. Inside rainshelter, RH ranged between -29.8% (1 x 5) and 15.8% (2 x 5). Three hybrids recorded significant HB, 3 x 5 (13.9%), 2 x 5 (11.4%) and 3 x 7 (4.6%). Five hybrids recorded significant positive SH.

4.4.2.1.3.2.3 Late stage of flowering

Under polyhouse condition the hybrid 1 x 7 recorded maximum number of fruits per cluster (2.9). Inside rainshelter the hybrid 3 x 7 and 3 x 5 recorded maximum number of fruits per cluster (4.2).

Under polyhouse, significant RH and HB were not observed. Two hybrids recorded significant positive SH, 1 x 7 (11.5%) and 3 x 7 (5.8%). Inside rainshelter, three hybrids recorded significant positive RH and HB, 3 x 5 (23.1% and 22.2% respectively), 2 x 5 (19.3% and 18.4% respectively) and 3 x 7 (14.4% and 5.1% respectively). Seven hybrids recorded significant positive SH, with range -18.3% (1 x 5) and 40.1% (3 x 7).

Table 95: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for number of fruits per cluster

Parents / hybrids / checks	Number of fruits / cluster (no.)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	3.2	3.6	3.4	3.6	2.7	3.2																		
2	3.5	4.1	3.4	3.7	2.6	3.4																		
3	2.9	3.6	3.1	3.9	2.9	3.4																		
4	3.6	4.6	3.2	4.2	3.2	3.8																		
5	3.3	4.1	3.0	4.0	2.9	3.4																		
6	2.9	3.5	3.1	4.1	3.0	3.5																		
7	3.0	4.4	3.0	4.4	3.1	4.0																		
1 x 4	3.4	4.1	3.1	3.4	2.4	3.2	-0.7	-5.6*	3.1	-1.2	-12.0*	**15.7***	-7.6*	-10.3*	-6.2*	-12.3*	-18.1*	-2.9	-17.2	-23.8*	-7.7*	-9.4*	-17.1*	**5.0***
1 x 5	3.1	2.9	3.1	2.7	2.5	2.5	-3.9	-4.6*	-4.6	-26.0*	-30.5*	-18.6*	-3.1	-8.8*	-4.6*	-29.8*	-32.9*	-24.3*	-6.3	-10.4*	-3.9	-25.2*	-27.9*	-18.3*
1 x 6	3.8	4.4	2.4	3.5	2.2	2.8	**24.6***	**18.8***	**16.9***	**23.9***	**22.2***	**25.7***	-26.2*	-29.4*	-26.2*	-9.1*	-14.6*	0.0	-23.2	-27.1*	-17.3*	-17.3*	-21.4*	-8.3
1 x 7	3.4	4.4	3.0	4.2	2.9	3.3	**10.6***	**6.3***	4.6	**10.0***	**22.2***	**25.7***	-6.3*	-11.8*	-7.7*	**3.6***	-5.7*	**18.6***	1.8	-4.9*	**11.5***	-9.1*	-18.8*	**8.3***
2 x 4	3.2	4.1	3.1	3.4	2.5	2.9	-10.6*	-11.3*	-3.1	-5.8*	-10.9*	**17.1***	-5.4	-7.5*	-4.6*	-14.1*	-19.3*	-4.3*	-9.6	-17.5*	-3.9	-18.9*	-23.7*	-3.3

Table 95: Continued

Parents / hybrids / checks	Number of fruits / cluster (no.)						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 5	2.5	4.2	2.6	4.4	2.0	4.0	-27.4*	-30.0*	-24.6*	1.2	1.2	**18.6***	-18.1*	-22.4*	-20.0*	**15.8***	**11.4***	**25.7***	-27.3	-31.0*	-23.1*	**19.3***	**18.4***	**34.2***
2 x 6	2.6	3.4	2.7	3.2	2.4	2.8	-18.7*	-25.7*	-20.0*	-11.8*	-18.3*	-4.3*	-17.8*	-20.9*	-18.5*	-17.4*	-22.0*	-8.6*	-15.3	-20.3*	-9.6*	-19.8*	-21.4*	-8.3*
2 x 7	3.1	4.2	3.1	3.6	2.5	3.1	-3.9	-11.4*	-4.6	-2.4	-5.8*	**18.6***	-2.4	-7.5*	-4.6*	-10.6*	-18.2*	2.9	-8.0	-14.8*	-3.9	-15.7*	-22.5*	**3.3**
3 x 4	3.2	4.2	3.2	3.7	2.7	3.0	-2.3	-11.3*	-3.1	1.2	-9.8*	**18.6***	0.0	-1.6	-3.1*	-8.8*	-12.1*	**4.3***	-10.0	-14.3*	3.9	-16.1*	-21.1*	0.0
3 x 5	2.8	4.7	3.0	4.5	2.5	4.2	-10.6*	-15.4*	-15.4*	**22.7***	**15.2***	**35.0***	-1.6	-3.2*	-7.7*	**15.4***	**13.9***	**28.6***	-13.0	-13.8*	-3.9	**23.1***	**22.2***	**38.4***
3 x 6	2.9	4.0	2.6	3.5	2.7	3.1	-1.7	-1.7	-12.3	**11.3***	**9.7***	**12.9***	-17.7*	-17.7*	-21.5*	-12.0*	-14.6*	0.0	-6.9	-8.5*	3.9	-11.0*	-12.9*	**1.7**
3 x 7	2.7	5.0	2.9	4.6	2.8	4.2	-7.7*	-8.5*	-16.9*	**25.5***	**14.1***	**43.5***	-4.9*	-6.5*	-10.8*	**11.5***	**4.6***	**31.4***	-6.8	-9.8*	**5.8***	**14.4***	**5.1***	**40.1***
Akshaya	3.6	3.5	3.5	4.0	2.9	3.0																		
Abhilash	3.3	3.3	3.3	3.5	2.6	3.0																		
CD (0.05	0.4	0.3	0.3	0.4	0.4	0.3																		
CV	5.45	3.8	4.0	4.7	7.6	5.0																		

4.4.2.1.3.3 Fruit set per cent (%)

4.4.2.1.3.3.1 Early stage of flowering

Under polyhouse the hybrid 1 x 5 and 3 x 6 recorded maximum fruit set per cent (59.2%). Inside rainshelter, 3 x 7 recorded highest fruit set per cent (65.2%).

Under polyhouse, positive significant RH was observed for four hybrids, 1 x 5 recorded highest value (3.6%), followed by 1 x 7 (1.9%). Positive significant HB was not observed. Inside rainshelter, only one hybrid exhibited positive significant RH, 3 x 7 (5.2%). None exhibited positive significant HB. Three hybrids recorded significant positive SH, 3 x 7 (3.6%), 2 x 5 (2.1%) and 3 x 5 (1.8%).

4.4.2.1.3.3.2 Mid stage of flowering

Under polyhouse, the hybrid 1 x 5 recorded maximum fruit set per cent (59.8%). Inside rainshelter, the hybrid 2 x 5 recorded maximum fruit set per cent (67.5%).

Under polyhouse, none exhibited significant positive HB. Seven hybrids recorded significant positive SH. Inside rainshelter, two hybrids exhibited positive significant RH, 2 x 5 (7.7%) and 3 x 7 (7.2%). Positive significant HB was observed for two hybrids, 2 x 5 (5.6%) and 3 x 7 (3.9%). Three hybrids exhibited significant positive SH.

4.4.2.1.3.3.3 Late stage of flowering

Under polyhouse, 3 x 7 recorded maximum fruit set per cent (57.0 Inside rainshelter, the hybrid 2 x 5 recorded maximum fruit set per cent (66.9%).

Under polyhouse, significant positive RH and HB were not observed. Five hybrids recorded positive significant SH. Inside rainshelter, one hybrid recorded significant positive RH and HB 2 x 5 (9.5% and 6.9% respectively). Four hybrids recorded significant positive SH

Table 96: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for fruit set per cent

Parents / hybrids / checks	Fruit set per cent						Per cent heterosis																	
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
1	57.0	63.2	55.1	63.9	55.6	61.1																		
2	58.3	63.8	58.5	63.9	54.5	62.6																		
3	59.7	64.6	57.6	63.9	55.4	60.7																		
4	48.7	44.5	43.7	46.2	47.1	45.8																		
5	43.6	50.4	52.1	55.5	56.4	54.3																		
6	48.7	50.6	54.0	58.2	54.2	58.8																		
7	50.1	49.3	48.5	50.0	45.6	48.4																		
1 x 4	54.6	61.6	53.2	61.1	53.5	59.5	-6.7*	-11.9*	0.7	-2.5	-2.6	-2.2*	-6.3*	-11.4*	-1.9	-2.9	-4.4*	-1.3	-2.3	-6.1*	2.8	-1.1	-2.7	-0.9
1 x 5	59.2	59.5	59.8	63.0	55.5	60.7	**3.6***	-4.5*	**9.2***	-3.3	-5.9*	-5.5*	**5.7***	-0.4	**10.3***	0.6	-1.3	1.9	-0.8	-1.5	**6.6***	0.5	-0.7	1.1
1 x 6	52.8	56.2	54.0	57.2	49.9	53.8	-8.7*	-14.8*	-2.6	-9.3*	-11.2*	-10.7*	-0.1	-10.2*	-0.5	-6.4*	-10.5*	-7.6	-9.1*	-10.2*	-4.1*	-10.2*	-12.0*	-10.3*
1 x 7	58.0	59.6	58.5	61.7	55.7	57.3	**1.9***	-6.5*	**7.0***	-2.7	-5.7*	-5.3*	**3.0***	-2.7	**7.8***	-0.4	-3.4*	-0.2	0.3	0.3	**7.0***	-4.1	-6.2*	-4.5*
2 x 4	57.5	59.5	57.6	60.9	53.8	59.5	-2.8*	-5.8*	**6.0***	-6.2*	-6.7*	-5.4*	-0.5	-4.8*	**6.3***	-3.1	-4.7*	-1.5	-0.8	-6.4*	3.4	-2.3	-5.0*	-0.9
2 x 5	56.4	63.9	54.3	67.5	50.6	66.9	-2.4*	-7.5*	**4.1***	3.5	0.2	**2.1***	-7.0*	-10.31*	0.1	**7.7***	**5.6***	**9.1***	-8.7*	-11.9*	-2.8	**9.5***	**6.9***	**11.4***
2 x 6	57.0	59.1	52.2	58.5	50.7	56.0	-2.5*	-6.6*	**5.2***	-5.0*	-7.4*	-6.1	-7.2*	-13.7*	-3.7*	-4.3	-8.5*	-5.5*	-6.7*	-11.8*	-2.6	-7.7*	-10.5*	-6.7*

Table 96: Continued

Parents / hybrids / checks	Fruit set per cent						Per cent heterosis																		
	Early stage of flowering		Mid stage of flowering		Late stage of flowering		Early stage of flowering						Mid stage of flowering						Late stage of flowering					
	PH	RS	PH	RS	PH	RS	Polyhouse			Rainshelter			Polyhouse			Rainshelter			Polyhouse			Rainshelter		
							RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
2 x 7	57.6	63.3	56.9	60.2	52.6	63.2	-2.6*	-5.6*	**6.3***	2.9	-0.7	0.6	-2.7*	-6.0*	**5.0***	-2.8	-5.8*	-2.7	-4.4*	-8.4*	1.1	4.5	1.0	**5.3***
3 x 4	56.6	60.6	58.6	64.4	54.4	60.2	-5.5*	-7.2*	**4.4***	-5.2*	-6.3*	-3.7*	0.03	-6.3*	**8.1***	2.5	0.9	**4.1***	-0.64	-10.0*	**4.4***	0.5	-0.8	0.3
3 x 5	58.1	64.0	53.8	63.3	51.5	62.1	**1.7***	-4.8*	**7.2***	2.9	-0.9	**1.8***	-7.1*	-14.1*	-0.8	1.0	-0.9	2.3	-7.9*	-14.8*	-1.2	3.3	2.3	**3.5***
3 x 6	59.2	59.7	56.3	61.0	56.1	59.0	**1.1***	-3.0	**9.1***	-4.6*	-7.6*	-5.1*	1.9*	-10.0*	**3.9***	-0.04	-4.5*	-1.4	2.4	-7.1*	**7.8***	-1.3	-2.9	-1.8
3 x 7	55.9	65.2	57.1	66.4	57.0	62.2	-6.7*	-8.4*	3.1	**5.2***	0.9	**3.6***	-0.6	-8.7*	**5.4***	**7.2***	**3.9***	**7.3***	2.7	-5.7*	**9.4***	4.4	2.4	**3.6***
Akshaya	54.5	57.7	52.5	56.4	47.0	53.1																		
Abhilash	54.2	62.9	54.2	61.9	52.1	60.0																		
CD (0.05	4.9	5.2	5.3	4.8	5.2	5.2																		
CV	4.6	5.3	4.6	5.0	4.6	6.0																		

4.4.2.1.3.4 Days to first fruit harvest (No. of days)

Under polyhouse 2 x 5 recorded minimum number of days to first fruit harvest (92.30 days). Inside the rainshelter, earlier fruit harvest was recorded. The hybrid 1 x 7 recorded minimum days (83.50 days).

Under polyhouse, three hybrids exhibited significant negative RH, 1 x 7 (-6.32%), 2 x 5 (-5.41%) and 1 x 5 (-3.46%). Two hybrids exhibited significant negative HB, 1 x 7 (-5.31%) and 2 x 5 (-3.05%). Three hybrids recorded significant negative SH, 2 x 5 (-5.91%), 1 x 5 (-4.03%) and 1 x 7 (-3.62%). Inside rainshelter, two hybrids exhibited significant negative RH, 1 x 7 (-7.25%) and 2 x 5 (-6.15%). Only one hybrid recorded significant HB, 1 x 7 (-6.18%). Three hybrids exhibited significant negative SH, 1 x 7 (-7.02%), 2 x 5 (-4.40%) and 1 x 5 (-4.35%).

Table 97: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for days to first fruit harvest

Parents / hybrids / checks	DTF fruit harvest (no. of days)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	99.85	89.0						
2	99.95	95.60						
3	98.05	89.40						
4	94.60	89.90						
5	95.20	89.05						
6	91.45	82.65						
7	102.00	91.05						
1 x 4	97.10	89.0	0.9	3.70*	-1.02	-0.50	-1.0	8.3*
1 x 5	94.15	86.70	**-3.46***	-1.10	**-4.03***	-2.61	-2.58	**-4.35***
1 x 6	100.85	92.90	5.44*	10.28*	2.80*	8.24*	12.40*	12.78*
1 x 7	94.55	83.50	**-6.32***	**-5.31***	**-3.62***	**-7.25***	**-6.18***	**-7.02***
2 x 4	101.90	93.95	4.76*	7.72*	3.87*	1.29	4.51*	11.99*
2 x 5	92.30	86.65	**-5.41***	**-3.05***	**-5.91***	**-6.15***	-2.7	**-4.40***
2 x 6	98.00	92.40	2.40	7.16*	-0.10	3.68*	11.8*	12.20*
2 x 7	101.35	92.0	0.37	1.40	3.31*	-1.42	1.04	11.75*
3 x 4	102.50	90.60	6.41*	8.35*	4.49*	1.06	1.34	10.14*
3 x 5	101.85	93.40	5.41*	6.99*	3.82*	4.68*	4.89*	13.36*
3 x 6	100.10	90.80	5.65*	9.46*	2.04	5.55*	9.86*	10.37*
3 x 7	100.05	94.0	0.03	2.04	1.99	4.18*	5.15*	14.05*
Akshaya	101.05	93.10						
Abhilash	98.10	87.0						
CD (0.05)	1.37	1.54						
CV	3.94	3.92						

4.4.2.1.3.5 Number of fruits per plant (No.)

Under polyhouse number of fruits per plant was in the range between 15.95 and 20.95. The hybrids 2 x 7 recorded maximum number of fruits per plant (20.95). Inside rainshelter, the hybrids produced fruits in the range between 21.88 and 26.95. The hybrid 1 x 4 recorded the highest value (26.95).

Under polyhouse, significant positive RH, HB and SH were not observed. Inside rainshelter, four hybrids recorded significant positive RH, 1 x 4 (14.68%), 3 x 7 (9.89%), 3 x 5 (6.08%) and 3 x 4 (3.89%). Three hybrids recorded significant positive HB, 1 x 4 (14.44%), 3 x 7 (8.72%) and 3 x 5 (4.35%). Two hybrids, 1 x 4 (8.67%) and 3 x 7 (3.02%), recorded significant positive SH.

Table 98: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for number of fruits per plant

Parents / hybrids / checks	Number of fruits per plant (no.)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	20.10	23.45						
2	19.80	24.35						
3	20.20	23.0						
4	13.7	16.5						
5	15.2	17.5						
6	16.5	17.0						
7	15.8	16.5						
1 x 4	18.25	26.95	-13.30*	-17.05*	-10.54*	**14.68***	**14.44***	**8.67***
1 x 5	15.95	23.05	-23.23*	-25.64*	-21.81*	0.88	-1.71*	-7.06*
1 x 6	18.00	22.03	-13.57*	-16.47*	-11.77*	-6.48*	-6.87*	-11.19*
1 x 7	18.55	21.88	-7.6	-7.71	-9.07*	-6.82*	-6.92*	-11.79*
2 x 4	16.40	23.68	-25.11*	-25.46*	-19.61*	-1.15	-2.77	-4.54*
2 x 5	19.85	22.92	-22.08*	-22.71*	-17.40*	-1.63	-5.87*	-7.58*
2 x 6	18.95	22.38	-12.57*	-13.07*	-7.11	-6.77*	-8.11*	-9.78*
2 x 7	20.95	24.19	-4.66	-8.49*	2.7	1.09	-0.68	-2.48
3 x 4	17.85	24.18	-17.36*	-18.86*	-12.50*	**3.89***	2.68	-2.50
3 x 5	17.20	24.00	-19.34*	-19.81*	-15.69*	**6.08***	**4.35***	-3.23*
3 x 6	17.45	23.25	-18.36*	-19.03*	-14.46*	-0.32	-1.7	-6.25*
3 x 7	19.95	25.55	-3.27	-5.9	-2.21	**9.89***	**8.72***	**3.02***
Akshaya	19.0	24.85						
Abhilash	20.40	24.80						
CD (0.05)	1.82	1.63						
CV	11.31	8.96						

4.4.2.1.3.6 Locule number per fruit (no.)

Under polyhouse the range observed for the hybrids was from 2.6 to 4.85. The hybrid, 1 x 5 recorded lowest value (2.6). Inside rainshelter the range observed for the hybrids was from 2.25 and 4.75. The lowest locule number was recorded for 1 x 5 and 3 x 7 (2.25).

Under polyhouse, the RH ranged between -45.26% (1 x 5) and 57.72% (2 x 6). Four hybrids recorded significant negative HB and SH, with highest value -43.48% and -22.39%, respectively for 1 x 5. Inside rainshelter, three hybrids recorded significant negative RH, HB and SH, 1 x 5 (-45.46%, -43.75% and -43.75% respectively), 3 x 7 (-33.82%, -31.82% and -43.75%respectively) and 1 x 4 (-27.22%, -26.28% and -28.13% respectively).

Table 99: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for locule number per fruit

Parents / hybrids / checks	Locule nymber per fruit (no.)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	4.90	4.0						
2	3.15	2.80						
3	3.85	3.30						
4	4.15	3.90						
5	4.60	4.25						
6	3.0	2.94						
7	3.30	3.50						
1 x 4	2.65	2.88	**-41.44***	**-36.15***	**-20.9***	**-27.22***	**-26.28***	**-28.13***
1 x 5	2.60	2.25	**-45.26***	**-43.48***	**-22.39***	**-45.46***	**-43.75***	**-43.75***
1 x 6	4.10	4.23	3.8	36.67*	22.39*	21.76*	43.71*	5.63
1 x 7	3.85	3.55	-6.1	16.67*	14.93*	-5.33	1.43	-11.25
2 x 4	3.50	4.40	-4.11	11.11	4.48	31.34*	57.14*	10.00
2 x 5	4.35	4.75	12.26	38.1*	29.85*	34.75*	69.64*	18.75
2 x 6	4.85	4.48	57.72*	61.67*	44.78*	55.92*	59.82*	11.88
2 x 7	3.70	3.95	14.73	12.12	10.45*	25.4*	41.07*	-1.25
3 x 4	3.0	3.50	**-25.0***	**-22.08***	**-10.45***	-2.78	6.06	-12.5
3 x 5	3.50	3.75	**-17.16***	-9.09	4.48	-0.66	13.64	-6.25
3 x 6	4.0	3.55	16.79*	33.33*	19.40*	13.72*	7.58	-11.25
3 x 7	2.85	2.25	**-20.28***	**-13.64***	**-14.93***	**-33.82***	**-31.82***	**-43.75***
Akshaya	4.35	3.92						
Abhilash	3.35	4.0						
CD (0.05)	1.33	1.29						
CV	17.21	16.47						

4.4.2.1.3.7 Pericarp thickness (cm)

Under polyhouse among the hybrids pericarp thickness ranged between 0.61 cm and 0.87 cm. The hybrid 2 x 5 recorded maximum pericarp thickness (0.87cm). Inside rainshelter the hybrids were in the range between 0.4 cm and 0.95 cm. The hybrid 3 x 5 recorded maximum pericarp thickness (0.95 cm).

Under polyhouse, three hybrids exhibited significant positive RH, 2 x 5 (10.13%), 3 x 6 (8.31%) and 3 x 7 (5.26%). Two hybrids, 2 x 5 (9.43%) and 3 x 7 (4.94%), recorded significant positive HB. Significant positive SH was not observed. Inside rainshelter, four hybrids recorded significant RH, 3 x 5 (13.77%), 2 x 5 (12.88%), 3 x 7 (12.12%) and 1 x 5 (11.8%). Three hybrids exhibited significant positive HB, 1 x 5 (8.43%), 2 x 5 (8.24%) and 3 x 5 (6.74%). Significant positive SH was recorded for three hybrids, 3 x 5 (8.57%), 3 x 7 (5.74%) and 2 x 5 (5.14%).

Table 100: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for pericarp thickness

Parents / hybrids / checks	Pericarp thickness (cm)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	0.86	0.83						
2	0.8	0.85						
3	0.81	0.89						
4	0.75	0.76						
5	0.79	0.78						
6	0.82	0.76						
7	0.81	0.76						
1 x 4	0.61	0.4	-24.61*	-29.65*	-27.98*	-50.31*	-52.41*	-54.86*
1 x 5	0.86	0.90	3.95	-0.58	1.79	**11.80***	**8.43***	2.86
1 x 6	0.81	0.75	-4.17	-6.4*	-4.17	-6.29	-10.24*	-14.86*
1 x 7	0.83	0.78	-1.2	-4.07	-1.79	-2.52	-6.63*	-11.43*
2 x 4	0.65	0.52	-16.23*	-18.87*	-23.21*	-35.40*	-38.82*	-40.57*
2 x 5	0.87	0.92	**10.13***	**9.43***	3.57	**12.88***	**8.24***	**5.14***
2 x 6	0.68	0.71	-15.79*	-17.07*	-19.05*	-12.42*	-17.06*	-19.43*
2 x 7	0.73	0.70	-9.66*	-10.49*	-13.69*	-13.04*	-17.65*	-20.0*
3 x 4	0.75	0.73	-3.87	-7.45*	-11.31*	-12.12*	-18.54*	-17.14*
3 x 5	0.69	0.95	-13.21*	-14.29*	-17.86*	**13.77***	**6.74***	**8.57***
3 x 6	0.75	0.77	**8.31***	-9.15*	-11.31*	-7.27	-14.05*	-12.57*
3 x 7	0.85	0.93	**5.26***	**4.94***	1.19	**12.12***	3.93	**5.71***
Akshaya	0.55	0.42						
Abhilash	0.84	0.88						
CD (0.05)	0.15	0.17						
CV	9.09	11.26						

4.4.2.1.3.8 Average fruit weight (g)

Under polyhouse, hybrids produced fruits with weight in the range between 58.35 g and 78.35 g. The hybrid 1 x 7 recorded maximum fruit weight (78.35 g). Inside rainshelter, the average fruit weight of hybrids was in the range between 74.95 g and 96.40 g. The hybrid 3 x 5 recorded maximum average fruit weight (96.40 g).

Under polyhouse, three hybrids recorded significant positive RH, 2 x 5 (17.28%), 1 x 7 (11.53%) and 3 x 4 (10.65%). Significant positive HB was not observed. Three hybrids recorded significant positive SH, 2 x 5 (5.74%), 1 x 7 (5.60%) and 3 x 4 (2.14%). Inside rainshelter, three hybrids, 3 x 7 (8.91%), 3 x 5 (5.76%) and 2 x 7 (2.5%) recorded significant positive RH. One hybrids, 3 x 5 (0.57%), recorded significant positive HB. Six hybrids recorded significant positive SH with highest value for 3 x 5 (12.75%).

Table 101: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for average fruit weight

Parents / hybrids / checks	Average fruit weight (g)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	82.20	93.65						
2	84.90	95.05						
3	82.40	95.85						
4	70.90	76.80						
5	67.95	86.45						
6	72.50	84.50						
7	68.40	76.95						
1 x 4	58.35	74.95	-30.58*	-39.97*	-19.3*	-12.06*	-19.97*	-12.34*
1 x 5	64.80	88.20	-31.84*	-33.33*	-10.37*	-2.05	-5.82*	**3.16***
1 x 6	65.55	86.95	-29.02*	-32.56*	-9.34*	-2.39*	-7.15*	1.7
1 x 7	78.35	82.90	**11.53***	-12.45*	**5.60***	-2.81*	-11.48*	-3.04*
2 x 4	61.50	79.55	-26.83*	-33.08*	-14.94*	-7.42*	-16.31*	-6.96*
2 x 5	76.45	92.45	**17.28***	-17.75*	**5.74***	1.87	-2.74*	**8.13***
2 x 6	71.35	89.95	-20.46*	-22.36*	-1.31	0.2	-5.37*	**5.21***
2 x 7	71.05	88.15	-15.06*	-22.69*	-1.73	**2.50***	-7.26*	**3.1***
3 x 4	73.85	86.50	**10.65***	-8.77*	**2.14***	-0.96	-10.8*	1.17
3 x 5	71.05	96.40	-24.15*	-24.74*	-1.73	**5.76***	**0.57***	**12.75***
3 x 6	70.10	86.40	-22.93*	-25.74*	-3.04	-4.19*	-9.86*	1.05
3 x 7	70.90	94.10	-16.49*	-24.89*	-1.94	**8.91***	**-1.83***	**10.06***
Akshaya	62.70	65.50						
Abhilash	72.30	85.50						
CD (0.05)	14.27	5.12						
CV	9.0	3.24						

4.4.2.1.3.9 Yield per plant (g)

Under polyhouse condition the yield per plant recorded for hybrids were in the range between 857.20 g and 1356.90 g. The highest was recorded for the hybrid 2 x 5 (1356.90 g). Inside rainshelter the fruit yield ranged between 1508.60 g and 2105.05 g. The highest yieldwas observed for the hybrid 3 x 7 (2105.05 g).

Under polyhouse, four hybrids recorded significant positive RH, 1 x 7 (17.28%), 2 x 5 (13.55%), 2 x 7 (8.14%) and 3 x 4 (6.13%). Significant positive HB was not observed. Two hybrids recorded significant positive SH, 2 x 5 (9.32%) and 1 x 7 (9.08%). Inside rainshelter, four hybrids, 3 x 7 (21.50%), 3 x 5 (11.57%), 2 x 7 (9.90%) and 1 x 5 (4.62%) recorded significant positive RH. Two hybrids, 3 x 7 (8.21%) and 3 x 5 (3.37%) recorded significant positive HB. Three hybrids recorded significant positive SH with highest value for 3 x 7 (16.65%).

Table 102: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for yield per plant

Parents / hybrids / checks	Yield per plant (g)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	1460.9	1837.35						
2	1321.6	1899.85						
3	1497.6	1945.35						
4	987.90	1620.95						
5	1142.0	1659.40						
6	1373.4	1787.30						
7	1038.6	1519.70						
1 x 4	875.45	1616.60	-41.35*	-45.20*	-28.74*	-6.51*	-12.02*	-10.42*
1 x 5	885.10	1829.20	-45.36*	-46.1*	-27.95*	**4.62***	-0.44	1.36
1 x 6	1001.65	1640.65	-36.82*	-37.30*	-18.47*	-9.47*	-10.71*	-9.09*
1 x 7	1326.30	1508.60	**17.28***	-29.5*	**9.08***	-10.12*	-17.89*	-16.41*
2 x 4	857.20	1679.05	-43.03*	-47.14*	-30.22*	-4.62*	-11.62*	-6.96*
2 x 5	1356.90	1780.45	**13.55***	-31.98*	**9. 32***	0.05	-6.29*	-1.34*
2 x 6	1204.30	1692.65	-24.61*	-25.73*	-1.97	-8.19*	-10.91*	-6.21*
2 x 7	1181.95	1879.10	**8.14***	-27.11*	-3.79	**9.90***	-1.09	**4.13***
3 x 4	1126.1	1804.55	**6.13***	-32.2*	-8.34	1.20	-7.24*	-0.01*
3 x 5	993.30	2010.90	-39.85*	-40.2*	-19.15*	**11.57***	**3.37***	**11.43***
3 x 6	1090.0	1721.20	-32.6*	-34.37*	-11.27*	-7.78*	-11.52*	-4.62*
3 x 7	1190.3	2105.05	-20.63*	-28.33*	-3.11	**21.50***	**8.21***	**16.65***
Akshaya	1027.6	1306.45						
Abhilash	1228.5	1804.65						
CD (0.05)	400.16	125.48						
CV	15.26	4.33						

4.4.2.1.3.10 Yield per plot (kg)

Under polyhouse the yield per plot was in the range between 5.14 kg and 8.14 kg, the highest being recorded for 2 x 5 (8.14 kg). Inside rainshelter, the hybrids recorded values between 9.70 kg and 12.63 kg. The highest yield per plot was observed for 3 x 7 (12.63 kg).

Under polyhouse, significant positive RH and HB were not observed. The hybrid 2 x 5 (10.45%) recorded significant positive SH. Inside rainshelter, four hybrids recorded significant positive RH, 3 x 7 (21.50%), 3 x 5 (11.60%), 2 x 7 (9.84%) and 1 x 5 (4.67%). Two hybrids, 3 x 7 (8.23%) and 3 x 5 (3.43%), recorded significant positive HB. Three hybrids, 3 x 7 (16.62%), 3 x 5 (11.45%) and 2 x 7 (4.06%), recorded significant positive SH.

Table 103: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for yield per plot

Parents / hybrids / checks	Yield per plot (kg)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	8.77	11.02						
2	7.93	11.40						
3	8.99	11.67						
4	5.93	9.73						
5	6.85	9.96						
6	8.24	10.72						
7	6.23	9.12						
1 x 4	5.25	9.70	-28.57*	-40.14*	-28.77*	-6.51*	-11.98*	-10.43*
1 x 5	5.31	10.98	-32.01*	-39.45*	-27.95*	**4.67***	-0.36	1.39
1 x 6	6.01	9.84	-29.34*	-31.47*	-18.45*	-9.48*	-10.71*	-9.14*
1 x 7	7.96	9.05	6.13	-9.24*	8.01	-10.13*	-17.88*	-16.44
2 x 4	5.14	10.07	-25.83*	-35.18*	-30.26*	-4.69*	-11.67*	-7.02*
2 x 5	8.14	10.68	10.15	2.65	**10.45***	0.00	-6.32*	-1.39
2 x 6	7.23	10.16	-10.58	-12.26*	-1.90	-8.14*	-10.88*	-6.19*
2 x 7	7.09	11.27	0.14	-10.59*	-3.80	**9.84***	-1.14*	**4.06***
3 x 4	6.76	10.83	-9.38	-24.81*	-8.28	1.21	-7.20*	0.00
3 x 5	5.96	12.07	-24.75*	-33.70*	-19.13*	**11.60***	**3.43***	**11.45***
3 x 6	6.54	10.33	-24.09*	-27.25*	-11.26*	-7.73*	-11.48*	-4.62*
3 x 7	7.14	12.63	-6.18*	-20.58*	-3.12	**21.50***	**8.23***	**16.62***
Akshaya	6.17	7.84						
Abhilash	7.37	10.83						
CD (0.05)	2.31	0.69						
CV	15.73	4.28						

4.4.2.1.4 Biochemical characters / quality characters

The traits studied were TSS (Table 104), lycopene (Table 105), ascorbic acid (Table 106), acidity (Table 107) and chlorophyll content (Table 108 –110).

4.4.2.1.4.1 TSS (^{0}Brix)

Under polyhouse, the hybrid 3 x 5 (5.96) produced fruits with maximum TSS. Inside rainshelter, the TSS ranges were less. The hybrid 2 x 5 (5.61) recorded highest value, followed by 2 x 4 (5.57).

Under polyhouse, all hybrids except two recorded significant positive RH with range from -3.4% (1 x 5) to 7.49% (3 x 5). HB was recorded between -4.95% (1 x 5) and 7.18% (2 x 5). Four hybrids recorded significant SH with highest value for 2 x 5 (5.57%). Inside rainshelter, two hybrids recorded significant RH, HB and SH, 2 x 5 (3.22%, 2.94% and 2.65% respectively) and 2 x 4 (2.25%, 1.83% and 1.83% respectively).

Table 104: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for TSS

Parents / hybrids / checks	TSS (^{0}Brix)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	5.76	5.45						
2	5.58	5.42						
3	5.51	5.64						
4	5.49	5.45						
5	5.58	5.45						
6	5.55	5.46						
7	5.57	5.47						
1 x 4	5.86	5.44	**4.09***	1.65	3.45	-0.32	-0.46	-0.46
1 x 5	5.48	5.54	-3.4*	-4.95*	-3.27	1.56	1.56	1.28
1 x 6	5.7	5.39	0.71	-1.13	0.62	-1.28	-1.37	-1.46
1 x 7	5.56	5.54	-1.94	-3.56*	-1.86	1.42	1.28	1.28
2 x 4	5.72	5.57	**3.3***	2.51	0.97	**2.25***	**1.83***	**1.83***
2 x 5	5.98	5.61	**7.18***	**7.18***	**5.57***	**3.22***	**2.94***	**2.65***
2 x 6	5.88	5.46	**5.71***	**5.47***	**3.89***	0.28	-0.09	-0.18
2 x 7	5.87	5.55	**5.34***	**5.29***	**3.71***	1.88	1.46	1.46
3 x 4	5.78	5.47	**5.14***	**5.0***	2.12	-1.44	-2.93*	0.09
3 x 5	5.96	5.52	**7.49***	**6.82***	**5.21***	-0.41	-2.04*	1.001
3 x 6	5.70	5.48	**3.12***	2.70	0.71	-1.31	-2.84*	0.18
3 x 7	5.64	5.54	1.85	1.26	-0.35	-0.27	-1.78*	1.28
Akshaya	6.10	5.63						
Abhilash	5.66	5.41						
CD (0.05)	0.65	0.74						
CV	4.86	2.54						

4.4.2.1.4.2 Lycopene (mg / 100g fresh weight)

Under polyhouse condition the hybrids recorded lycopene values between 7.94 mg / 100 g fresh weight and 11.99 mg / 100 g fresh weight. The hybrid, 3 x 6 recorded maximum lycopene content (11.99 mg / 100 g fresh weight). Inside rainshelter lower lycopene values were observed. The range observed was between 6.31 mg / 100 g fresh weight and 8.93 mg / 100 g fresh weight. The hybrid, 3 x 4 recorded maximum lycopene (8.93 mg / 100 g fresh weight).

Under polyhouse, only one hybrid 3 x 6 recorded significant positive RH (7.18%). Significant positive HB was not observed. Two hybrids, 3 x 6 (19.79%) and 2 x 4 (10.45%) recorded significant positive SH. Inside rainshelter, significant positive RH and HB were not observed. Seven hybrids recorded significant positive SH with range from -11.51% (2 x 5) to 25.26% (3 x 4).

Table 105: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for lycopene

Parents / hybrids / checks	Lycopene (mg / 100g fresh weight)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	12.0	9.47						
2	9.64	8.4						
3	10.35	9.26						
4	13.14	11.87						
5	11.34	10.27						
6	12.02	10.720						
7	11.18	10.19						
1 x 4	9.25	8.28	-26.44*	-29.64*	-7.6*	-22.43*	-30.26*	**16.14***
1 x 5	7.94	7.08	-31.95*	-33.81*	-20.64*	-28.27*	-31.06*	-0.63
1 x 6	9.66	8.18	-19.59*	-19.68*	-3.5	-18.97*	-23.69*	**14.81***
1 x 7	8.3	6.94	-28.4*	-30.85*	-17.09*	-29.43*	-31.91*	-2.67
2 x 4	11.05	8.72	-2.99	-15.91*	**10.45***	-13.92*	-26.51*	**22.39***
2 x 5	8.85	6.31	-15.63*	-21.96*	-11.54*	-34.03*	-38.61*	-11.51*
2 x 6	8.75	7.975	-19.25*	-27.25*	-12.59*	-14.26*	-25.70*	**11.79***
2 x 7	10.14	7.84	-2.57	-9.26*	1.35	-15.66*	-23.07*	**9.97***
3 x 4	10.30	8.93	-12.28*	-21.61*	2.95	-15.48*	-24.78*	**25.26***
3 x 5	8.29	7.03	-23.54*	-26.9*	-17.14*	-28.04*	-31.6*	-1.40
3 x 6	11.99	7.74	**7.18***	-0.29	**19.79***	-22.55*	-27.85*	**8.56***
3 x 7	10.2	7.20	-5.25	-8.77*	1.9	-25.93*	-29.31*	1.05
Akshaya	9.29	7.92						
Abhilash	10.01	7.13						
CD (0.05)	1.91	1.50						
CV	8.88	8.33						

4.4.2.1.4.3 Ascorbic acid (mg / 100 g fresh weight)

Under polyhouse among hybrids ascorbic acid was in the range between 10.87 mg / 100 g fresh weight and 18.65 mg / 100 g fresh weight. The hybrid 1 x 6 recorded the highest value (18.65 mg / 100 g fresh weight). Inside rainshelter, the values ranged between 13.06 mg / 100 g fresh weight and 24.01 mg / 100 g fresh weight. The hybrid 3 x 6 recorded the highest value (24.01 mg / 100 g fresh weight).

Under polyhouse, three hybrids recorded significant positive RH, 1 x 6 (28.48%), 3 x 6 (19.38%) and 2 x 7 (17.16%). The hybrids 1 x 6 (28.81%) and 3 x 6 (11.87%) recorded significant positive HB. SH ranged between -29.92% (2 x 6) and 27.31% (2 x 7). Inside rainshelter, 1 x 6 (18.59%), 3 x 6 (11.66%) and 2 x 7 (9.57%) recorded significant positive RH. Two hybrids, 1 x 6 (16.28%) and 3 x 6 (6.93%) recorded significant positive HB.

Table 106: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for ascorbic acid

Parents / hybrids / checks	Ascorbic acid (mg / 100 g fresh weight)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	14.55	19.75						
2	15.08	18.31						
3	16.56	22.45						
4	18.01	21.21						
5	14.52	19.5						
6	14.48	20.55						
7	18.63	23.54						
1 x 4	11.72	17.42	-28.01*	-34.93*	-24.44*	-14.95*	-17.87*	-14.42*
1 x 5	13.51	18.25	-7.04	-7.15	-12.9*	-7.01	-7.6*	-10.34*
1 x 6	18.65	23.89	**28.48***	**28.81***	**20.21***	**18.59***	**16.28***	**17.4***
1 x 7	17.38	20.66	4.75	-6.71	**12.03***	-4.55	-12.24*	1.5
2 x 4	14.8	16.58	-10.58*	-17.85*	-4.61	-16.11*	-21.83*	-18.55*
2 x 5	12.81	16.11	-13.47*	-15.09*	-17.44*	-14.80*	-18.44*	-20.86*
2 x 6	10.87	13.06	-26.44*	-27.92*	-29.92*	-32.80*	-36.46*	-35.85*
2 x 7	19.75	22.93	**17.16***	6.01	**27.31***	**9.57***	-2.59	**12.65***
3 x 4	12.04	15.66	-30.34*	-33.15*	-22.37*	-28.28*	-30.27*	-23.07*
3 x 5	11.02	13.97	-29.08*	-33.45*	-28.95*	-33.41*	-37.8*	-31.38*
3 x 6	18.53	24.01	**19.38***	**11.87***	**19.44***	**11.66***	**6.93***	**17.96***
3 x 7	14.84	18.65	-15.67*	-20.35*	-4.35	-18.91*	-20.78*	-8.38*
Akshaya	13.02	16.99						
Abhilash	15.51	20.35						
CD (0.05)	3.93	3.55						
CV	12.52	8.86						

4.4.2.1.4.4 Acidity (per cent)

Under polyhouse among the hybrids acidity ranged between 0.12 per cent and 0.18 per cent. The hybrid, 3 x 7 recorded the highest value (0.18 per cent). Inside rainshelter higher values were observed. The range observed for hybrids were between 0.14 per cent and 0.21 per cent, highest being recorded for 1 x 4, followed by 1 x 7, 3 x 6 and 3 x 7 (0.20 per cent).

Under polyhouse, only two hybrids recorded significant positive RH, 3 x 7 (16.17%) and 3 x 6 (9.57%). Significant positive HB and SH were not observed. Inside rainshelter, significant positive RH, HB and SH were not observed.

Table 107: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for acidity

Parents / hybrids / checks	Acidity (per cent)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	0.17	0.20						
2	0.17	0.20						
3	0.13	0.19						
4	0.15	0.17						
5	0.2	0.21						
6	0.18	0.19						
7	0.18	0.22						
1 x 4	0.17	0.21	2.48	-1.79	-11.29	-17.65*	4.93	-7.39
1 x 5	0.13	0.15	-30.77*	-35.71*	-32.26*	-22.71*	-27.01*	-33.04*
1 x 6	0.12	0.16	-29.45*	-30.86*	-34.95*	3.55	-21.18*	-30.44*
1 x 7	0.17	0.20	-2.62	-4.57	-10.22	-14.49*	-6.42	-11.30
2 x 4	0.13	0.18	-18.38*	-21.56*	-29.57*	2.13	-12.2	-21.74*
2 x 5	0.16	0.19	-9.64*	-16.33*	-11.83	-16.35*	-9.0	-16.52*
2 x 6	0.15	0.17	-14.04*	-16.0*	-20.97*	-28.28*	-15.12	-24.35*
2 x 7	0.13	0.14	-23.98*	-25.71*	-30.11*	-30.5*	-34.86*	-38.26*
3 x 4	0.13	0.15	-10.639	-18.18*	-32.26*	-21.43*	-23.83*	-36.09*
3 x 5	0.12	0.15	-26.54*	-39.29*	-36.02*	0.5	-32.23*	-37.83*
3 x 6	0.17	0.20	**9.57***	-5.14	-10.75	1.56	6.28	-11.74
3 x 7	0.18	0.2	**16.17***	0.57	-5.38	-21.0*	-10.55	-15.22*
Akshaya	0.12	0.14						
Abhilash	0.19	0.23						
CD (0.05)	0.03	0.04						
CV	9.436	11.10						

4.4.2.1.4.5 Chlorophyll (mg / 100 g fresh tissue)
4.4.2.1.4.5.1 chl a

Under polyhouse condition, the hybrid 2 x 4 recorded maximum chl a (1.56 mg / 100 g plant tissue), followed by 1 x 4 and 3 x 7 (1.55 mg / 100 g plant tissue). Inside rainshelter lower ranges were recorded. The maximum chl a content was recorded for 1 x 4 (1.16 mg / 100 g plant tissue), followed by 2 x 4 (1.15 mg / 100 g plant tissue) (Table 108).

Under polyhouse, three hybrids recorded significant positive RH, 3 x 7 (14.92%), 1 x 4 (10.49%) and 1 x 6 (9.86%). One hybrid recorded significant positive HB, 3 x 7 (13.16%). Inside rainshelter, 3 x 7 (24.52%), 1 x 6 (18.1%) and 1 x 4 (15.25%), exhibited significant positive RH. 3 x 7 (21.38%) and 1 x 6 (12.86%) recorded significant positive HB. Significant positive SH was not observed (Table 108).

Table 108: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for chlorophyll a

Parents / hybrids / checks	chl a (mg / 100 g plant tissue)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	1.31	0.91						
2	1.54	1.14						
3	1.37	1.07						
4	1.5	1.1						
5	1.52	1.13						
6	1.43	1.0						
7	1.33	1.02						
1 x 4	1.55	1.16	**10.49***	3.41	3.96	**15.25***	5.55	-10.46*
1 x 5	1.21	0.87	-14.12*	-20.2*	-18.54*	-14.58*	-22.74*	-32.54*
1 x 6	1.50	1.13	**9.86***	5.0	1.01	**18.1***	**12.86***	-12.52*
1 x 7	1.39	0.92	5.89	5.05	-6.45	-4.3	-9.15*	-28.59*
2 x 4	1.56	1.15	2.9	1.56	4.84	2.55	0.70	-11.28*
2 x 5	1.14	0.82	-25.61*	-26.03*	-23.64*	-28.11*	-28.42*	-36.94*
2 x 6	1.16	0.85	-22.09*	-24.72*	-22.3*	-20.86*	-25.61*	-34.47*
2 x 7	1.29	0.91	-9.82*	-16.01*	-13.3*	-15.99*	-20.53*	-29.99*
3 x 4	1.4	1.15	-2.48	-6.68	-6.18	5.53	4.19	-11.52*
3 x 5	1.26	0.91	-12.95*	-17.30*	-15.58*	-17.77*	-19.91*	-30.06*
3 x 6	1.31	0.91	-6.46	-8.58*	-12.02*	-12.25*	-15.03*	-29.68*
3 x 7	1.55	1.30	**14.92***	**13.16***	3.96	**24.52***	**21.38***	0.46
Akshaya	0.83	0.59						
Abhilash	1.49	1.29						
CD (0.05)	0.3	0.22						
CV	10.48	10.14						

4.4.2.1.4.5.2 chl b

Under polyhouse, 2 x 4 recorded maximum chl b content (1.47 mg / 100 g plant tissue), followed by 3 x 7 (1.46 mg / 100 g plant tissue). Inside rainshelter also 2 x 4 recorded higher chl b content (1.41 mg / 100 g plant tissue), followed by 3 x 7 (1.31 mg / 100 g plant tissue) (Table 109).

Under polyhouse, three hybrids *viz:* 3 x 7 (21.77%), 2 x 4 (21.37%) and 1 x 7 (8.43%) exhibited significant positive RH. Two hybrids recorded significant positive HB and SH, 3 x 7 (20.81% and 11.56% respectively) and 2 x 4 (25.45% and 12.86% respectively). Inside rainshelter, two hybrids recorded significant positive RH and HB, 2 x 4 (42.57% and 33.05% respectively) and 3 x 7 (23.91% and 24.38%). Four hybrids recorded significant positive SH, with highest value for 2 x 4 (31.8%) (Table 109).

Table 109: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for chlorophyll b

Parents / hybrids / checks	chl b (mg / 100 g plant tissue)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	1.25	.99						
2	1.25	1.06						
3	1.19	1.05						
4	1.18	0.92						
5	1.26	1.04						
6	1.06	0.94						
7	1.21	1.06						
1 x 4	1.20	0.96	-0.82	2.38	-7.89	1.05	-2.92	-7.57*
1 x 5	1.05	0.91	-16.70*	-16.93*	-19.99*	-11.0	-13.14*	-15.01*
1 x 6	1.05	0.97	-9.02*	-16.15*	-19.68*	0.52	-2.42	-9.09*
1 x 7	1.33	1.15	**8.43***	6.48	1.99	11.85	9.97	**9.6***
2 x 4	1.47	1.41	**21.37***	**25.45***	**12.86***	**42.57***	**33.05***	**31.8***
2 x 5	1.23	1.03	-2.31	-2.46	-6.05	-1.67	-2.27	-3.19
2 x 6	1.10	0.96	-4.63	-12.20*	-15.7*	-3.87	-9.38	-10.23*
2 x 7	1.18	1.03	-4.39	-6.22	-9.95*	-2.84	-2.75	-3.66
3 x 4	1.25	1.1	5.93*	6.47	-4.21	11.96	4.76	**5.19***
3 x 5	1.01	0.87	-17.38*	-19.71*	-22.67*	-16.68*	-16.95*	-18.2*
3 x 6	1.14	0.91	1.78	-3.88	-12.63*	-8.21	-13.24*	-14.54*
3 x 7	1.46	1.31	**21.77***	**20.81***	**11.56***	**23.91***	**24.38***	**22.51***
Akshaya	0.9	0.69						
Abhilash	1.31	1.07						
CD (0.05)	0.03	0.65						
CV	12.91	14.41						

4.4.2.1.4.5.3 Total chl

Under polyhouse, the hybrid 2 x 4 recorded the highest total chl content (2.48 mg / 100 g plant tissue), followed by 3 x 7 (2.44 mg / 100 g plant tissue). Inside rainshelter lower ranges were observed for total chlorophyll. The same hybrid, 2 x 4, recorded maximum total chl (2.31 mg / 100 g plant tissue), followed by 3 x 7 (2.30 mg / 100 g plant tissue) (Table 110).

Under polyhouse, only one hybrid recorded significant positive RH, 3 x 7 (9.77%). Significant positive HB and SH were not observed. Inside rainshelter, 3 x 7 (10.44%) recorded significant positive mid RH. Significant positive HB and SH were not observed (Table 110).

Table 110: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for total chlorophyll

Parents / hybrids / checks	chl total (mg / 100 g plant tissue)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	2.4	2.24						
2	2.51	2.35						
3	2.03	1.87						
4	2.07	1.89						
5	2.31	2.25						
6	1.97	1.77						
7	2.39	2.29						
1 x 4	2.26	1.98	1.25	-5.67	-9.99*	-4.0	-11.61*	-16.28*
1 x 5	1.98	1.76	-15.78*	-17.31*	-21.09*	-21.86*	-22.07*	-25.79*
1 x 6	1.80	1.66	-17.49*	-24.94*	-28.37*	-17.46*	-26.12*	-30.02*
1 x 7	1.64	1.42	-31.46*	-31.53*	-34.66*	-37.31*	-37.99*	-39.96*
2 x 4	2.48	2.31	8.09	-1.39	-1.47	9.09	-1.7	-2.33
2 x 5	1.81	1.61	-25.01*	-28.0*	-28.05*	-30.03*	-31.49*	-31.92*
2 x 6	2.0	1.85	-10.45*	-20.19*	-20.26*	-10.44*	-21.49*	-21.99*
2 x 7	2.05	1.91	-16.48*	-18.44*	-18.50*	-17.89*	-18.94*	-19.45*
3 x 4	2.18	2.05	6.12	5.07	-13.45*	9.0	8.75	-13.32*
3 x 5	2.07	1.95	-4.84	-10.65*	-17.83*	-5.74	-13.63*	-17.76*
3 x 6	1.86	1.75	-6.71	-8.18	-25.87*	-3.98	-6.67	-26.0*
3 x 7	2.44	2.30	**9.77***	1.42	-3.42	**10.44***	0.444	-2.75
Akshaya	1.82	1.61						
Abhilash	2.51	2.37						
CD (0.05)	0.86	0.50						
CV	12.57	12.32						

4.4.2.1.5 Incidence of pest and diseases

The traits studied were bacterial wilt incidence (Table 111), blossom end rot (Table 112) and fruit cracking (Table 113).

4.4.2.1.5.1 Bacterial wilt incidence (%)

Under polyhouse three hybrids, 1 x 6, 2 x 4 and 3 x 6, were observed with bacterial wilt incidence. Inside rainshelter four hybrid 1 x 6, 2 x 4, 2 x 5 and 3 x 6 recorded bacterial wilt incidence (Table 110). The maximum wilting was observed for 2 x 4 (35.0%), followed by 1 x 6 and 2 x 6 (25.0%).

Table 111: Scoring of F_1 hybrids, parents and checks for bacterial wilt

Score	**Polyhouse**	**Rainshelter**
R	4, 5, 6, 7, 1 x 4, 1 x 5, 1 x 7, 2 x 5, 2 x 6, 2 x 7, 3 x 4, 3 x 5, 3 x 7, Akshaya and Abhilash	4, 5, 6, 7, 1 x 4, 1 x 5, 1 x 7, 2 x 5, 2 x 7, 3 x 4, 3 x 5, 3 x 7, Akshaya and Abhilash
MR	Nil	Nil
MS	1, 2, 1 x 6, 2 x 4 and 3 x 6	1, 2, 1 x 6, 2 x 6 and 3 x 6
S	3	3 and 2 x 4
HS	Nil	Nil

4.4.2.1.5.2 Blossom end rot (%)

The incidence of blossom end rot was not reported under either polyhouse or inside rainshelter.

4.4.2.1.5.3 Fruit crack (%)

Under polyhouse condition fruit crack was not recorded for either hybrids or parents or checks. Inside rainshelter two hybrids recorded fruit cracking, 1 x 6 (18.54%) and 2 x 4 (23.26%).

Table 112: Scoring of F_1 hybrids, Parents and checks for Blossom end rot

Score	Polyhouse	Rainshelter	Category
0	1, 2, 3, 4, 5, 6, 7, 1 x 4, 1 x5, 1 x 6, 1 x 7, 2 x 4, 2 x 5, 2 x 6, 2 x7, 3 x 4, 3 x 5, 3 x 6, 3 x 7, Akshaya and Abhilash	1, 2, 3, 4, 5, 6, 7, 1 x 4, 1 x5, 1 x 6, 1 x 7, 2 x 4, 2 x 5, 2 x 6, 2 x7, 3 x 4, 3 x 5, 3 x 6, 3 x 7, Akshaya and Abhilash	HR
1	Nil	Nil	R
2	Nil	Nil	MR
3	Nil	Nil	MS
4	Nil	Nil	S
5	Nil	Nil	HS

Table 113: Scoring of F_1 hybrids, Parents and checks for fruit crack

Score	Polyhouse	Rainshelter	Category
0	1, 2, 3, 4, 5, 6, 7, 1 x 4, 1 x5, 1 x 6, 1 x 7, 2 x 4, 2 x 5, 2 x 6, 2 x7, 3 x 4, 3 x 5, 3 x 6, 3 x 7, Akshaya and Abhilash	1, 2, 3, 4, 5, 6, 7, 1 x 4, 1 x5, 1 x 7, 2 x 4, 2 x 6, 2 x7, 3 x 4, 3 x 5, 3 x 6, 3 x7, Akshaya and Abhilash	HR
1	Nil	Nil	R
2	Nil	1 x 6 and 2 x 4	MR
3	Nil	Nil	MS
4	Nil	Nil	S
5	Nil	Nil	HS

4.4.2.1.5.4 Other pest and diseases (%)

Other pest and diseases are exhibited in Table 114 and Table 115

Table 114: Scoring of susceptible F_1 hybrids and parents for leaf minor

Genotypes	Score
1 x 5	2
2 x 6	2
3 x 7	2
5	2
7	2

Table 115: Scorinf of susceptible of F_1 hybrids for fruit borer infestation

Genotypes	Score		
	Polyhouse	Rainshelter	
1 x 5	0	16.74	2
2 x 6	0	12.5	1
3 x 7	0	10.67	1

4.4.2.1.6 Shelf life (no. of days)

Longer shelf life ranges were observed for fruits produced under polyhouse (Table 116), between 7.35 days and 12.0 days. The hybrid 3 x 6 recorded longer shelflife (12.0 days). Inside rainshelter, the range was between 5.25 days and 10.05 days 3 x 6 with highest.

Under polyhouse, five hybrids recorded significant positive RH. Inside rainshelter, the range for RH was from -26.65% (2 x 4) to 36.27% (3 x 6). Two hybrids, 3 x 6 (28.03% and 28.85% respectively) and 3 x 4 (12.74% and 13.46% respectively), exhibited significant positive HB and SH.

Table 116: Mean performance of hybrids, parents and check, and relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of hybrids for shelf life

Parents / hybrids / checks	Shelf life (no. of days)		Per cent heterosis					
	Polyhouse	Rainshelter	Polyhouse			Rainshelter		
			RH	HB	SH	RH	HB	SH
1	8.5	8.2						
2	9.0	8.35						
3	9.35	7.85						
4	8.75	7.6						
5	9.75	8.35						
6	8.55	6.9						
7	7.35	6.0						
1 x 4	9.0	7.9	**4.35***	2.86	-21.74*	-1.27	-4.88	1.28
1 x 5	9.45	8.4	**3.56***	-3.08	-17.83*	1.51	0.6	7.69
1 x 6	8.35	7.2	-2.05	-2.34	-27.39*	-4.64	-12.2*	-7.69
1 x 7	7.35	5.25	-7.26*	-13.53*	-36.09*	-26.06*	-35.98*	-32.69*
2 x 4	7.65	5.85	-13.80*	-15.0*	-33.48*	-26.65*	-29.94*	-25.0*
2 x 5	8.85	7.3	-5.60*	-9.23	-23.04*	-12.58	-12.58*	-6.41
2 x 6	8.5	7.45	-3.13*	-5.56	-26.09*	-2.3	-10.78	-4.49
2 x 7	8.3	7.3	1.53	-7.78	-27.83*	1.74	-12.58*	-6.41
3 x 4	9.95	8.85	**9.94***	6.42	-13.48*	**14.56***	**12.74***	**13.46***
3 x 5	9.65	7.9	1.05	-1.03	-16.09*	-2.47	-5.39	1.28
3 x 6	12.0	10.05	**34.08***	**28.34***	4.35	**36.27***	**28.03***	**28.85***
3 x 7	8.8	7.7	**5.39***	-5.88	-23.48*	**13.19***	-1.91	-1.28
Akshaya	7.35	6.80						
Abhilash	11.50	7.80						
CD (0.05)	1.26	1.27						
CV	13.66	16.65						

4.4.2.2 Qualitative characters of F_1 hybrids

The qualitative observations were taken on fruit size, fruit shape, immature fruit skin colour, presence of green shoulders, fruit colour, fruit surface and blossom end fruit shape (Table 117 -119 and Plate 23)

4.4.2.2.1 Fruit size

Under polyhouse all hybrids produced medium sized fruits. Inside rainshelter all hybrids, except two *viz*: 1 x 4 and 2 x 4, were observed with medium large fruits.

447.2.2.2 Fruit shape

There was no change in the fruit shape between polyhouse and rainshelter. Slightly flattened, round, banana type and plum shaped fruits were observed.

4.4.2.2.3 Immature fruit colour

There was no change in the immature fruit colour between polyhouse and rainshelter. Greenish white, light green and green colour were observed.

4.4.2.2.4 Presence of green shoulders

Green shoulders were observed in two hybrids, 2 x 5 and 2 x 6. 2 x 6 recorded green shoulders in both the growing structures.

4.4.2.2.5 Mature fruit colour

Under polyhouse, orange, red, crimson, yellow and red, tangerine and red and yellow, tangerine and red colours were observed. Polyhouse plants produced more red fruits. Inside rainshelter red, tangerine, yellow and red and yellow, tangerine and red colours were observed.

4.4.2.2.6 Fruit surface

There was no change between polyhouse and rainshelter fruits for fruit surface. The surface was either corrugated or smooth.

4.7.2.2.7 Blossom end fruit shape

There was no change for blossom end fruit shape between rainshelter and polyhouse plants. Only three hybrids, 1 x 6, 3 x 5, 3 x 6 and 3 x 7 recorded pointed blossom end. All other hybrids recorded flat blossom end.

Table 117: Fruit size, fruit shape and immature fruit colour of F_1 hybrids

Crosses	Fruit size		Fruit shape		Immature fruit colour	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	Medium	Medium	Slightly flattened	Slightly flattened	Greenish white	Greenish white
1 x 5	Medium	Medium large	Banana type	Banana type	Light green	Light green
1 x 6	Medium	Medium large	Banana type	Banana type	Light green	Light green
1 x 7	Medium	Medium large	Round	Round	Green	Green
2 x 4	Medium	Medium	Round	Round	Greenish white	Greenish white
2 x 5	Medium	Medium large	Round	Round	Light green	Light green
2 x 6	Medium	Medium large	Banana type	Banana type	Greenish white	Greenish white
2 x 7	Medium	Medium large	Round	Round	Green	Green
3 x 4	Medium	Medium large	Plum shaped	Plum shaped	Greenish white	Greenish white
3 x 5	Medium	Medium large	Banana type	Banana type	Light green	Light green
3 x 6	Medium	Medium large	Banana type	Banana type	Light green	Light green
3 x 7	Medium	Medium large	Heart shaped	Heart shaped	Green	Green

Table 118: Presence of green shoulders, fruit surface and blossom end fruit shape of F_1 hybrids

Crosses	Green shoulders		Fruit surface		Blossom end fruit shape	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	Absent	Absent	Corrugated	Corrugated	Flat	Flat
1 x 5	Absent	Absent	Smooth	Smooth	Flat	Flat
1 x 6	Absent	Absent	Smooth	Smooth	Pointed	Pointed
1 x 7	Absent	Absent	Corrugated	Corrugated	Flat	Flat
2 x 4	Absent	Absent	Corrugated	Corrugated	Flat	Flat
2 x 5	Absent	Present	Corrugated	Corrugated	Flat	Flat
2 x 6	Absent	Present	Smooth	Smooth	Flat	Flat
2 x 7	Absent	Absent	Corrugated	Corrugated	Flat	Flat
3 x 4	Absent	Absent	Corrugated	Corrugated	Flat	Flat
3 x 5	Absent	Absent	Smooth	Smooth	Pointed	Pointed
3 x 6	Absent	Absent	Smooth	Smooth	Pointed	Pointed
3 x 7	Absent	Absent	Corrugated	Corrugated	Pointed	Pointed

119: Mature fruit skin colour of F_1 hybrids

Crosses	Mature fruit skin colour	
	Polyhouse	Rainshelter
1 x 4	Orange	Yellow and red
1 x 5	Red	Red
1 x 6	Red	Red
1 x 7	Red	Yellow and red
2 x 4	Tangarine and red	Tangarine
2 x 5	Tangarine and red	Tangarine
2 x 6	Yellow and red	Yellow and red
2 x 7	Yellow, tangerine and red	Yellow and red
3 x 4	Yellow and red	Yellow and red
3 x 5	Red	Red
3 x 6	Crimson	Red
3 x 7	Yellow and red	Yellow, tangerine and red

4.4.3 Screening for bacterial wilt

The 12 tomato hybrids were screened for wilt incidence in the seedling stage. Data was taken as the per cent disease incidence for all hybrids. Days taken for wilting and per cent disease incidence are given in the Table 120. The observations were taken from the third day of inoculation. There was no difference observed among the hybrids for wilting. None of the hybrid recorded wilting in the challenge inoculation method.

According to the reaction scores (3.2.2), all hybrids were categorized to R.

Table 120: Reaction of F_1 hybrids to artificial inoculation of wilt pathogen

Sl No.	Cross combination	No. of days taken for wilting	Per cent disease incidence	Reaction
1	1 x 4	Nil	0	R
2	1 x 5	Nil	0	R
3	1 x 6	Nil	0	R
4	1 x 7	Nil	0	R
5	2 x 4	Nil	0	R
6	2 x 5	Nil	0	R
7	2 x 6	Nil	0	R
8	2 x 7	Nil	0	R
9	3 x 4	Nil	0	R
10	3 x 5	Nil	0	R
11	3 x 6	Nil	0	R
12	3 x 7	Nil	0	R

1 x 4

1 x 5

1 x 6

1 x 7

2 x 4

2 x 5

Plate 23: Fruits of F_1 hybrids

2 x 6

2 x 7

3 x 4

3 x 5

3 x 6

3 x 7

Plate 23: Continued

4.4.4 Combining ability analysis

The analysis of variance for the combining ability revealed significance of general combining ability and specific combining ability for all the characters in both the structures.

4.4.4.1 Estimation of combining ability (GCA and SCA) effects

The general combining ability effects (*gca*) and specific combining ability effects (*sca*) were estimated for seven parents (three lines and four testers) and 12 line x tester crosses respectively for both the structures. The estimates for all characters are presented in Table121 to Table 144. The results are briefed below.

4.4.4.1.1 Vegetative characters

4.4.4.1.1.1 Plant height at flowering

Genotypes differed for GCA with respect to plant height at flowering. Under polyhouse condition among the lines, the highest positive significant GCA was for 3 (EC-620410) (2.8) indicating its selection for tallness. The highest negative GCA was for 1 (EC-620401) (-3.88) indicating the selection for dwarfness. Among the testers, only 5 (EC-620427) had positive and significant GCA (2.62). The highest significant negative GCA was observed for 7 (Arka Abha) (-1.35) (Table 121)

Among the hybrids, significant positive SCA was obersvesd for 3 x 7 (5.39), 2 x 6 (3.35), 1 x 5 (3.15), 2 x 4 (1.12) and 1 x 4 (0.93). The highest negative SCA was observed for the cross 2 x 7 (-3.25) (Table 122).

Inside rainshelter among the lines, 3 (EC-620410) expressed highest positive significant GCA (3.01) and highest significant negative GCA was for 1 (EC-620401) (-5.41). Among the testers, the highest positive significant GCA was observed for 5 (EC-620427) (2.64) and highest negative significant GCA was observed for 4 (EC-620382) (-2.0) (Table 121).

Among the hybrids, the three hybrids recorded positive significant SCA 1 x 5 (4.64), 2 x 6 (4.3) and 3 x 7 (2.77) (Table 122).

4.4.4.1.1.2 Internodal length

Under polyhouse among the lines, GCA effect of 3 (EC-620410) was positive and significant (0.23) and the GCA effect of 1 (EC-620401) was negative and significant (-0.23). Among the testers, the positive significant GCA effect was observed only 5 (EC-620427) (1.35). The highest negative significant GCA effect was observed for 6 (EC-620429) (-0.82) (Table 121).

Among the hybrids, the highest positive significant SCA effect was observed for 2 x 4 (1.93). The highest negative significant SCA was observed for 3 x 4 (-1.74) (Table 122).

Inside rainshelter among lines, significant positive GCA was observed only for 3 (EC-620410) (0.27), the highest negative GCA was observd in the line 1 (EC-620401) (-0.2). Among the testers, 5 (EC-620427), recorded highest positive significant GCA (1.29). The highest negative GCA was observed for 6 (EC-620429) (-0.9) (Table 121).

In the SCA effect the hybrids 2 x 4 recorded highest positive significant SCA effect (2.22). The highest negative significant SCA effect was for the hybrid 1 x 7 (-0.81) (Table 122).

The highest positive effect was observed for the hybrid 1 x 4 under both the structures for tallness.

4.4.4.1.1.3 Plant height at harvest

Under polyhouse among the lines, the highest positive GCA was for 3 (EC-620410) (2.9). The line 1 (EC-620401) recorded highest significant negative GCA (-3.26). Among the testers, the GCA effect was highest for 5 (EC-620427) (2.98). The highest significant negative GCA was observed for 7 (Arka Abha) (-1.29) (Table 121).

Table 121: General combining ability effect of parents for plant height at flowering, intermodal length and plant height at harvest

Parents	Plant height at flowering		Internodal length		Plant height at harvest	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
	Lines					
1	-3.88*	-5.41*	-0.23*	-0.2*	-3.26*	-2.65*
2	1.08*	2.39*	0.00	-0.07*	0.36	0.51*
3	2.8*	3.01*	0.23*	0.27*	2.90*	2.14*
Testers						
4	-0.52*	-2.0*	-0.08	0.003	-0.78*	0.59*
5	2.62*	2.64*	1.35*	1.29*	2.98*	1.12*
6	-0.75*	-1.22*	-0.82*	-0.9*	-0.91*	0.71*
7	-1.35*	0.59*	-0.45*	-0.39*	-1.29*	-2.42*

Table 122: Specific combining ability effect of crosses for plant height at flowering, intermodal length and plant height at harvest

Cross	Plant height at flowering		Internodal length		Plant height at harvest	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	0.93*	0.47	-0.19*	-0.05	1.16*	5.17*
1 x 5	3.15*	4.64*	0.23*	0.06	2.56*	1.62*
1 x 6	-1.94*	-3.10*	0.74*	0.8*	-1.80*	-1.15*
1 x 7	-2.14*	-2.01*	-0.78*	-0.81*	-1.92*	-5.64*
2 x 4	1.12*	-1.83	1.93*	2.22*	0.04	-3.48*
2 x 5	-1.22*	-1.71	-0.90*	-1.11*	-0.76*	-0.15
2 x 6	3.35*	4.3*	-1.38*	-1.43*	2.77*	2.05*
2 x 7	-3.25*	-0.76	0.35*	0.32	-2.05*	1.58*
3 x 4	-2.05*	1.35	-1.74*	-2.17*	-1.20*	-1.69*
3 x 5	-1.93*	-2.93*	0.68*	1.05*	-1.80*	-1.47*
3 x 6	-1.41*	-1.2	0.64*	0.63*	-0.97*	-0.9
3 x 7	5.39*	2.77*	0.43*	0.49*	3.97*	4.06*

The hybrids 3 x 7 (3.97), 2 x 6 (2.77), 1 x 5 (2.56) and 1 x 4 (1.16) recorded significant positive SCA. The highest negative significant SCA was observed for 2 x 7 (-2.05) (Table 122)

Inside rainshelter, the line 3 (EC-620410) recorded highest positive GCA (2.14). The highest negative GCA was for 1 (EC-620401) (-2.65). The highest positive significant GCA was observed for 5 (EC-620427) (1.12) among the testers. Only 7 (Arka Abha) recorded negative significant GCA effect (-2.42) (Table 121).

The highest positive significant SCA was for the hybrid 1 x 4 (5.17). The highest negative significant SCA was observed for 3 x 5 (-1.47) (Table 122).

4.4.4.1.1.4 Leaf area

Under polyhouse, the line 2 (EC-620406), recorded highest positive significant GCA (4.97). The highest negative significant GCA was seen for 1 (EC-620401) (-4.55). Among the testers, 5 (EC-620427) recorded highest positive GCA (4.88) and 6 (EC-620429) recorded highest negative GCA (-5.06) (Table 123).

Among the hybrids the highest positive and significant SCA effect was observed for 3 x 4 (6.03). The highest negative SCA was exhibited for 3 x 7 (-7.68) (Table 124).

Inside rainshelter among the lines, 3 (EC-620410) recorded highest positive significant GCA (2.86) and 1 (EC-620401) recorded highest significant negative GCA (-3.84). Among the testers, the highest positive GCA was observed for 5 (EC-620427) (2.38). The highest negative GCA was observed for 4 (EC-620382) (-2.22) (Table 123).

Among the hybrids 2 x 7 (6.22) recorded highest significant positive SCA and 3 x 7 (-6.47) exhibited highest significant negative SCA (Table 124).

4.4.4.1.1.5 Crop duration

Under polyhouse, among the lines only 1 (EC-620401) recorded significant positive GCA (0.35). Among the testers, 6 (EC-620429) recorded highest significant positive GCA (2.43). Only 4 (EC-620382) recorded significant negative GCA among the testers (-4.09) (Table 123).

Only two hybrids, 1 x 7 (1.4) and 2 x 5 (1.31), recorded positive significant SCA effect. The highest negative significant effect was observed for 2 x 7 (-1.70) (Table 124).

Inside rainshelter, the line 3 (EC-620410) recorded highest significant positive GCA effect (1.33) and 2 (EC-620406) recorded highest negative significant GCA (-1.21). Among the testers, the highest significant positive GCA effect was seen for 5 (EC-620427) (3.17) and highest negative significant effect was for 4 (EC-620382) (-6.13) (Table 123).

The hybrid 3 x 4 recorded the highest significant positive SCA effect (2.72). The highest significant negative SCA effect was observed for 1 x 4 (-0.53) (Table 124).

4.4.4.1.2 Flowering characters

4.4.4.1.2.1 Days to 50% flowering

Under polyhouse, 1 (EC-620401) recorded highest negative significant GCA (-1.88) and 3 (EC-620410) recorded highest positive significant GCA (1.38). Among the testers, 5 (EC-620427) (-1.88) exhibited highest significant negative GCA, followed by 7 (Arka Abha) (-1.21) (Table 123).

In the estimation of SCA, ten hybrids recorded significant effect. Among these three hybrids, 1 x 7 (-4.29), 2 x 5 (-4.0) and 1 x 4 (-0.29), recorded significant negative SCA effect. The highest positive SCA was observed for 2 x 7 (3.83) (Table 124).

Inside rainshelter among the lines, only 1 (EC-620401) recorded significant negative GCA (-1.78). Among the testers, 5 (EC-620427) recorded highest negative significant GCA (-2.55), followed by 7 (Arka Abha) (-1.71) (Table 123).

Three hybrids were observed to have significant negative SCA effect *viz*: 2 x 5 (-6.33), 1 x 7 (-5.55) and 3 x 6 (-4.30). The highest positive significant SCA was observed for 2 x 7 (3.34) (Table 124).

Table 123: General combining ability effect of parents for leaf area, crop duration and days to 50% flowering

Parents	Leaf area		Crop duration		Days to 50% flowering	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	-4.55*	-3.84*	0.35*	-0.12	-1.88*	-1.78*
2	4.97*	0.97*	-0.65*	-1.21*	0.50*	0.33*
3	-0.42	2.86*	0.29	1.33*	1.38*	1.45*
Testers						
4	0.64	-2.22*	-4.09*	-6.13*	1.79*	1.95*
5	4.88*	2.38*	1.28*	3.17*	-1.88*	-2.55*
6	-5.06*	-2.073*	2.43*	3.15*	1.29*	2.30*
7	-0.46	1.91*	0.39	-0.19	-1.21*	-1.71*

Table 124: Specific combining ability effect of crosses for leaf area, crop duration and days to 50% flowering

Cross	Leaf area		Crop duration		Days to 50% flowering	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-1.76*	1.43*	-0.92*	-0.53*	-0.29*	-0.72
1 x 5	-0.79*	-4.04*	-0.39	0.68*	1.88*	3.28*
1 x 6	-1.80*	2.37*	-0.09	0.89*	2.71*	2.98*
1 x 7	4.35*	0.24	1.4*	-1.04*	-4.29*	-5.55*
2 x 4	4.35*	-4.25*	-0.22	-2.19*	0.33*	1.67*
2 x 5	-0.65	0.55	1.31*	2.21*	-4.0*	-6.33*
2 x 6	1.58*	-2.53*	0.61*	0.58*	-0.17	1.32*
2 x 7	3.33*	6.22*	-1.70*	-0.6*	3.83*	3.34*
3 x 4	6.03*	2.82*	1.14*	2.72*	-0.04	-0.95
3 x 5	1.44*	3.49*	-0.93*	-2.89*	2.13*	3.05*
3 x 6	0.22	0.16	-0.53	-1.46*	2.54*	-4.30*
3 x 7	-7.68*	-6.47*	0.31	1.63*	0.46*	2.21*

4.4.4.1.2.2 Intercluster distance

Under polyhouse among the lines the highest significant negative GCA was observed for 1 (EC-620401) (-1.85). Among the testers the highest significant negative GCA was seen for 7 (Arka Abha) (-1.28), followed by 4 (EC-620382) (-1.21) (Table 125).

Six hybrids *viz*: 1 x 6 (-2.32), 3 x 4 (-2.17), 2 x 7 (-1.61), 3 x 5 (-0.80), 1 x 7 (-0.74) and 2 x 5 (-0.56) recorded significant negative SCA. The highest positive significant SCA was observed for 3 x 7 (2.35) (Table 126).

Inside rainshelter, only the line 1 (EC-620401) recorded negative significant GCA (-1.93). Among the testers 7 (Arka Abha) recorded highest negative significant GCA (-1.16), followed by 4 (EC-620382) (-1.01) (Table 125).

The hybrid, 2 x 7 (-1.58) recorded highest negative significant SCA, followed by 3 x 4 (-1.45). The highest positive significant SCA effect was observed for the hybrid 3 x 7 (2.2) (Table 126)

4.7.4.1.2.3 Pollen viability (%)

4.7.4.1.2.3.1 Early stage of flowering

Under polyhouse, only one line 2 (EC-620406) recorded significant positive GCA effect (0.55). 1 (EC-620401) recorded significant negative GCA (-0.52). Among the testers, 6 (EC-620429) exhibited highest positive significant GCA (0.73), followed by 7 (Arka Abha) (0.20) (Table 127).

Highest positive significant SCA was recorded for the hybrid 1 x 7 (1.30), followed by 2 x 4 (0.44). The hybrid, 1 x 4 recorded highest significant negative GCA (-1.25) (Table 128).

Inside rainshelter, among the lines, significant positive GCA was observed only for 2 (EC-620406) (1.14). Among the testers, 6 (EC-620429) recorded highest positive significant GCA (0.96) (Table 127).

The cross, 1 x 7 recorded highest significant positive SCA (1.26). Highest significant negative SCA was observed for 1 x 4 (-1.09) (Table 128).

Table 125: General combining ability effect of parents for intercluster distance, days to first fruit set and days from anthesis to fruit maturity

Parents	Intercluster distance		Days to first fruit set		Days from anthesis to fruit maturity	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	-1.85*	-1.93*	-1.80*	-2.27*	-0.03	0.04
2	0.93*	1.03*	0.21*	1.05*	0.49*	-0.35*
3	0.92*	0.90*	1.59*	1.23*	0.52*	0.30*
Testers						
4	-1.21*	-1.01*	1.23*	1.14*	0.5*	0.16*
5	2.03*	2.43*	-2.20*	-1.35*	-0.70*	-0.82*
6	0.46*	-0.26*	0.68*	0.74*	0.21*	0.92*
7	-1.28*	-1.16*	0.28	-0.53	-0.004	-0.25*

Table 126: Specific combining ability effect of crosses for intercluster distance, days to first fruit set and days from anthesis to fruit maturity

Cross	Intercluster distance		Days to first fruit set		DFAT fruit maturity	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	1.7*	0.93*	-0.13	0.69*	-1.67*	-0.78*
1 x 5	1.36*	0.90*	0.85*	1.97*	-1.01*	-0.28
1 x 6	-2.32*	-1.22*	3.02*	2.44*	0.76*	1.36*
1 x 7	-0.74*	-0.62*	-3.73*	-5.09*	1.33*	-0.31
2 x 4	0.47*	0.52*	-0.75*	0.11	2.79*	1.98*
2 x 5	-0.56*	-0.06	-3.26*	-3.62*	-1.01*	-0.50
2 x 6	1.70*	1.12*	-0.4	0.8*	-0.68*	-0.8*
2 x 7	-1.61*	-1.58*	4.40*	2.72*	-1.11*	-0.68*
3 x 4	-2.17*	-1.45*	0.88*	-0.79*	-1.12*	-1.21*
3 x 5	-0.80*	-0.84*	2.41*	1.65*	1.43*	0.78*
3 x 6	0.62*	0.1	-2.62*	-3.24*	-0.09	-0.56
3 x 7	2.35*	2.2*	-0.67	2.38*	-0.22	0.99*

4.4.4.1.2.3.2 Mid stage of flowering

Under polyhouse, only line 2 (EC-620406) recorded positive significant GCA (0.83). The tester, 4 (EC-620382) exhibited highest positive significant GCA (1.03). The highest negative significant GCA was observed for 5 (EC-620427) (-0.98) (Table 127).

The hybrid, 2 x 7 recorded highest positive significant SCA (1.44). The highest negative significant SCA was observed for 3 x 7 (-1.54) (Table 128).

Inside rainshelter, only 2 (EC-620406) recorded positive significant GCA among lines (0.48) and 5 (EC-620427) recorded highest positive significant GCA among testers (1.06) (Table 127).

The hybrid, 1 x 7 recorded highest positive significant SCA (2.58), followed by 3 x 5 (1.55). The highest negative significant SCA was observed for 3 x 7 (-1.30) (Table 128).

4.4.4.1.2.3.3 Late stage of flowering

Under polyhouse, among the lines 3 (EC-620410) recorded highest significant and positive GCA (0.36). Among the testers 7 (Arka Abha) exhibited highest positive significant GCA (0.80), followed by 4 (EC-620382) (0.43) (Table 127).

The hybrid, 3 x 6 recorded highest significant positive SCA (0.69), followed by 1 x 7 (0.65). The highest negative significant SCA effect was observed for 1 x 6 (-0.55) (Table 128).

Inside rainshelter, the line 3 (EC-620410) recorded highest significant positive GCA (1.21) and 1 (EC-620401) recorded significant negative GCA (-1.30). Among the testers, 7 (Arka Abha) recorded highest positive significant GCA (0.74). Only 4 (EC-620382) recorded significant negative GCA (-1.16) (Table 140). The hybrid, 2 x 6 recorded highest significant positive SCA (2.21), followed by 1 x 7 (1.93). The highest significant negative SCA was observed for 3 x 6 (-1.91) (Table 127).

4.4.4.1.2.4 Flowers with exerted stigma (%)

4.4.4.1.2.4.1 Early stage of flowering

Under polyhouse, the line 1 (EC-620401) recorded highest negative significant GCA (-0.08), followed by 2 (EC-620406) (-0.07). Among the testers, only 4 (EC-620382) recorded highest negative significant GCA (-1.45) (Table 127). The highest negative SCA effect was observed for 3 x 7 (-3.48), followed by 2 x 6 (-1.90). The highest positive significant SCA was recorded for 1 x 7 (2.25) (Table 128).

Inside rainshelter, the highest negative GCA was observed for 1 (EC-620401) (-0.60) among the lines, and 4 (EC-620382) (-1.44) among the testers (Table 127). Among hybrids, 2 x 5 recorded highest negative significant SCA (-1.81). The highest positive significant SCA was observed for 1 x 5 (2.20) (Table 128).

4.7.4.1.2.4.2 Mid stage of flowering

Under polyhouse among the lines, 1 (EC-620401) recorded highest significant negative GCA (-0.77) and 3 exhibited highest positive significant GCA (0.6). Among the tester, 4 (EC-620382) recorded highest significant negative GCA (-0.92), and 5 (EC-620427) and 6 (EC-620429) recorded positive significant GCA (0.71) (Table 127). The hybrid, 2 x 6 recorded highest negative significant SCA (-3.59), followed by 1 x 4 (-3.08). The highest positive SCA was observed for 3 x 6 (2.79) (Table 128).

Inside rainshelter, 2 (EC-620406) recorded highest significant negative GCA (-0.17), and 3 (EC-620410) recorded highest positive significant GCA (0.17) among the lines. The tester 6 (EC-620429) recorded highest negative significant GCA (-1.48) (Table 127). The hybrid, 2 x 4 (-2.96) exhibited to have highest negative significant SCA, followed by 3 x 6 (-2.05). The highest positive significant SCA was observed for 3 x 4 (2.40) (Table 128).

Table 127: General combining ability effects of parents for pollen viability and flowers with exerted stigma

Parents	Pollen viability						Flowers with exerted stigma					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Lines												
1	-0.52*	-0.33*	-0.45*	-0.3*	-0.43*	-1.30*	-0.08	-0.77*	-0.01	-0.60*	0.004	0.02
2	0.55*	0.83*	0.09	1.14*	0.48*	0.09	-0.07	0.17*	-1.59*	0.01	-0.17*	1.004
3	-0.03	-0.5*	0.36*	-0.85*	-0.05	1.21*	0.15	0.6*	1.60*	0.6*	0.17*	-1.02*
Testers												
4	0.15*	1.03*	0.43*	-0.03	-0.90*	-1.16*	-1.45*	-0.92*	0.29*	-1.44*	-0.98*	-1.09*
5	-1.08*	-0.98*	-1.08*	-1.26*	1.06*	0.39*	0.30	0.75*	1.12*	1.0*	1.76*	1.26*
6	0.73*	0.40*	-0.15	0.96*	-0.42*	0.03	0.59	0.75*	0.27*	0.88*	-1.48*	0.28*
7	0.20*	-0.45*	0.80*	0.33*	0.26*	0.74*	0.55	-0.58*	-1.68*	-0.44*	0.69*	-0.45*

Table 128: Specific combining ability effects of crosses for pollen viability and flowers with exerted stigma

Crosses	Pollen viability						Flowers with exerted stigma					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
1 x 4	-1.25*	-0.03	-0.48*	-1.09*	-1.41*	-0.77*	-1.20*	-3.08*	-1.54*	-1.56*	0.56*	1.25*
1 x 5	0.083	-0.17*	0.38*	-0.30*	-0.88*	-0.87*	-0.80*	1.60*	1.83*	2.20*	0.18*	1.20*
1 x 6	-0.13	0.10*	-0.55*	0.13	-0.29*	-0.30*	-0.24	0.80*	0.18	0.07	0.06	-0.82
1 x 7	1.30*	0.10*	0.65*	1.26*	2.58*	1.93*	2.25*	0.68*	-0.47*	-0.71*	-0.80*	-1.63*
2 x 4	0.44*	-0.3*	0.43*	0.93*	0.44*	-0.60*	0.68*	1.98*	0.39	-0.58*	-2.96*	-2.44*
2 x 5	0.87*	-0.53*	-0.05	-0.14	-0.68*	0.25*	-0.02	-0.04	0.55*	-1.81*	-0.6*	-0.69
2 x 6	-0.25	-0.61*	-0.14	-0.21*	1.51*	2.21*	-1.90*	-3.59*	0.35	0.46	1.99*	3.5*
2 x 7	-1.06*	1.44*	-0.24*	-0.58*	-1.28*	-1.85*	1.23*	1.65*	-1.3*	1.93*	1.57*	-0.37
3 x 4	0.81*	0.33*	0.05	0.16	1.0*	1.37*	0.52*	1.10*	1.15*	2.14*	2.40*	1.19*
3 x 5	-0.95*	0.7*	-0.33*	0.45*	1.55*	0.62*	0.82*	-1.56*	-2.38*	-0.4	0.42*	-0.51
3 x 6	0.38*	0.51*	0.69*	0.08	-1.227*	-1.91*	2.14*	2.79*	-0.53*	-0.53	-2.05*	-2.68*
3 x 7	-0.24	-1.54*	-0.41*	-0.69*	-1.30*	-0.08	-3.48*	-2.33*	1.77*	-1.21*	-0.77*	2.0*

4.4.4.1.2.4.3 Late stage of flowering

Under polyhouse among the lines, 2 (EC-620406) recorded highest negative significant GCA (-1.59) and 3 (EC-620410) recorded highest positive significant GCA (1.60). Only 7 (Arka Abha) recorded negative significant GCA (-1.68) among the testers. 5 (EC-620427) recorded highest positive significant GCA (1.12) (Table 127). In the case of hybrids, 3 x 5 recorded highest negative SCA (-2.38), followed by 1 x 4 (-1.54), 2 x 7 (-1.3), 3 x 6 (-0.53) and 1 x 7 (-0.47). The highest positive significant SCA was observed for 1 x 5 (1.83) (Table 128).

Inside the rainshelter among the lines, only 3 (EC-620410) recorded significant negative GCA (-1.02). Among the testers, 4 (EC-620382) recorded highest significant negative GCA (-1.09) and 5 (EC-620427) recorded highest positive significant GCA (1.26) (Table 127). The hybrid, 3 x 6 recorded highest negative significant GCA (-2.68), followed by 2 x 4 (-2.44). The highest positive significant GCA was observed for 2 x 6 (3.5) (Table 127).

4.4.4.1.2.5 Length of the style (cm)

4.4.4.1.2.5.1 Early stage of flowering

Under polyhouse, among lines only 1 (EC-620401) recorded negative significant GCA (-0.01). Among the testers, 7 (Arka Abha) (-0.03) and 6 (EC-620429) (-0.01) recorded negative significant GCA (Table 129). Among the crosses, 3 x 4 and 1 x 7 recorded highest negative significant SCA (-0.04) (Table 130).

Inside rainshelter, among the lines 1 (EC-620401) recorded highest negative significant GCA (-0.02). Among testers, 7 (Arka Abha) recorded highest negative significant GCA (-0.03), followed by 6 (EC-620429) (-0.02) (Table 129). Only two hybrids recorded significant SCA effect. The hybrids, 1 x 7 (-0.03) and 3 x 4 (-0.02) recorded negative significant SCA (Table 130).

4.4.4.1.2.5.2 Mid stage of flowering

Under polyhouse, none of the lines exhibited significant negative GCA. Among the testers, 7 (Arka Abha) recorded highest negative GCA (-0.02), followed by 6 (EC-620429) (-0.01) (Table 129). The hybrid, 1 x 7 recorded highest significant positive SCA (-0.05), followed by 3 x 6 (-0.02) (Table 130).

Inside rainshelter, among lines there was no negative significant GCA effect. In the case of testers, 6 (EC-620429) (-0.03) and 7 (Arka Abha) (-0.02) recorded significant negative GCA effect (Table 129). The highest significant negative SCA was recorded for 1 x 7 (-0.035) (Table 130).

4.4.4.1.2.5.3 Late stage of flowering

Under polyhouse, 2 (EC-620406) recorded significant negative GCA (-0.02) among the lines. Among the testers, 6 (EC-620429) and 7 (Arka Abha) (-0.02) recorded significant negative GCA (Table 129). The hybrid, 3 x 6 (-0.04) recorded highest significant negative SCA, followed by 1 x 7 (-0.03) (Table 130).

Inside rainshelter, among lines the highest negative significant GCA was recorded for 2 (EC-620406) (-0.03). Among the testers, the highest significant negative GCA was observed for 7 (Arka Abha) (-0.02) (Table 129). The highest negative significant SCA effect was recorded for the hybrid 1 x 5 (-0.05) (Table 130).

4.4.4.1.2.6 Anther length (cm)

4.4.4.1.2.6.1 Early stage of flowering

Under polyhouse, among the lines only 3 (EC-620410) had significant GCA effect (-0.01). Among the testers, 5 (EC-620427) and 4 (EC-620382), recorded significant positive GCA (0.02). 7 (Arka Abha) recorded highest negative significant GCA effect (-0.03) (Table 129). The hybrid, 3 x 7 recorded highest positive significcnat SCA effect (0.04), followed by 1 x 4 (0.03). The highest negative SCA effect was observed for 1 x 7 (-0.04), followed by 3 x 4 (-0.04) (Table 130).

Inside rainshelter, among the lines 3 (EC-620410) recorded significant positive GCA (0.01) and 1 (EC-620401) recorded significant negative GCA (-0.01). Among the testers, 4 (EC-620382) recorded highest significant positive GCA (0.03) and 7 (Arka Abha) recorded highest significant negative GCA (-0.03) (Table 129). Only four hybrids recorded significant SCA effect for anther length. 3 x 7 (0.04) and 1 x 4 (0.02) recorded significant positive SCA and 1 x 7 (-0.03) and 3 x 4 (-0.02) recorded significant negative SCA (Table 130).

4.4.4.1.2.6.2 Mid stage of flowering

Under polyhouse among the lines, there was no significant difference. Among the testers, only two testers recorded significant GCA *viz*: 4 (EC-620382) (0.02) and 7 (Arka Abha) (-0.02) (Table 129). Only five hybrids recorded significant SCA effect. The highest SCA effect was recorded for 3 x 7 (0.05), followed by 1 x 4 (0.03), and 1 x 5 (0.01). The hybrids, 1 x 7 (-0.05) and 3 x 4 (-0.02) recorded significant negative SCA effect (Table 130).

Inside rainshelter, among the lines only 3 (EC-620410) recorded significant SCA (0.01). Among the testers, 4 (EC-620382), recorded significant positive GCA effect (0.03). The highest negative significant GCA was recorded for 6 (EC-620429) (-0.03), followed by 7 (Arka Abha) (-0.02.) (Table 129). Seven hybrids recorded significant SCA effect. 3 x 7 (0.05) recorded highest significant positive SCA, followed by 2 x 5 (0.04). The highest significant negative SCA was observed for 1 x 7 and 3 x 5 (-0.03) (Table 130).

4.4.4.1.2.6.3 Late stages of lowering

Under polyhouse, among the lines only 3 (EC-620410) recorded positive significant GCA effect (0.01). Among the testers, 4 (EC-620382) (0.03) and 5 (EC-620427), recorded significant positive GCA effect (0.02) (Table 129). Among the hybrids, 3 x 7 recorded highest significant positive SCA (0.04), followed by 2 x 6 (0.03). The highest significant negative SCA effect was observed for 3 x 6 (-0.03) (Table 130).

Inside rainshelter only two lines recorded significant GCA, 3 (EC-620410) (0.02) and 2 (EC-620406) (-0.03). Among the testers, 4 (EC-620382) recorded highest significant positive GCA (0.02), and 7 (Arka Abha) recorded highest significant negative GCA (-0.03) (Table 129). Only two hybrids recorded positive significant SCA *viz:* 3 x 7 (0.02) and 2 x 5 (0.02). The highest significant negative SCA was observed for 3 x 6 (-0.02) (Table 130).

4.4.4.1.2.7 Number of flowers per cluster

447.4.1.2.7.1 Early stage of flowering

Under polyhouse, among the lines only 1 (EC-620401) exhibited significant positive GCA effect (0.81). 3 (EC-620410) and 2 (EC-620406) recorded significant negative GCA effect (-0.47 and -0.34, respectively). Among the testers, only 4 (EC-620382) and 5 (EC-620427) recorded significant GCA effect (0.41 and -0.49, respectively) (Table 131). Out of twelve, eight hybrids showed significant SCA effect. The hybrid 1 x 6 recorded highest significant SCA effect (0.36), followed by 3 x 5 (0.32). Highest significant negative SCA was recorded for 3 x 7 (-0.47) (Table 132).

In the rainshelter, among the lines 3 (EC-620410) recorded highest significant positive GCA (0.19), followed by 1 (EC-620401) (0.15). Among the testers, 7 (Arka Abha) recorded highest significant positive GCA (0.34), followed by 4 (EC-620382) (0.16). 5 (EC-620427) (-0.28) and 6 (EC-620429) (-0.23) recorded significant negative GCA (Table 131). Six hybrids recorded significant SCA effect. 2 x 5 (1.19), 1 x 6 (0.75) and 1 x 4 (0.27) recorded significant positive SCA effect. 1 x 5 (-1.10), 2 x 6 (-0.66) and 2 x 4 (-0.4) recorded significant negative SCA effect (Table 132).

4.7.4.1.2.7.2 Mid stage of flowering

Under polyhouse, among the lines 3 (EC-620410) recorded significant positive GCA effect (0.12) and 2 (EC-620406) recorded significant negative GCA effect (-0.15). Among the testers, 4 (EC-620382) (0.20) and 7 (Arka Abha) (0.12) recorded significant positive GCA effect. 5 (EC-620427) (-0.21) and 6 (EC-620429) (-0.11) recorded significant negative GCA effect (Table 131). Six hybrids recorded significant SCA effect for number of flowers per cluster. 1 x 6 (0.59), 2 x 5 (0.31) and 3 x 5 (0.30) recorded positive SCA and 1 x 5 (-0.612), 3 x 6 (-0.35) and 2 x 6 (-0.24) recorded negative SCA effect (Table 132).

Inside rainshelter, among the lines only 3 (EC-620410) recorded positive significant GCA (0.43). The highest negative significant GCA was exhibited for 1 (EC-620401) (-0.30). Among the testers, 7 (Arka Abha) recorded highest significant positive GCA (0.28) and 6 (EC-620429) recorded highest significant negative GCA (-0.23) (Table 131). The hybrid, 1 x 6 (0.69) recorded highest significant positive SCA, followed by 3 x 5 (0.50). The highest negative significant SCA was observed for 1 x 5 (-0.76) (Table 132).

4.7.4.1.2.7.3 Late stage of flowering

Under polyhouse, the line 1 (EC-620401) recorded highest significant negative GCA (-0.14), followed by 2 (EC-620406) and 3 (EC-620410) (0.28). Among the testers, only 7 (Arka Abha) recorded significant positive GCA (0.48). The highest negative GCA was recorded for 5 (EC-620427) (-0.40) (Table 131).

The hybrid, 2 x 4 (0.4) recorded highest significant SCA, followed by 1 x 7 (0.36). The highest negative SCA was observed for 1 x 4 (-0.69) (Table 132).

Inside rainshelter, among the lines, 3 (EC-620410) (0.56) recorded significant positive GCA effect, while 1 (EC-620401) recorded highest significant negative GCA (-0.75). Among the testers, only 7 (Arka Abha) recorded significant positive GCA (0.33). Other testers were non-significant (Table 131).

1 x 7 (0.62) recorded highest significant positive SCA, followed by 3 x 5 (0.54). The highest negative significant SCA effect was observed for 1 x 5 (-0.75) (Table 132).

Table 129: General combining ability effects of parents for length of the style and anther length

Parents	Length of the style						Anther length					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Lines												
1	-0.01*	-0.01	0.01	-0.02*	-0.01	-0.003	-0.01*	-0.01	0.004	-0.01*	-0.003	0.01
2	-0.01*	-0.01	-0.02*	0.003	-0.01	-0.03*	0.003	-0.001	-0.02*	0.001	-0.01	-0.03*
3	0.01*	0.01*	0.02*	0.02*	0.01*	0.03*	0.01*	0.01	0.01*	0.01*	0.01*	0.02*
Testers												
4	0.01*	0.02*	0.03*	0.03*	0.03*	0.03*	0.02*	0.02*	0.03*	0.03*	0.03*	0.02*
5	0.03*	0.01*	0.02*	0.02*	0.02*	-0.001	0.02*	0.01	0.02*	0.02*	0.02	0.02
6	-0.01*	-0.01*	-0.02*	-0.02*	-0.03*	-0.01	-0.01	-0.01	-0.02*	-0.02*	-0.03*	-0.01
7	-0.03*	-0.02*	-0.02*	-0.03*	-0.02*	-0.02*	-0.03*	-0.02*	-0.03*	-0.03*	-0.02*	-0.03*

Table 130: Specific combining ability effects of crosses for length of the style and anther length

Crosses	Length of the style						Anther length					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
1 x 4	0.03*	0.02*	0.02*	0.02*	0.02*	0.02*	0.03*	0.03*	0.02*	0.02*	0.02*	0.000
1 x 5	0.001	0.03*	0.01	-0.01	-0.01	-0.05*	0.002	0.01*	0.001	-0.17	-0.01	-0.004
1 x 6	0.01	0.01	0.01	0.01	0.02*	0.03*	0.01	0.01	0.01	0.02	0.02	0.01
1 x 7	-0.04*	-0.05*	-0.03*	-0.03*	-0.04*	0.004	-0.04*	-0.05*	-0.035*	-0.03*	-0.03*	-0.01
2 x 4	0.01*	-0.002	-0.03*	-0.003	-0.03*	-0.02*	0.01	-0.01	-0.03*	-0.001	-0.03*	-0.02*
2 x 5	-0.03*	-0.02*	0.003	0.01	0.04*	0.06*	-0.02*	-0.01	0.01	0.01	0.04*	0.02*
2 x 6	0.02*	0.02	0.03*	-0.003	0.003	-0.01	0.01	0.01	0.03*	-0.01	0.004	0.01
2 x 7	-0.002	0.01	-0.01	-0.003	-0.01	-0.03*	0.002	0.01	-0.01*	-0.01	-0.02	-0.02*
3 x 4	-0.04*	-0.02*	0.01	-0.02*	0.01	0.01	-0.04*	-0.02*	0.01	-0.02*	0.01	0.02*
3 x 5	0.03*	-0.01	-0.01	0.004	-0.03*	-0.01	0.02	-0.01	-0.01*	-0.01	-0.03*	-0.02*
3 x 6	-0.03*	-0.02*	-0.04*	-0.01	0.02*	-0.02*	-0.02*	-0.01	-0.03*	-0.01	-0.02*	-0.02*
3 x 7	0.04*	0.05*	0.04*	0.03*	0.05*	0.02*	0.04*	0.05*	0.04*	0.04*	0.05*	0.02*

Table 131:General combining ability effects of parents for number of flowers per cluster

Parents	Number of flowers per cluster					
	Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late
Lines						
1	0.81*	0.03	-0.14*	0.15*	-0.30*	-0.75*
2	-0.34*	-0.15*	-0.28*	-0.34*	-0.13*	0.19*
3	-0.47*	0.12*	-0.28*	0.19*	0.43*	0.56*
Testers						
4	0.41*	0.20*	-0.17*	0.16*	-0.18*	-0.15
5	-0.49*	-0.21*	-0.40*	-0.28*	0.13*	-0.10
6	0.04	-0.11*	0.1	-0.23*	-0.23*	-0.08
7	0.04	0.12*	0.48*	0.34*	0.28*	0.33*

Table 132:Specific combining ability effects of crosses forfor number of flowers per cluster

Parents	Number of flowers per cluster					
	Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late
1 x 4	-0.16*	-0.03	-0.69*	0.27*	-0.31*	-0.10
1 x 5	-0.36*	-0.61*	0.24*	-1.10*	-0.76*	-0.75*
1 x 6	0.36*	0.59*	0.09	0.75*	0.69*	0.23*
1 x 7	0.16*	0.05	0.36*	0.08	0.39*	0.62*
2 x 4	0.09	-0.05	0.4*	-0.4*	0.26*	0.16*
2 x 5	0.04	0.31*	-0.27*	1.19*	0.26*	0.21*
2 x 6	-0.44*	-0.24*	-0.12*	-0.66*	-0.69*	-0.25*
2 x 7	0.31*	-0.02	-0.004	-0.13	0.16*	-0.12
3 x 4	0.07	0.08	0.3*	0.13	0.05	-0.06
3 x 5	0.32*	0.30*	0.03	-0.09	0.50*	0.54*
3 x 6	0.08	-0.35*	0.03	-0.09	0.000	0.02
3 x 7	-0.47*	-0.03	-0.35*	0.05	-0.55*	-0.5*

4.4.4.1.2.8 Days to first fruit set

Under polyhouse, among the lines, highest significant negative GCA was observed for 1 (EC-620401) (-1.8). Among the testers, the highest negative significant GCA was observed for 5 (EC-620427) (-2.20). The highest positive significant GCA was observed for 4 (EC-620382) (1.23) (Table 125). Only four hybrids recorded significant negative SCA for days to first fruit set *viz:* 1 x 7 (-3.73), 2 x 5 (-3.26), 3 x 6 (-2.62) and 3 x 4 (-0.75) (Table 126).

Inside rainshelter, among the lines only 1 (EC-620401) recorded significant negative SCA (-2.27). Among the testers, only 5 (EC-620427) (-1.35) recorded significant negative SCA (Table 125). Only four hybrids recorded significant negative SCA for days to first fruit set *viz*: 1 x 7 (-5.09), 2 x 5 (-3.62), 3 x 6 (-3.24) and 3 x 4 (-0.79) (Table 126).

4.4.4.1.3 Fruit characters and yield

4.4.4.1.3.1 Days from anthesis to fruit maturity

Under polyhouse, among lines significant negative GCA was not recorded. Among the testers, the highest negative GCA was observed for 5 (EC-620427) (-0.70) (Table 125). Six hybrids exhibited significant negative SCA, *viz:* 1 x 4 (-1.67), 3 x 4 (-1.12), 2 x 7 (-1.11), 2 x 5 (-1.01), 1 x 5 (-1.01) and 2 x 6 (-0.68) (Table 126).

Inside rainshelter, among the lines significant GCA was observed for 2 (EC-620406) (-0.35). Among the testers, 5 (EC-620427) and 7 (Arka Abha) recorded significant negative GCA (-0.82 and -0.25 respectively) (Table 125). Among the hybrids, 3 x 4 (-1.21) recorded highest significant negative SCA, followed by 2 x 6 (-0.8) (Table 126).

4.4.4.1.3.2 Number of fruits per cluster

4.4.4.1.3.2.1 Early stage of flowering

Under polyhouse, among the lines 1 (EC-620401) recorded highest significant positive GCA (0.38). 2 (EC-620406) recorded highest significant negative GCA (-0.21). Among the testers, only 4 (EC-620382) and 5 (EC-620427) recorded significant GCA effect (0.18 and -0.27 respectively) (Table 133). 1 x 6

(0.34) recorded highest significant SCA effect, followed by 2 x 7 (0.24). The highest negative SCA was observed for 2 x 6 (-0.28) (Table 134).

Inside rainshelter, significant GCA was not observed for lines, whereas two testers, 4 (EC-620382) (0.14) and 5 (EC-620427) (-0.33) exhibited significant GCA (Table 133). The hybrid, 2 x 5 (0.54) recorded significant positive SCA for number of fruits per cluster, followed by 1 x 6 (0.53). The highest significant negative SCA was recorded for 1 x 5 (-0.75) (Table 134).

4.4.4.1.3.2.2 Mid stage of flowering

Under polyhouse, there was no significant GCA among the lines. The tester, 4 (EC-620382) recorded significantly high positive GCA (0.22). The highest significant negative GCA was observed for 6 (EC-620429) (-0.35) (Table 133). 1 x 5 recorded highest significant positive SCA (0.2), followed by 2 x 6 (0.14). The highest significant negative SCA was observed for 2 x 5 (-0.28) (Table 134).

Inside rainshelter, among the lines positive GCA was recorded only for 3 (EC-620410) (0.24). The highest significant negative GCA was recorded for 1 (EC-620401) (-0.13). Among the testers only 7 (Arka Abha) recorded significant positive GCA (0.17), and 6 (EC-620429) recorded highest significant negative GCA (-0.15) (Table 133). 3 x 5 (0.75) recorded highest significant positive GCA, followed by 1 x 7 (0.56). The highest negative significant SCA was observed for 1 x 5 (-0.84) (Table 134).

4.4.4.1.3.2.3 Late stage of flowering

Under polyhouse, among the lines 3 (EC-620410) (0.14) and 2 (EC-620406) (-0.13) recorded significant GCA**.** Among the testers, only 7 (Arka Abha) recorded positive significant GCA (0.23). The highest significant negative GCA was observed for 5 (EC-620427) (-0.15), followed by 6 (EC-620429) (-0.12) (Table 133). 1 x 5 (0.24) recorded highest significant positive SCA, followed by 2 x 4 (0.17). The highest negative SCA was observed for 1 x 6 (-0.24) (Table 134).

Inside rainshelter, among the lines only 3 (EC-620410) recorded significant positive GCA (0.15) for number of fruits per cluster. The highest significant negative GCA was recorded for 1 (EC-620401) (-0.11). Among the testers, only 7 (Arka Abha) (0.14) and 6 (EC-620429) (-0.16) recorded significant GCA (Table 133). 3 x 5 recorded highest significant positive SCA (0.33), followed by 1 x 4 (0.24). The highest negative significant SCA was observed for 1 x 5 (-0.46) (Table 134).

4.4.4.1.3.3 Fruit set per cent

4.4.4.1.3.3.1 Early stage of flowering

Under polyhouse, among the lines 2 (EC-620406) (0.21) and 3 (EC-620410) (0.54) recorded significant positive GCA. Among the testers, 5 (EC-620427) (1.0) and 7 (Arka Abha) (0.27) recorded significant positive GCA. Highest significant negative GCA was observed for 4 (EC-620382) (-0.68) (Table 133). The hybrid, 3 x 6 recorded highest significant positive SCA (2.3), followed by 1 x 5 (2.05) (Table 134).

Inside rainshelter, among the lines, 3 (EC-620410) recorded highest significant positive GCA (1.2). 1 (EC-620401) recorded highest significant negative GCA (-0.97). Among the testers, highest significant positive GCA effect was recorded for 7 (Arka Abha) (1.19) and highest negative GCA effect was observed for 5 (EC-620427) (-1.14) (Table 133). The hybrid, 3 x 6 (3.08) recorded highest significant positive SCA, followed by 2 x 7 (2.17). The hybrid, 1 x 6 exhibited highest significant negative SCA (-2.61) (Table 134).

4.4.4.1.3.3.2 Mid stage of flowering

Under polyhouse, among the lines, 3 (EC-620410) (0.43) and 1 (EC-620401) (0.34) recorded significantly high positive GCA for fruit set per cent. Among the testers, 7 (Arka Abha) recorded highest positive significant GCA (1.48), followed by 4 (EC-620382) (0.46). The significant negative GCA was observed for 6 (EC-620429) (-1.86) (Table 133). Highest significant positive SCA was observed for 1 x 5 (3.53), followed by 2 x 4 (1.90). The highest negative significant SCA was observed for 1 x 4 (-3.61) (Table 134).

Inside rainshelter, among the lines, only 3 (EC-620410) (1.68) and 2 (EC-620406) (-1.57) recorded significant GCA. Among the testers, 4 (EC-620382) (1.28) recorded highest significant positive GCA. The highest significant negative GCA was observed for 6 (EC-620429) (-1.97) (Table 133). The hybrid, 1 x 5 (2.51) recorded highest significant positive SCA, followed by 2 x 6 (1.15). The highest negative significant SCA was observed for 1 x 6 (-1.61) (Table 134).

4.4.4.1.3.3.3 Late stage of flowering

Under polyhouse, among the lines, 3 (EC-620410) recorded significant positive GCA (1.28) and 2 (EC-620406) recorded significant negative GCA (-1.50). Among the testers, only 7 (Arka Abha) recorded significant positive GCA (1.65). The highest significant negative GCA was observed for 6 (EC-620429) (-1.2) (Table 133). The hybrid, 1 x 5 (2.76) recorded highest significant positive SCA, followed by 3 x 6 (2.58). The highest significant negative SCA was observed for 1 x 6 (-2.55) (Table 134).

Inside rainshelter, 3 (EC-620410) recorded highest significant positive GCA (1.51). The significant negative GCA was observed for 1 (EC-620401) (-1.79). Among the testers, 4 (EC-620382) recorded highest significant positive GCA (0.86) and 6 (EC-620429) exhibited highest significant negative GCA (-1.59) (Table 133). The hybrid 3 x 6 recorded highest significant positive SCA (1.192), followed by 1 x 7 (0.875). The highest significant negative SCA was observed for 1 x 6 (-0.658) (Table 134).

Table 133: General combining ability effects of parents for number of fruits per cluster and fruit set per cent

Parents	Number of fruits per cluster						Fruit set per cent					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Lines												
1	0.38*	0.004	-0.01	-0.03	-0.13*	-0.11*	-0.75*	0.34*	0.22	-0.97*	-0.11	-1.79*
2	-0.21*	-0.02	-0.13*	-0.02	-0.11*	-0.05*	0.21*	-0.77*	-1.50*	-0.22	-1.57*	0.28*
3	-0.17*	0.02	0.14*	0.05	0.24*	0.15*	0.534*	0.43*	1.28*	1.19*	1.68*	1.51*
Testers												
4	0.18*	0.22*	0.05	0.14*	-0.08	0.01	-0.68*	0.46*	0.45	0.38*	1.28*	0.86*
5	-0.67*	0.02	-0.15*	-0.33*	0.07	0.01	1.0*	-0.08	-0.91*	-1.14*	-0.23	0.36*
6	0.05	-0.35*	-0.12*	-0.06	-0.15*	-0.16*	-0.58*	-1.86*	-1.2*	-0.43*	-1.97*	-1.59*
7	0.03	0.12*	0.23*	-0.06	0.17*	0.14*	0.27*	1.48*	1.65*	1.19*	0.92*	0.38*

Table 134: Specific combining ability effects of crosses for number of fruits per cluster and fruit set per cent

Crosses	Number of fruits per cluster						Fruit set per cent					
	Polyhouse			Rainshelter			Polyhouse			Rainshelter		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
1 x 4	-0.25*	-0.05	-0.16*	-0.02	0.06	0.24*	-0.87	-3.61*	-0.60	1.99*	-0.96*	-0.46*
1 x 5	-0.05	0.2*	0.24*	-0.75*	-0.84*	-0.46*	2.05*	3.53*	2.76*	1.40*	2.51*	0.24*
1 x 6	0.34*	-0.14*	-0.24*	0.53*	0.23*	0.01	-2.77*	-0.54	-2.55*	-2.61*	-1.61*	-0.66*
1 x 7	-0.05	-0.004	0.16*	0.23*	0.56*	0.21*	1.58*	0.63	0.4	-0.78*	0.06	0.88*
2 x 4	0.14	0.02	0.17*	0.02	-0.004	-0.07*	1.02	1.90*	1.42*	-0.81*	0.35	0.47*
2 x 5	-0.11	-0.28*	-0.23*	0.54*	0.1	0.13*	-1.71*	-0.91	-0.41	-0.9*	-1.53*	0.37
2 x 6	-0.28*	0.14*	0.08	-0.53*	-0.09	-0.05*	0.47	-1.18*	-0.03	-0.46	1.15*	-0.53*
2 x 7	0.24*	0.12*	-0.02	-0.03	-0.004	-0.004	0.22	0.19	-1.0*	2.17*	0.02	-0.30
3 x 4	0.10	0.03	-0.01	-0.004	-0.05	-0.17*	-0.15	1.70*	-0.82*	-1.18*	0.60*	-0.01
3 x 5	0.15*	0.08*	-0.01	0.21*	0.75*	0.33*	-0.34	-2.61*	-2.35*	-0.51	-0.98*	-0.61*
3 x 6	-0.06	0.000	0.16*	-0.004	-0.14*	0.05*	2.3*	1.72*	2.58*	3.08*	0.45	1.19*
3 x 7	-0.2*	-0.12*	-0.14*	-0.20*	-0.55*	-0.20*	-1.80*	-0.81	0.58	-1.39*	-0.08	-0.58*

4.4.4.1.3.4 Days to first fruit harvest

Under polyhouse, among the lines, significant negative GCA was observed for 1 (EC-620401) (-1.9). 3 (EC-620410) recorded significant positive GCA (2.32). Among the testers, 5 (EC-620427) recorded significant negative GCA (-2.71). 4 (EC-620382) recorded highest significant positive GCA (2.03) (Table 135). Among the hybrids, 2 x 5 (-3.38) recorded highest significant negative SCA, followed by 1 x 7 (-2.20) (Table 136).

Inside rainshelter, among the lines, significant negative GCA was recorded only for 1 (EC-620401) (-2.47). Among the testers, 5 (EC-620427) (-1.58) and 7 (Arka Abha) (-0.66) exhibited significant negative GCA (Table 135). Only four hybrids recorded significant negative SCA, *viz*: 1 x 7(-3.87), 2 x 5(-3.03), 3 x 6 (-2.94) and 3 x 4 (-2.29) (Table 136).

4.4.4.1.3.5 Number of fruits per plant

Under polyhouse, among lines, only 3 (EC-620410) recorded significant positive GCA (0.17). 1 (EC-620401) recorded significant negative GCA (-0.26). Among the testers, significant GCA was observed for 5 (EC-620427) (-1.28) and 7 (Arka Abha) (1.54) (Table 135). Only two hybrids recorded positive significant SCA *viz*: 1 x 4 (1.01), followed by 2 x 6 (0.73). The hybrid, 2 x 4 recorded highest significant positive SCA (-1.19) (Table 136).

Inside the rainshelter, among the lines, the highest significant GCA was observed for 2 (EC-620406) (0.54), followed by 1 (EC-620401) (0.22). 3 (EC-620410) recorded significant negative GCA (-0.76). Among the testers, 7 (Arka Abha) (1.37) and 6 (EC-620429) (0.38) recorded significant positive GCA (Table 135).

The hybrid, 1 x 4 (1.79) recorded highest significant positive SCA, followed by 2 x 5 (1.06). The highest significant negative SCA was observed for 2 x 4 (-1.8) (Table 136).

Table 135: General combining ability effect of parents for days to first fruit harvest, number of fruits per plant and locule number per fruit

Parents	Days to first fruit harvest		Number of fruits / plant		Locule number / fruit	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	-1.9*	-2.47*	-0.26*	0.22*	-0.28*	-0.40*
2	-0.42	0.76*	0.09	0.54*	0.52*	0.77*
3	2.32*	1.71*	0.17*	-0.76*	-0.24*	-0.37*
Testers						
4	2.03*	0.69*	-0.45	-0.57*	-0.53*	-0.04
5	-2.71*	-1.58*	-1.28*	-1.18*	-0.1	-0.04
6	0.84*	1.54*	0.19	0.38*	0.74*	0.46*
7	-0.16	-0.66*	1.54*	1.37*	-0.11*	-0.38*

Table 136: Specific combining ability effect of crosses for days to first fruit harvest, number of fruits / plant and locule number per fruit

Cross	Days to first fruit harvest		Number of fruits / plant		Locule number / fruit	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-0.84*	0.28	1.01*	1.79*	-0.12*	-0.32*
1 x 5	-0.05	0.25	-0.46	-0.5*	-0.60*	-0.93*
1 x 6	3.1*	3.33*	0.13	-1.08*	0.06	0.54*
1 x 7	-2.20*	-3.87*	-0.68*	-0.22	0.66*	0.70*
2 x 4	1.49*	2.01*	-1.19*	-1.8*	-0.07	0.04
2 x 5	-3.38*	-3.03*	0.09	1.06*	0.35*	0.40*
2 x 6	-1.23*	-0.39	0.73*	0.96*	0.01	-0.38*
2 x 7	3.12*	1.41*	0.38	-0.22	-0.29*	-0.07
3 x 4	-0.65	-2.29*	0.18	0.003	0.19*	0.27*
3 x 5	3.43*	2.78*	0.37	-0.57*	0.26*	0.53*
3 x 6	-1.87*	-2.94*	-0.85*	0.13	-0.08	-0.17*
3 x 7	-0.92	2.46*	0.30	0.44*	-0.38*	-0.64*

4.4.4.1.3.6 Locule number per fruit

Under polyhouse, among the lines, significant negative GCA was recorded for 1 (EC-620401) (-0.28) and 3 (EC-620410) (-0.24). Among the testers, 4 (EC-620382) (-0.53) and 7 (Arka Abha) (-0.11) recorded significant negative GCA

(Table 135). Four hybrids exhibited significant negative SCA for locule number per fruit *viz*: 1 x 5 (-0.60), 3 x 7 (-0.38), 2 x 7 (-0.29) and 1 x 4 (-0.12). The highest significant positive SCA was recorded for 2 x 5 (0.35) (Table 136).

Inside rainshelter, among the lines 1 (EC-620401) (-0.40) and 3 (EC-620410) (-0.37) recorded significant negative GCA. Among the testers significant negative GCA was recorded for 7 (Arka Abha) (-0.38) (Table 135). 1 x 5 (-0.93) recorded highest significant negative SCA, followed by 3 x 7 (-0.64). The highest significant positive SCA was observed for 1 x 7 (0.70) (Table 136).

4.4.4.1.3.7 Pericarp thickness

Under polyhouse, among the lines 1 (EC-620401) (0.02) and 3 (EC-620410) (0.004) recorded significant positive GCA. Among the testers 5 (EC-620427) (0.05) exhibited highest significant positive GCA, followed by 7 (Arka Abha) (0.05) (Table 137). 2 x 5 (0.09) recorded highest significant positive SCA, followed by 3 x 4 (0.08) and 3 x 7 (0.05) (Table 138).

Inside rainshelter, among the lines significant positive GCA was observed only for 3 (EC-620410) (0.05). Among the testers, 5 (EC-620427) (0.11), 7 (Arka Abha) (0.05) and 6 (EC-620429) (0.02) recorded significant positive GCA (Table 137). Among the hybrids, 3 x 4 (0.13) exhibited highest significant positive SCA, followed by 1 x 5 (0.09). The highest significant negative SCA was recorded for 1 x 4 (-0.14) (Table 138).

4.4.4.1.3.8 Average fruit weight

Under polyhouse, among the lines, 3 (EC-620410) (2.20) and 2 (EC-620406) (0.81) recorded significant positive GCA. Among the testers, 7 (Arka Abha) (3.49) and 5 (EC-620427) (1.49) recorded positive significant GCA (Table 137). Four hybrids *viz:* 3 x 4 (7.08), 1 x 7 (6.6), 2 x 5 (4.87) and 2 x 6 (1.54) recorded significant positive SCA Table 138).

Inside rainshelter, among the lines, 3 (EC-620410) (2.39) and 2 (EC-620406) (0.32) exhibited significant positive GCA. Among the testers, 5 (EC-

620427) recorded highest significant positive GCA (5.56), followed by 7 (Arka Abha) (0.93) (Table 137). Four hybrids, 2 x 5 (6.12), 3 x 4 (5.78), 1 x 7 (3.23) and 3 x 6 (2.91) exhibited positive significant SCA. The highest significant negative SCA was recorded for 3 x 5 (-6.01) (Table 138).

4.4.4.1.3.9 Yield per plant

Under polyhouse, among the lines, 3 (EC-620410) (45.88) recorded highest positive significant GCA, followed by 2 (EC-620406) (36.04). Among the testers, 7 (Arka Abha) (112.14) and 6 (EC-620429) (44.60) recorded significant positive GCA for yield per plant (Table 137). Only four hybrids, 3 x 4 (127.30), 2 x 5 (82.43), 2 x 6 (69.61) and 1 x 7 (42.04) recorded significant positive GCA (Table 138).

Inside rainshelter, among the lines, only 2 (EC-620406) recorded significant positive GCA (27.64). Among the testers, 6 (EC-620429) (100.16) recorded highest significant positive GCA, followed by 5 (EC-620427) (67.52) (Table 137). Four hybrids *viz*: 2 x 5 (232.62), 1 x 7 (173.24), 3 x 4 (89.88) and 3 x 6 (61.11) recorded significant positive SCA. The hybrid, 2 x 7 (-152.80) recorded highest significant negative SCA(Table 138).

4.4.4.1.3.10 Yield per plot

Under polyhouse, among the lines, 3 (EC-620410) (0.39) and 2 (EC-620406) (0.30) recorded significant positive GCA. 1 (EC-620401) recorded significant negative GCA (-0.69). Among the testers, 7 (Arka Abha) (0.79) and 6 (EC-620429) (0.42) exhibited significant positive GCA. The highest significant negative GCA was recorded for 4 (EC-620382) (-0.97) (Table 139). The hybrid, 3 x 4 recorded highest significant positive SCA (1.12), followed by 1 x 7 (0.44) (Table 140).

2 (EC-620406) recorded significant positive GCA inside rainshelter among lines (0.19). Among the testers, 6 (EC-620429) (0.52) and 5 (EC-620427) (0.44) recorded significant positive GCA (Table 139). 2 x 5 exhibited highest

significant positive SCA (1.31), followed by 1 x 7 (0.97). The highest significant negative SCA was observed for 2 x 7 (-0.85) (Table 140).

Table 137: General combining ability effect of parents for pericarp thickness, average fruit weight and yield per plant

Parents	Pericarp thickness		Average fruit weight		Yield per plant	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	0.02*	-0.01*	-3.01*	-2.71*	-81.92*	-18.90*
2	-0.02*	-0.03*	0.81*	0.32*	36.04*	27.64*
3	0.004*	0.05*	2.20*	2.39*	45.88*	-8.74*
Testers						
4	-0.09*	-0.17*	-4.71*	-7.13*	-101.13*	-139.26*
5	0.05*	0.11*	1.49*	5.56*	-55.61*	67.52*
6	-0.01*	0.02*	-0.28*	0.64	44.60*	100.16*
7	0.05*	0.05*	3.49*	0.93*	112.14*	-28.41*

Table 138: Specific combining ability effect of crosses for pericarp thickness, average fruit weight and yield per plant

Cross	Pericarp thickness		Average fruit weight		Yield per plant	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-0.08*	-0.14*	-3.20*	-3.68*	4.45	-7.87
1 x 5	0.03*	0.09*	-2.95*	-0.11	-31.41*	-102.07*
1 x 6	0.04*	0.02	-0.44	0.56	-15.08	-63.3*
1 x 7	0.01*	0.03*	6.6*	3.23*	42.04*	173.24*
2 x 4	0.003*	0.01	-3.88*	-2.10*	-131.76*	-82.01*
2 x 5	0.09*	0.03*	4.87*	6.12*	82.43*	232.62*
2 x 6	-0.04*	-0.002	1.54*	-3.47*	69.61*	2.19
2 x 7	-0.05*	-0.03*	-2.53*	-0.55	-20.28*	-152.80*
3 x 4	0.08*	0.13*	7.08*	5.78*	127.30*	89.88*
3 x 5	-0.12*	-0.12*	-1.92*	-6.01*	-51.01*	-130.55*
3 x 6	-0.002*	-0.02	-1.10*	2.91*	-54.53*	61.11*
3 x 7	0.05*	0.01	-4.07*	-2.68*	-21.76*	-20.44

4.4.4.1.4 Biochemical characters

4.4.4.1.4.1 TSS

Under polyhouse, among the lines, 2 (EC-620406) (0.010) recorded significant positive GCA and 1 (EC-620401) (-0.11) recorded significant negative GCA. Among the testers, 5 (EC-620427) (0.04) recorded significant positive GCA and 7 (Arka Abha) (-0.07) recorded significant negative GCA (Table 139). 1 x 4 (0.19) recorded highest significant positive SCA, followed by 2 x 7 (0.08) (Table 140).

Inside rainshelter, two lines recorded significant GCA, 2 (EC-620406) (0.04) and 1 (EC-620401) (-0.03). Among the testers, 5 (EC-620427) (0.05) and 7 (Arka Abha) (0.03) recorded significant positive GCA (Table 139). 3 x 6 (0.04) exhibited highest significant positive GCA, followed by 2 x 4 (0.04) (Table 140).

4.4.4.1.4.2 Lycopene

Under polyhouse, among the lines, 3 (EC-620410) recorded highest significant positive GCA (0.64), followed by 2 (EC-620406) (0.14). 4 (EC-620382) recorded highest significant positive GCA (0.64), followed by 5 (EC-620427) (0.57) (Table 139).

Among the hybrids, significant positive GCA was in the range between 1 x 6 (0.30) and 3 x 6 (1.22). The highest significant negative GCA was recorded for 2 x 6 (-1.52) (Table 140).

Inside rainshelter, among the lines, 3 (EC-620410) recorded highest significant positive GCA effect (0.04). Among the testers, 4 (EC-620382) (0.956) and 6 (EC-620429) (0.28) recorded significant positive GCA effect (Table 139).

The highest significant positive SCA was recorded for 2 x 7 (0.49), followed by 1 x 5 (0.34) (Table 140).

Table 139: General combining ability effect of parents for yield per plot, TSS and lycopene

Parents	Yield per plot		TSS		Lycopene	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	-0.69*	-0.22*	-0.11*	-0.03*	-0.77*	-0.06*
2	0.30*	0.19*	0.10*	0.04*	0.14*	0.03*
3	0.39*	0.03	0.01	-0.01	0.64*	0.04*
Testers						
4	-0.97*	-0.86*	0.03	-0.01	0.64*	0.96*
5	-0.24*	0.44*	0.04*	0.05*	-1.2*	-0.88*
6	0.42*	0.52*	0.000	-0.07*	0.57*	0.28*
7	0.79*	-0.1*	-0.07*	0.03*	-0.01	-0.36*

Table 140: Specific combining ability effect of crosses for yield per plot, TSS and lycopene

Cross	Yield per plot		TSS		Lycopene	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-0.57*	-0.09	0.19*	-0.02*	-0.18*	-0.30*
1 x 5	0.03	-0.54*	-0.21*	0.01	0.35*	0.34*
1 x 6	0.11*	-0.34*	0.05	-0.02*	0.30*	0.28*
1 x 7	0.44*	0.97*	-0.02	0.03*	-0.48*	-0.32*
2 x 4	-0.55*	-0.42*	-0.17*	0.04*	0.71*	0.06
2 x 5	0.39*	1.31*	0.07*	0.02	0.35*	-0.52*
2 x 6	0.32*	-0.04	0.02	-0.02*	-1.52*	-0.02
2 x 7	-0.16*	-0.85*	0.08*	-0.03	0.46*	0.49*
3 x 4	1.12*	0.51*	-0.01	-0.02	-0.53*	0.25*
3 x 5	-0.41*	-0.77*	0.14*	-0.03*	-0.71*	0.18*
3 x 6	-0.43*	0.38*	-0.07*	0.04*	1.22*	-0.27*
3 x 7	-0.28*	-0.12	-0.06*	0.003	0.02	-0.16

4.4.4.1.4.3 Ascorbic acid

Under polyhouse, among the lines, positive significant GCA was recorded for 1 (EC-620401) (0.66). Among the testers, 7 (Arka Abha) (2.66) and 6 (EC-620429) (1.36) recorded significant positive GCA effect (Table 141). Among the hybrids, the significant positive SCA was in the range between 1 x 5 (0.41) and 3 x 6 (3.06) (Table 142).

Inside rainshelter, among the lines, 1 (EC-620401) recorded significant positive GCA (1.62). Among the testers, positive significant GCA was recorded for 7 (Arka Abha) (2.31) and 6 (EC-620429) (1.89) (Table 141). The hybrid, 3 x 6(4.05) recorded highest significant SCA effect, followed by 2 x 7 (3.45) (Table 142).

4.4.4.1.4.4 Acidity

Under polyhouse, none of the parents exhibited significant GCA effect (Table 141). Among the hybrids, positive significant SCA was in the range between 0.02 (1 x 4, 3 x 6 and 3 x 7) and 0.03 (2 x 5) (Table 142).

Inside rainshelter, also significant GCA effect was not observed among the parents (Table 141). Among the hybrids, the significant positive SCA was in the range between 0.02 (3 x 7) and 0.03 (1 x 4, 2 x 5 and 3 x 6) (Table 142).

4.4.4.1.4.5 Chlorophyll

4.4.4.1.4.5.1 Chlorophyll a

Under polyhouse, the line 1 (EC-620401) recorded highest significant positive GCA (0.06). Among the testers, 4 (EC-620382) (0.14) and 7 (Arka Abha) (0.05) exhibited significant positive GCA (Table 143). Among the hybrids, 1 x 6 and 2 x 4 (0.13) recorded highest significant positive SCA (Table 144).

Inside rainshelter, line 3 (EC-620410) recorded significant positive GCA (0.06). Among the testers, 4 (EC-620382) recorded significant positive GCA effect (0.15) (Table 143). The hybrid, 3 x 7 (0.2) recorded highest significant SCA effect, followed by 1 x 6 (0.15) (Table 144).

4.4.4.1.4.5.2 Chlorophyll b

Under polyhouse, the line 2 (EC-620406) recorded significant positive GCA (0.04). Among testers 7 (Arka Abha) recorded highest significant positive GCA effect (0.12) (Table 143). Among the hybrids the positive significant SCA was in the range between 0.09 (2 x 5) and 0.13 (2 x 4 and 3 x 7) (Table 144).

Inside rainshelter, the lines 2 (EC-620406) (0.07) recorded significant positive GCA effect. Among the testers, positive significant GCA was recorded for 4 (EC-620382) and 7 (Arka Abha) (0.11) (Table 143). Among the hybrids, only two hybrids *viz*: 2 x 4 (0.19) and 3 x 7 (0.15) recorded positive significant SCA effect (Table 144).

4.4.4.1.4.5.3 Total chlorophyll

Under polyhouse, the line 3 (EC-620410) recorded significant positive GCA effect (0.09). Among the testers, only 4 (EC-620382) exhibited significant positive GCA effect (0.26) (Table 143). Among the hybrids, the significant positive SCA was in the range between 0.08 (1 x 4 and 2 x 6) and 0.30 (3 x 7) (Table 144).

Inside rainshelter, significant GCA was recorded for the lines 3 (EC-620410) (0.13) and 1 (EC-620401) (-0.18). Among testers, only 4 (EC-620382) (0.24) recorded significant positive GCA (Table 143). Among the hybrids, the positive significant SCA was in the range between 0.16 (1 x 5 and 2 x 4) and 0.29 (3 x 7) (Table 144).

4.4.4.1.4.6 Shelf life

Under polyhouse, among the lines, only 3 (EC-620410) (1.11) recorded significant positive GCA effect. Among the testers, 6 (EC-620429) (0.63) and 5 (EC-620427) (0.33) recorded significant positive GCA effect (Table 141).

Among the hybrids, 3 x 6 (1.27) recorded highest significant positive SCA, followed by 1 x 4 and 1 x 5 (0.58) (Table 142).

Inside the rainshelter, the line 3 (EC-620410) exhibited significant positive GCA effect (1.04). Among the testers, 6 (EC-620429) (0.65) and 5 (EC-620427) (0.28) recorded significant positive GCA effect (Table 141).

Among the hybrids, only three hybrids *viz*: 2 x 7 (1.16), 1 x 5 (0.96) and 3 x 6 (0.78) exhibited significant positive SCA effect (Table 142).

Table 141: General combining ability effect of parents for ascorbic acid, acidity and shelf life

Parents	Ascorbic acid		Acidity		Shelf life	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	0.66*	1.62*	0.000	0.01	-0.45*	-0.43*
2	-0.10*	-1.26*	-0.002	-0.004	-0.66*	-0.61*
3	-0.55*	-0.36*	0.002	-0.003	1.11*	1.04*
Testers						
4	-1.81*	-1.88*	-0.004	0.01	-0.12*	-0.09*
5	-2.21*	-2.32*	-0.01	-0.01	0.33*	0.28*
6	1.36*	1.89*	0.000	0.003	0.63*	0.65*
7	2.66*	2.31*	0.01	0.01	-0.84*	-0.84*

Table 142: Specific combining ability effect of crosses for ascorbic acid, acidity and shelf life

Cross	Ascorbic acid		Acidity		Shelf life	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-1.79*	-0.76*	0.02*	0.03*	0.58*	0.73
1 x 5	0.41*	0.52*	-0.01	-0.02*	0.58*	0.96*
1 x 6	1.98*	1.95*	-0.02*	-0.03*	-0.81*	-0.61
1 x 7	-0.6*	-1.71*	0.01	0.02*	-0.35*	-1.08*
2 x 4	2.05*	1.29*	-0.01	0.004	-0.55*	-1.04*
2 x 5	0.46*	1.26*	0.03*	0.03*	0.2*	0.05*
2 x 6	-5.04*	-6.0*	0.004	-0.001	-0.45*	-0.17
2 x 7	2.53*	3.45*	-0.03*	-0.04*	0.81*	1.16*
3 x 4	-0.26*	-0.53	-0.02	-0.03*	-0.03	0.31
3 x 5	-0.87*	-1.78*	-0.02*	-0.02*	-0.78*	-1.004*
3 x 6	3.06*	4.05*	0.02*	0.03*	1.27*	0.78*
3 x 7	-1.93*	-1.74*	0.02	0.02*	-0.46*	-0.09

Table 143: General combining ability effect of parents for chlorophyll a, chlorophyll b and total chlorophyll

Parents	chl a		chl b		chl total	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Lines						
1	0.06*	0.02	-0.05*	-0.05*	-0.12*	-0.18*
2	-0.07*	-0.08*	0.04*	0.07*	0.04	0.04
3	0.02*	0.06*	0.01	-0.002	0.09*	0.13*
Testers						
4	0.14*	0.15*	0.10*	0.11*	0.26*	0.24*
5	-0.16*	-0.14*	-0.11*	-0.11*	-0.09*	-0.117*
6	-0.04*	-0.04	-0.118*	-0.10*	-0.16*	-0.13*
7	0.05*	0.04	0.12*	0.11*	-0.01	-0.002

Table 144: Specific combining ability effect of crosses for chlorophyll a, chlorophyll b and total chlorophyll

Cross	chl a		chl b		chl total	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
1 x 4	-0.01	-0.01	-0.06	-0.14*	0.08*	0.04
1 x 5	-0.04	-0.01	-0.001	0.023	0.16*	0.16*
1 x 6	0.13*	0.15*	0.000	0.08	0.04	0.08
1 x 7	-0.07*	-0.14*	0.06	0.04	-0.27*	-0.28*
2 x 4	0.13*	0.07*	0.13*	0.19*	0.13*	0.16*
2 x 5	0.01	0.03	0.09*	0.04	-0.18*	-0.20*
2 x 6	-0.09*	-0.04	-0.04	-0.04	0.08*	0.06
2 x 7	-0.05	-0.06*	-0.18*	-0.19	-0.03	-0.01
3 x 4	-0.12*	-0.07*	-0.07*	-0.05	-0.22*	-0.2*
3 x 5	0.04	-0.02	-0.09*	-0.06	0.03	0.04
3 x 6	-0.03	-0.11*	0.04	-0.03	-0.11*	-0.13*
3 x 7	0.12*	0.2*	0.13*	0.15*	0.30*	0.29*

4.4.4.2 Combining ability variance

Estimates of components of variance σ^2 line, σ^2 tester, σ^2 gca and σ^2 sca are presented in Table 145 and 146. The estimates of variance for lines under polyhouse were significant for all traits except for crop duration, days to 50% flowering, locule number per fruit, TSS, acidity, chl a and chl b. Inside rainshelter, the significance was observed for all traits except for intercluster distance. Variance due to tester was significant for plant height at flowering, internodal length, leaf area, days to 50% flowering, intercluster distance, days to first fruit set, days to first fruit harvest, number of fruits per cluster, locule number per fruit, pericarp thickness, average fruit weight, yield per plant, yield per plot, TSS, lycopene and shelf life. Inside rainshelter estimates of variance were significant for all traits studied. Estimates of variance due to gca was significant for all traits except for ascorbic acid, acidity and chl a under polyhouse, and significant for all traits under study inside rainshelter. Variance estimates due to sca was observed to be significant for all traits except for days to 50% flowering, locule number per fruit and TSS under polyhouse, whereas inside rainshelter all traits studied were significant.

For reproductive traits, the lines recorded significant variance for flowers with exerted stigma early and late stage of flowering, pollen viability early and mid stage of flowering, length of the style late stage of flowering, anther length early and mid stage of flowering and number of flowers per cluster, number of fruits per cluster and fruit set per cent in early, mid and late stage of flowering, under polyhouse. Inside rainshelter, flowers with exerted stigma early stage of flowering, pollen viability early and mid stage of flowering, length of the style in the early and late stage of flowering, anther length in the early and mid stage of flowering, number of flowers per cluster in the early stage of flowering and number of fruits per cluster and fruit set per cent in the early, mid and late stage of flowering. Testers exhibited significant variance for all traits except for flowers with exerted stigma mid and late stage of flowering, pollen viability early stage of flowering, length of the style in the late stage of flowering, anther length in the early stage of flowering, number of flowers per cluster in the early and late stage of flowering and number of fruits per cluster in the early stage of flowering under polyhouse. Inside rainshelter, the estimates were significant for all traits studied. Under polyhouse, variance due to gca was significamt for all traits except for pollen viability mid and late stage of flowering, length of the style in all three stage of flowering, anther length in the early stage of flowering and number of flowers per cluster in the early and mid stage of flowering. Inside rainshelter, the significant variance estimates were not observed for length of the style and anther length in all three stages of flowering and number of flowers per cluster in the late stage of flowering. Estimates of variance due to sca was significant for flowers with exerted stigma early and mid stage of flowering, pollen viability in the early and mid stage of flowering, length of the style in the mid stage of flowering, anther length in the mid and late stage of flowering, number of flowers per cluster in the late stage of flowering and number of fruits per cluster and fruit set per cent in the early, mid and late stage of flowering under polyhouse. Inside rainshelter variance was significant except for length of the style late stage of flowering, anther length early stage of flowering, number of flowers per cluster in all three stages of flowering and number of fruits per cluster in the early stage of flowering.

4.4.4.3 Gene action

The estimates of additive genetic variance, dominance genetic variance and average degree of dominance for the various characters are presented in Table 147 and Table 148 .

4.4.4.3.1 Additive variance

Additive genetic variance was significant for six characters *viz*: plant height at flowering, plant height at harvest, days to 50% flowering, average fruit weight, yield per plant and yield per plot under polyhouse. Inside rainshelter, significance was observed for eight traits *viz*: plant height at flowering, crop duration, days to 50% flowering, days to first fruit set, pericarp thickness, average fruit weight, yield per plant and yield per plot.

In the case of reproductive traits, the polyhouse crop exhibited significant additive variance for flowers with exerted stigma early stage of flowering, pollen viability early and mid stage of flowering, anther length in the late stage of flowering, number of flowers in the mid and late stage of flowering, number of fruits per cluster in the late stage of flowering and fruit set per cent in the early and mid stage of flowering. Inside rainshelter, flowers with exerted stigma, pollen viability and fruit set per cent in all three stage of flowering, number of flowers per cluster and number of fruits per cluster in the mid and late stage of flowering were significant.

4.4.4.3.2 Dominance variance

Under polyhouse, dominance genetic variance was found to be significant for plant height at flowering, plant height at harvest, leaf area, crop duration, average fruit weight, yield per plant and shelf life. Inside rainshelter, significant dominace variance was observed for all traits except for leaf area, intercluster distance, days from anthesis to fruit maturity, locule number per fruit, averge fruit weight, yield per plot, ascorbic acid, acidity, chlorophyll a, chlorophyll b, total chlorophyll and shelf life.

For reproductive traits, dominance genetic variance was significant for flowers with exerted stigma in the early stage of flowering, pollen viability during early and mid stage of flowering, length of the style at the late stage of flowering, number of flowers in the early and late stage of flowering and fruit set per cent in the early and mid stage of flowering under polyhouse. Inside rainshelter, flowers with exerted stigma in the early stage of flowering, pollen viability during early and mid stage of flowering, length of the style in the mid and late stges of flowering, anther length in the late stage of flowering, number of flowers per cluster and number of fruits per cluster in the mid and late stages of flowering and fruit set per cent in the early and mid stage of flowering exhibited significant dominance genetic variance.

4.4.4.3.3 Average degree of dominance

Under polyhouse, over dominace was observed for plant height at flowering, leaf area, crop duration, intercluster distance, days to first fruit harvest, number of fruits per plant, lycopene, ascorbic acid, total chlorophyll and shelf life. Pericarp thickness, TSS and chlorophyll b were observed with partial dominance. Inside rainshelter, pericarp thickness recorded complete dominace. Plant height at flowering, plant height at harvest, leaf area, days to 50% flowering, intercluster distance, days from anthesis to fruit maturity, number of fruits per plant, locule number per fruit, average fruit weight, yield per plant, yield per plot, chlorophyll b, total chlorophyll and shelf life recorded over dominace.

For reproductive traits, over dominace was exhibited for flowers with exerted stigma in the mid stage of flowering, anther length at the late stage of flowering, number of flowers per cluster in the early and late stage of flowering and number of fruits per cluster in the early, mid and late stage of flowering, under polyhouse. Inside rainshelter, flowers with exerted stigma and pollen viability in the early and mid stage of flowering, length of the style and anther length in the early and late stage of flowering, number of flowers per cluster in the late and fruit set per cent in the early stage of flowering exhibited over dominance.

4.5 EXPERIMENT V: GENOMIC DNA EXTRACTION AND PCR ASSAY

The results of genomic DNA extraction and PCR assay of 10 tomato genotypes *viz;* EC-165700, EC-620382, EC-620387, EC-620401, EC-620406, EC-620410, EC-620427, EC-620429, EC-631369 and Arka Abha used in the study "Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation" are described in this chapter. The genotypes EC-620387, EC-620401, EC-620406, EC-620410, and EC-631369 were susceptible to bacterial wilt, whereas the genotypes EC-165700, EC-620382, EC-620427, EC-620429 and Arka Abha were resistant to bacterial wilt.

4.5.1. Isolation and quantification of DNA

The genomic DNA isolation through modified CTAB method (Doyle and Doyle, 1987) was attempted. Treatment with ammonium acetate was given before incubation to remove the colour due to polyphenols. Sufficient quantity (Table 149) of good quality DNA was found to obtain from tender leaves of tomato. The agarose gel electrophoresis has shown clear and discrete bands.

Table 145: Analysis of variance for combining ability of various characters in tomato

Character	σ ² line		σ ²tester		σ ²gca		σ ²sca	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Plant height at flowering	2.1*	1.56*	7.18*	2.10*	7.37*	9.42*	8.41*	12.25*
Internodal length	4.97*	1.40*	10.67*	1.47*	8.41*	4.32*	6.05*	5.61*
Plant height at harvest	13.05*	3.20*	3.46	4.29*	16.83*	21.96*	10.39*	31.19*
Leaf area	24.66*	8.35*	29.43*	11.14*	12.47*	47.85*	35.2*	95.65*
Crop duartion	9.98	3.11*	28.51	3.53*	22.74*	11.42*	39.93*	20.47*
Days to 50 % flowering	4.06	7.24*	4.04*	7.8*	2.37*	8.44*	4.11	11.37*
Intercluster distance	0.52*	0.05	0.07*	0.07*	0.04*	0.01*	0.77*	0.313*
DTF fruit set	14.03*	14.45*	5.50*	15.41*	17.42*	26.73*	20.15*	43.6*
DFAT fruit maturity	3.39*	3.01*	0.68	3.42*	3.17*	4.27*	6.6*	6.11*
DTF fruit harvest	1.8*	1.716*	2.45*	2.27*	8.64*	12.11*	13.76*	13.04*
No. of fruits / plant	7.66*	7.09*	3.56*	7.65*	13.26*	10.75*	20.56*	11.06*
Locule no. / fruit	0.05	0.08*	0.07*	0.1*	0.83*	0.21*	0.22	0.42*

Table 145: Continued

Character	σ ² line		σ ²tester		σ ²gca		σ ²sca	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Pericarp thickness	0.01*	0.002*	.001*	0.003*	0.87*	0.004*	0.49*	0.83*
Average fruit weight	5.22*	11.02*	7.8*	13.54*	27.51*	36.78*	43.14*	58.37*
Yield / plant	7474.12*	1908.2*	9965.63*	2544.2*	7423.6*	3112.75*	31296.09*	35105.64*
Yield / plot	0.4*	0.06*	0.22*	0.08*	0.02*	0.06*	.99*	0.59*
TSS	0.01	0.003*	0.01*	0.004*	0.31*	0.06*	.04	0.09*
Lycopene	5.89*	5.53*	12.20*	5.78*	28.64*	46.73*	34.26*	32.50*
Ascorbic acid	2.82*	2.7*	0.61	3.04*	9.42	13.75*	11.27*	10.79*
Acidity	0.0001	0.0001*	0.0001	0.0005*	0.02	0.37*	0.0002*	0.21*
chl a	0.01	0.004*	0.01	0.006*	0.04*	0.15*	0.12*	0.11*
chl b	0.004	0.003*	0.01	0.005*	0.1	.001*	0.05*	0.1*
chl total	0.01*	0.01*	0.02	0.01*	0.03*	0.01*	0.17*	0.25*
Shelflife	0.41*	0.25*	0.51*	0.33*	0.74*	0.62*	1.12*	3.98*

Table 146: Analysis of variance for combining ability for reproductive traits in tomato

Character	Stage of flowering	σ 2 line		σ 2tester		σ 2gca		σ 2sca	
		Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Flowers with exerted stigma	Early	1.37*	1.28*	1.82*	1.69*	27.39*	13.21*	28.41*	39.15*
	Mid	2.99	1.42	3.96	1.88*	14.37*	27.42*	20.70*	40.7*
	Late	2.13*	1.41	2.82	1.88*	28.47*	19.46*	34.93	28.94*
Pollen viability	Early	0.79*	1.83*	1.06	1.32*	4.32*	23.83*	7.73*	48.82*
	Mid	1.13*	3.17*	1.51*	1.31*	13.45	18.63*	17.06*	24.84*
	Late	4.33	3.76	10.56*	1.17*	18.72	12.63*	51.41	34.55*
Length of the style	Early	0.001	0.00004*	0.0002*	0.0001*	0.001	0.003	0.11	0.02*
	Mid	0.001	0.0001	0.0002*	0.0001*	0.001	0.8	0.11*	0.06*
	Late	.0001*	0.00004*	0.0001	0.0001*	0.25	0.002	0.18	0.053
Anther length	Early	0.0001*	0.0001*	0.0002	0.0001*	0.33	0.002	0.11*	0.17
	Mid	0.0001*	0.00003*	0.0001*	0.00004*	0.29*	0.22	0.18*	0.21*
	Late	0.0001	0.00001	0.0001*	0.00004*	0.001*	0.001	0.01	0.17*
No. of flowers / cluster	Early	0.08*	0.01*	0.04	0.01*	0.14	0.01*	0.74	0.46
	Mid	0.12*	0.004	0.07*	0.01*	0.004	0.01*	0.1*	0.85
	Late	0.10*	0.01	0.05	0.01*	0.23*	0.03	0.87*	0.54
No. of fruits / cluster	Early	0.01*	0.01*	0.008	0.01*	0.03*	0.02*	0.21*	0.13
	Mid	0.004*	0.004*	0.01*	0.01*	0.01*	0.15*	0.26*	0.28*
	Late	0.009*	0.01*	0.01*	0.01*	0.12*	0.21*	0.34*	0.35*
Fruit set per cent	Early	9.55*	4.85*	1.59*	1.93*	46.75*	46.27*	51.7*	54.82*
	Mid	10.0*	1.51*	11.16*	0.18*	38.64*	20.74*	69.22*	29.9*
	Late	5.43*	2.31*	12.46*	1.74*	44.32*	26.16*	75.0*	31.7*

Table 147: Additive genetic variance (σ^2A), dominance variance (σ^2D) and average degree of dominance

Character	σ^2A		σ^2D		Average degree of dominance	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter	Polyhouse	Rainshelter
Plant height at flowering	1.31*	3.47*	5.32*	7.13*	2.01	1.43
Internodal length	0.03	-0.12	-1.77	2.54*		
Plant height at harvest	1.69*	3.25	-2.28*	4.44*		1.17
Leaf area	4.77	0.63	9.29*	8.5	1.39	3.67
Crop duartion	1.58	3.72*	3.62*	3.26*	1.51	0.94
Days to 50 % flowering	-0.17*	0.93*	7.79	21.51*		4.81
Intercluster distance	0.46	0.82	4.19	2.33	3.02	1.69
DTF fruit set	-0.31	-0.5*	5.79	10.23*		
DFAT fruit maturity	-0.27	0.09	1.16	0.29		1.83
DTF fruit harvest	0.06	-0.05	2.08	4.71*	1.85	
No. of fruits / plant	0.22	0.004	1.56	0.14*	2.69	5.92
Locule no. / fruit	0.07	0.05	-0.003	0.17		1.81
Pericarp thickness	1.40	0.002*	0.003	0.002*	0.05	1.0
Average fruit weight	0.4*	3.89*	-12.84*	5.71		1.21
Yield / plant	1848.38*	528.94*	-20785.63*	18694.47*		5.95
Yield / plot	0.14*	0.33*	-0.52	0.6		1.36
TSS	0.03	0.001	0.02	-0.01*	0.77	
Lycopene	0.13	0.11	0.26	-0.31*	1.39	
Ascorbic acid	0.14	0.12	0.78	0.71	2.34	0.41
Acidity	0.06	-0.0001	0.0005	0.0007	0.09	
chl a	0.003	0.002	-0.006	0.001		0.86
chl b	0.002	0.001	0.0009	0.009	0.69	2.62
chl total	0.003	0.004	0.007	0.01	1.51	1.71
Shelflife	0.16	0.1	0.27*	0.20	1.65	2.06

Table 148: Additive genetic variance (σ^2A), dominance variance (σ^2D) and average degree of dominance for reproductive traits

Character	Stage of flowering	σ^2A		σ^2D		Average degree of dominance	
		Polyhouse	**Rainshelter**	**Polyhouse**	**Rainshelter**	**Polyhouse**	**Rainshelter**
Flowers with exerted stigma	Early	0.39*	0.08*	0.37*	1.46*	0.97	4.39
	Mid	0.72	0.06*	3.66	1.12	2.26	4.44
	Late	0.41	-0.34*	-5.37	0.69		
Pollen viability	Early	0.04*	0.29*	-1.97*	3.14*		3.31
	Mid	0.15*	0.21*	-3.51*	0.51*		1.56
	Late	0.13	0.05*	-4.35	-0.22		
Length of the style	Early	-0.02	0.0002	0.0007	0.0003		1.36
	Mid	-0.05	0.05	0.0006	0.001*		0.16
	Late	0.09	0.0001	0.0006*	0.001*	0.08	3.35
Anther length	Early	0.02	0.0001	0.0006	0.0004	0.17	1.97
	Mid	0.55	0.28	0.0006	0.001	0.03	0.07
	Late	0.0001*	0.0002	0.0005	0.0004*	2.09	1.53
No. of flowers / cluster	Early	0.10	-0.04	0.13*	0.62	1.12	
	Mid	-0.01*	-0.01*	0.17	0.4*		
	Late	0.03*	0.06*	0.14*	0.26*	2.0	2.04
No. of fruits / cluster	Early	0.02	-0.02	0.05	0.24	1.53	
	Mid	0.01	-0.03*	0.02	0.31*	1.38	
	Late	0.004*	-0.003*	0.02	0.05*	2.0	
Fruit set per cent	Early	0.33*	0.2*	0.12*	0.32*	0.61	1.26
	Mid	-0.39*	0.65*	2.2*	-3.57*		
	Late	0.13	0.69*	-1.88	-6.22		

4.5.2 Molecular marker analysis

The protocol for different SSR marker assays, in the screening of genotypes for bacterial wilt, was validated with DNA of genotypes into two categories, either resistant or susceptible. Different primers were screened with genomic DNA using the validated protocols.

Table 149: The reaction and quantity of DNA isolated from tomato genotypes

Sl. No.	Genotype	Reaction to bacterial wilt	Quantity of DNA ng / µml
1	EC-620387	S	346.0
2	EC-620401	S	344.6
3	EC-620406	S	311.5
4	EC-620410	S	376.8
5	EC-631369	S	368.5
6	EC-165700	R	1048.0
7	EC-620382	R	423.1
8	EC-620427	R	314.0
9	EC-620429	R	360.0
10	Arka Abha	R	362.3

4.5.2.1 SSR analysis

Eleven primer sets were screened for their ability to amplify the SSR regions in the genomic DNA of samples. The thermal setting is mentioned in Table 11 (3.5.5). Based on the amplification pattern primers are selected / recommended for bacterial wilt screening. Among the eleven primers used for the study, only two primers gave polymorphism among the genotypes. All other primers gave monomorphism among the genotypes studied. The two primers gave polymorphic amplicons for SLM6124 and SLM6-110. The amplicons pattern of these primers is detailed below (Table 150).

Table 150: Amplification pattern observed for SSR primers

Sl. No.	Primer	Amplification pattern			
		No. of bands	Type of the band		Remarks
			Distinct	Faint	
1	SLM 12-2	1	0	1	Not selected / not recommended
2	SLM12-10	1	0	1	Not selected / not recommended
3	**SLM6124**	**4**	**2**	**2**	**Selected / recommended**
4	SLM6118	1	0	1	Not selected / not recommended
5	SLM6119	1	0	1	Not selected / not recommended
6	SLM6136	4	2	2	Not selected / not recommended
7	SLM6-17	4	3	1	Not selected / not recommended
8	SLM6-94	1	0	1	Not selected / not recommended
9	**SLM6-110**	**4**	**2**	**2**	**Selected / recommended**
10	KHU-1-F	3	2	1	Not selected / not recommended
11	SSR 20	2	1	1	Not selected / not recommended

4.5.2.1.1 SLM6124

SSR assay using primer set SLM6124 followed by electrophoresis on 1.5 per cent agarose gel has generated four amplicons among the accessions under study (Plate 24). The molecular weight of the band varied from 300bp to 950bp. Two distinct bands at 300bp and 800bp were monomorphic among the genotypes studied. Two faint bands at 400bp and 950bp were present only in the susceptible accessions. So these bands at 400bp and 950bp were found polymorphic between resistant and susceptible genotypes.

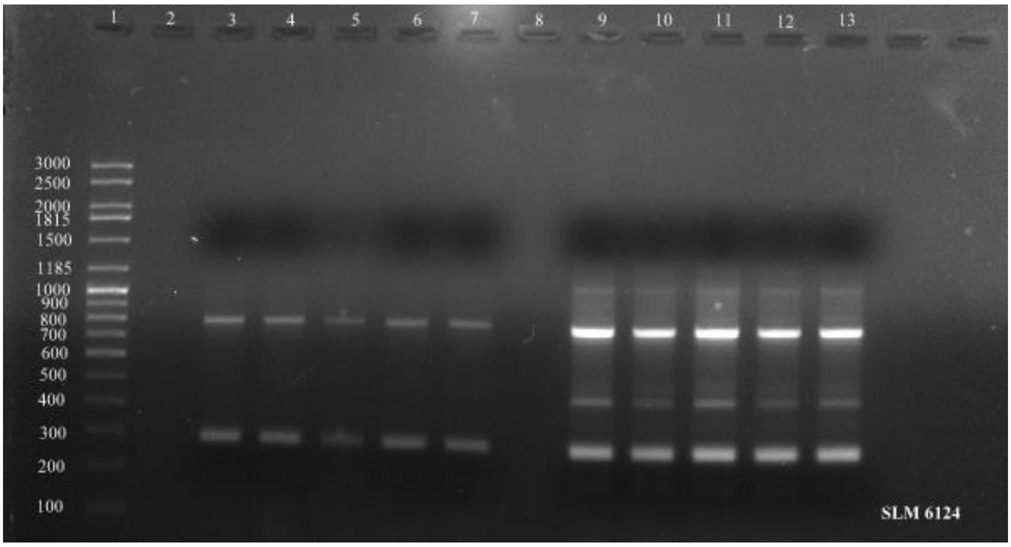
4.5.2.1.2 SLM6-110

When the accessions were analysed using the SSR primer SLM6-110, the bands of four distinct sizes were observed (Plate 25). The molecular weight of the bands varied from 300bp and 900bp. Two distinct monomorphic bands were obtained at 300bp and 900 bp for all genotypes studied. Two faint bands at 500bp and 700bp were present only in the susceptible genotypes. So these bands at 500bp and 700bp were found polymorphic between resistant and susceptible genotypes.

Thus, from the study two SSR primers SLM6124 and SLM6-110 were suggested for the validation of genotypes for bacterial wilt susceptibility (Table 151).

Table 151: Details of the SSR primers suggested for validation of bacterial wilt susceptibility

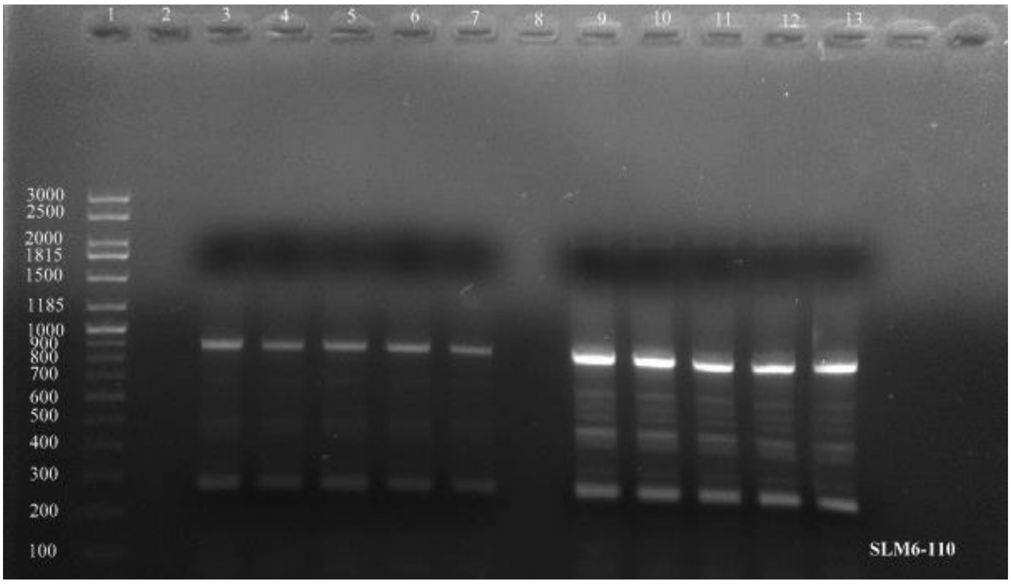
Sl. No.	Oligo name	Annealing temperature (^{0}C)	Sequence
1	SLM6124	56	F5'- CATGGGTTAGCAGATGATTCAA -3' R5'- GCTAGGTTATTGGGCCAGAA -3'
2	SLM6-110	55	F5' - AGAATGCGGAGGTCTGAGAA - 3' R5' – ATCCCACTGTCTTTCCACCA -3'



1: Ladder, 2: Blank, 3: EC-165700*, 4: EC-620382*, 5: EC-620427*, 6: EC-620429*, 7: Arka Abha*, 8: Blank, 9: EC-620387**, 10: EC-620401**, 11: EC-620406**, 12: EC-620410** and 13: EC-631369**

*: Resistant, **: Susceptible

Plate 24: Amplification profile for the primer SLM6124



1: Ladder, 2: Blank, 3: EC-165700*, 4: EC-620382*, 5: EC-620427*, 6: EC-620429*, 7: Arka Abha*, 8: Blank, 9: EC-620387**, 10: EC-620401**, 11: EC-620406**, 12: EC-620410** and 13: EC-631369**

*: Resistant, **: Susceptible

Plate 25: Amplification profile for the primer SLM6-110

Discussion

5. Discussion

5.1 SCREENING OF THE TOMATO GENOTYPES

Tomato is a very important commercial vegetable crop coming under the family Solanaceae which can be grown both in the open field and in the protected structures. The protected cultivation of tomato in Kerala is limited due to the unavailability of suitable indeterminate genotype with bacterial wilt resistance and hotset characters. Prolonged hours of solar radiation in the tropics results in the increase of temperature of protected structures. This increased temperature may affect the vegetative, flowering and reproductive stages of the crop. Breeding inbred lines with bacterial wilt resistance and desirable heat tolerance will boost the protected cultivation of tomato in Kerala.

Investigations were carried out at Department of Vegetable Science, College of Agriculture, Vellanikkara, Thrissur, to identify suitable hotset and bacterial wilt resistant genotypes and to utilize them in breeding program.

5.1.1 Quantitative characters

Alterations in the light intensity, temperature and relative humidity can make changes in the performance, final yield and quality of tomato. So, it is important for assessing these variations. In the present study tomato genotypes were grown in two different structures, naturally ventilated polyhouse and rainshelter, at two different seasons to assess the performance for vegetative, flowering and fruit characters, yield characters, biochemical characters and reactions to major pests and diseases.

5.1.1.1 Vegetative characters

The vegetative characters studied in the present investigation were plant height at flowering, plant height at harvest, internodal length, leaf area and crop duration. In the pooled mean the plant height at flowering, internodal length and plant height at harvest were found to be higher for polyhouse plants, EC-151568 (111.9 cm) and EC-165690 (79.6 cm), EC-165690 (13.9 cm and 12.1 cm) and

EC-151568 (135.2 cm) and EC-165690 (102.8 cm), respectively for polyhouse and rainshelter. EC-165690 recorded the highest value for intermodal length under both the structures indicating the suitability of genotype for the protected structures (Lekshmi and Celin, 2015). The internodal length is a function of temperature and light (both light quality (red: far red ration) and quantity). More than temperature, light influences the internodal length under a protected environment (Chen *et al*., 2014). The plants under polyhouse receive comparatively less light intensity than the rainshelter plants (Lekshmi and Celin, 2015 and Singh and Kumar, 2017). This will facilitate cell elongation and the longer internodes and thus resulting in higher plant height. This is also in accordance with the finding of Chapagain *et al*., (2011) and Naik *et al*., (2018). Chapagain *et al*. (2011) and Lekshmi and Celin, 2015 also suggest the more adaptability of indeterminate and semideterminate genotypes for protected cultivation.

Leaf area is considered as an important trait for polyhouse plants since, it can determine the light capturing, photosynthesis and biomass accumulation. In the present study it was observed that the leaf area of polyhouse plants are fairly high compared to rainshelter plants in both the seasons. In the pooled mean, EC-631369 (136.4 mm^2) and Arka Saurabh (89.5 mm^2), recorded maximum leaf area for polyhouse and rainshelter, respectively. Under shaded conditions, for better light interception and to increase the light harvesting efficiency, the plants tend to adjust with long petioles and large leaves resulting in more area (Lekshmi and Celin, 2015). Smitha (2002) also observed similar trend in polyhouse tomato cultivation. Also higher carbon dioxide concentration could result in higher leaf expansion resulting in more area (Suseela, 2015)

The crop duration was found to be more for polyhouse plants compared to rainshelter plants for both the seasons. In the pooled mean, under polyhouse EC-620410 (140.9 days) and inside rainshelter EC-620406 (133.8 days), recorded maximum duration. Polyhouse is a covered structure which can provide crop plants the optimal growth conditions and protection from diseases and pests. In the tropics it can provide an extension of production season and protection from diseases and pests (Shamshiri *et al*., 2018). It is further supported by the finding of Chapagain *et al*., (2011) under plastic house. Moreover, the genotype EC-620406, which was better performing inside rainshelter, could also record a comparatively long duration under polyhouse (135.1 days). This shows the more adaptability of this genotype for both the structures. The extension of harvest period under protected structure also demands the genotypes with long duration (Shamshiri *et al*., 2018). The morphological developments *viz*: plant height, internodal length, leaf area and crop duration were positively favoured by the microclimate of polyhouse (Parvej *et al.,* 2010) compared to rainshelter.

5.1.1.2Flowering characters

The flowering characters studied in this investigation were days to 50% flowering, intercluster distance, flowers with exerted stigma, pollen viability, number of flowers per cluster, length of the style, anther length and days to first fruit set

In the summer evaluation, the rainshelter plants were earliest to flower. Under polyhouse EC-538153 and EC-620378 (35.0 days) exhibited earliest flowering. Inside the rainshelter the earliest to flower was EC-538153 and EC-620378 (35.0 days). The days to 50% flowering clearly indicates the earliness of the crop. The elevated levels of CO_2 are reported to be sensitive for tomato crop for the phenological development. The elevated levels of CO_2 can improve the vegetative growth of the plant, but can delay the phenological development (Sato *et al*., 2006). In the rainy season polyhouse plants exhibited earliest flowering, EC-620376 (42.0 days) and Arka Alok (45.5 days), for polyhouse and rainshelter, respectively. High humidity and low temperature of rainshelter could delay the phenological development of plants (Sato *et al*., 2006). The result also shows that the genotype EC-620378 exhibited earliest flowering in summer under both the structures indicating the suitability of the genotype, under protected conditions.

The intercluster distance was found to be more for polyhouse plants than rainshelter plants for both the seasons. In the pooled mean, under polyhouse and inside rainshelter, Akshaya recorded the shortest intercluster distance (8.0 cm and 7.4 cm, respectively). The low light intensity under polyhouse condition results in the longer internodes in tomato (Chen *et al*., 2014).

Stigma exertion is regarded as a physiological disorder at higher temperature regimes (Golam *et al*., 2012). In the mean value of different flowering stages, during summer evaluation more genotypes exhibited stigma exertion inside rainshelter. Under polyhouse EC-620401 exhibited minimum exertion (17.2%), and inside rainshelter EC-620410 exhibited least exertion (18.1%). As a result of gene activation and signaling changes at an elevated temperature, the biosynthesis of phytohormones auxin and jasmonic acid increases. This makes alterations in the pectin and sugar translocation to pistil and stamen. Also there will be a transcriptive abundance of the proteins expansin and cyclins, altering the number and size of cells in pistil and stamens. This make morphological changes in the pistil and stamen resulting stigma exertion and was further regarded as a protective mechanism for pistil (Pan *et al.,* 2018). In the mean value of different flowering stages, in the rainy season evaluation, number of genotypes exhibiting stigma exertion was more under polyhouse. Under polyhouse EC-620410 exhibited minimum exertion (15.7%), and inside rainshelter EC-620417 exhibited minimum exertion (15.2%) Even though compared to temperature it is negligible, the light intensity can also influence stigma exertion, and the lower light intensity in the rainy season can cause stigma exertion in tomato under protected structures (Fernandez – Munoz and Cuartero, 1991). The genotype EC-620387, EC-620401, EC-620406, EC-620410 and EC-620395 exhibited less stigma exertion under both the structures for both the seasons, and could be considered for good heat tolerance (Chen *et al*., 2004, Alsamir *et al.,* 2017).

Number of flowers per cluster can influence the total yield of the plant. Plants inside rainshelter produced more number of flowers per cluster than the plants under polyhouse for both the season. In the mean value of different flowering stages, during summer crop, under polyhouse, EC-620376 (6.1) and inside rainshelter EC-165395(8.6), recorded the maximum number of flowers per cluster. In the mean value of different flowering stages, during rainy season crop, under polyhouse EC-620410 (7.1) and inside raishelter EC-165395 (7.7), exhibited maximum number of flowers per cluster. The reduced availability of photosynthates to the developing sinks under polyhouse might have affected the flower bud initiation, thus decreasing the number of flower per cluster (Golam *et al*., 2012). EC-620476, EC-620401, EC-620406, EC-620410 and EC-620417 exhibited better flower production under both the structures, indicating the better adaptability of these genotypes to the given environmental condition (Lekshmi and Celin, 2015)

Pollen viability is a measure of hotset in tomato. During summer evaluation, in the mean value of different flowering stages, the pollen viability was recorded highest for EC-164263 (54.4%) and inside rainshelter EC-165395 exhibited highest value (62.9%). Any stress in the before flowering period is associated with developmental alterations in the anthers including poor pollen formation and reduced pollen viability. Before anthesis there observed an accumulation of starch in the pollen grains (Sato *et al.,* 2006). The light availability (Jones, 2013) and insufficient ventilation are constraint for efficient photoassimilate accumulation in the pollen grains. The anther wall and pollen grain cells shrink and fail to accumulate photoassimilates (Harel *et al*., 2014). The reduction in the photosynthesis and availability of photoassimilates might result in the reduced pollen viability under polyhouse. The genotypes *viz:* EC-164263, EC-165700, EC-528368, EC-620376, EC-620395, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369 maintained the high level of pollen viability under both the structures (Figure 9). The genotypes with high level of pollen viability under both the structures could be considered as hotset types. The high level of pollen viability was observed for heat tolerant genotypes by several other workers, Golam *et al*., (2012), Harel *et al.,* (2014), Singh *et al*., (2015), Alsamir *et al.,* (2017) and Yenda *et al*., (2018). During rainy season evaluation, in the mean value of different flowering stages, under polyhouse conditions, EC-620410 exhibited maximum pollen viability (60.9%), followed by EC-164263 (60.3%) and EC-620406 (60.1%). Inside rainshelter, EC-165395 (61.6%), exhibited maximum pollen viability (Figure 10). During rainy season under polyhouse condition a temperature increase of up to 8°C is reported (Parvej *et al.,* 2010). The increase in the temperature inside the structure could improve the pollen viability (Harel *et al.,* 2014, Singh and Kumar, 2017). In the rainy season EC-165700, EC-620376, EC-620401, EC-620406 and EC-620410 are included in the better performing genotypes under both the conditions, indicating the superiority of the genotype. Lekshmi and Celin, (2015) also reported the better performance of superior genotypes for two consecutive years.

In the pooled mean, the genotype EC-164263, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369 recorded minimum stigma exertion and maximum pollen viability under both the seasons irrespective of the structure. So this genotype could be considered as hotset type according to (Golam *et al*., 2012, Harel *et al*., 2014 and Alsamir *et al*., 2017).

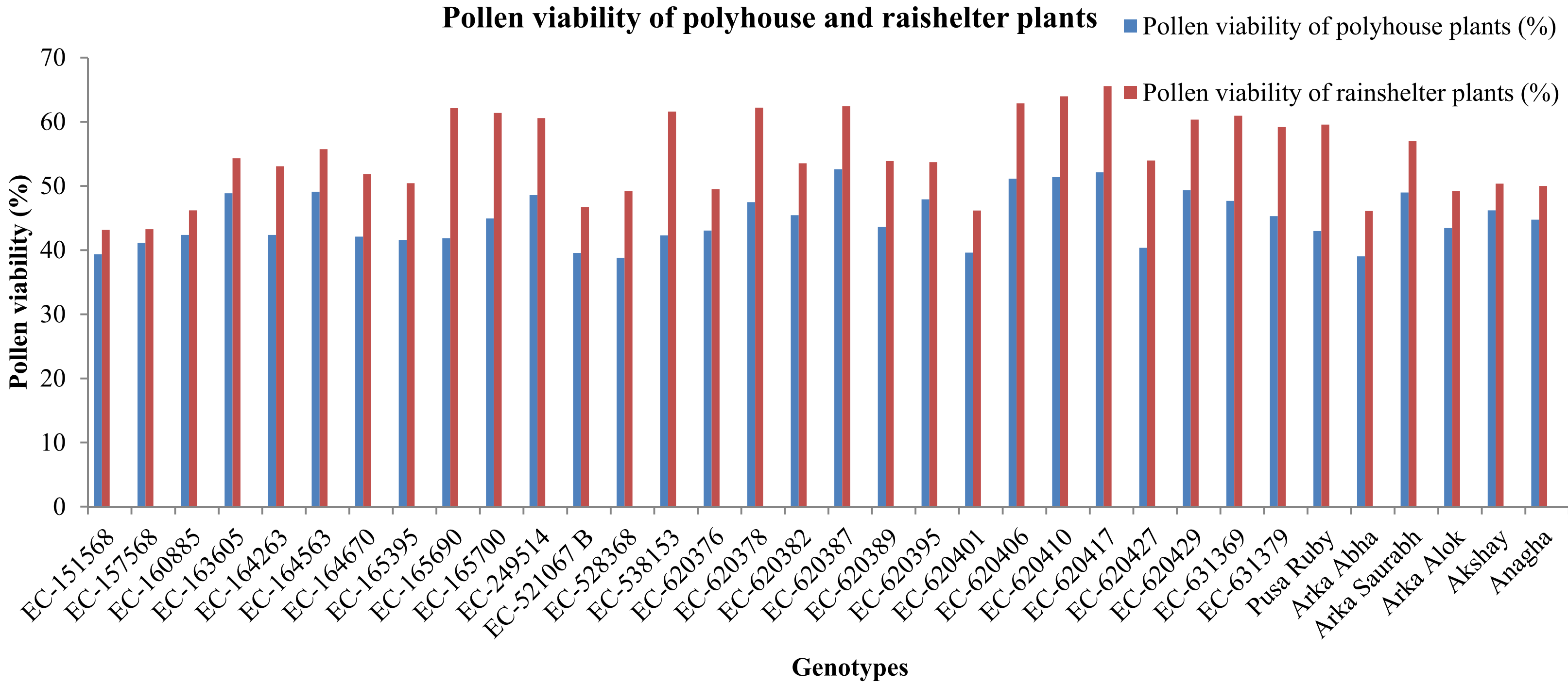


Figure 9: Pollen viability (mean of three stages of flowering)of polyhouse and rainshelter plants for summer season

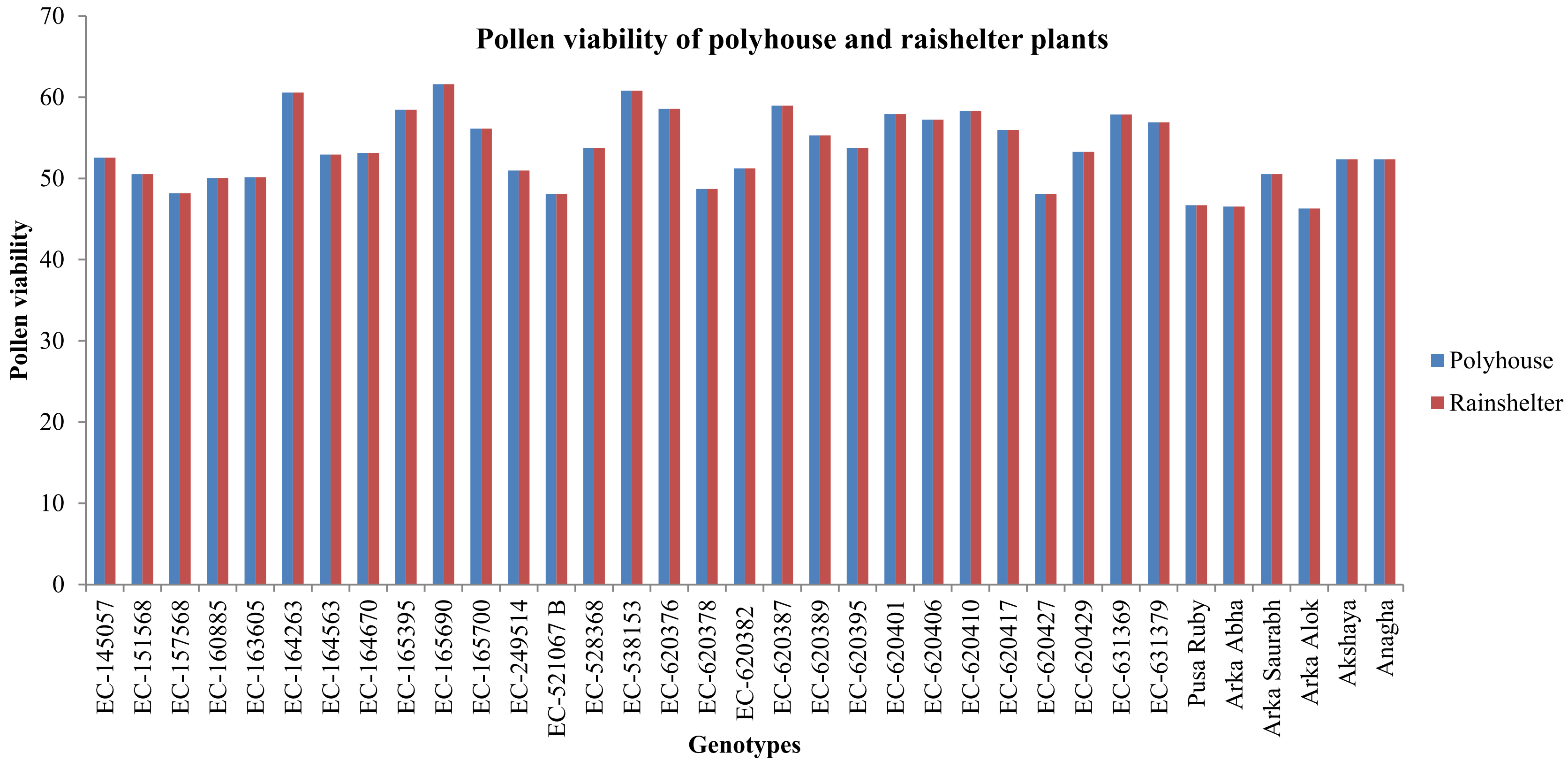


Figure 10: Pollen viability (mean of three stages of flowering)of polyhouse and rainshelter plants for rainy season season

In the mean value of different flowering stages, under both the structures, EC-145057 (0.54 cm, 0.59 cm) exhibited shortest style in both the season. The genotype EC-145057 consistently exhibited short style, indicating the particular feature of the genotype. In the case of anther length, the pooled mean revealed that the genotype EC-164563 produced the longest anthers for all three stages of flowering under both the conditions, and EC-145057 with shortest anthers. The hormonal changes can alter the changes in the style morphology are more common in plants under varied stress conditions (Chen and Tanksley, 2004) and pollen transfer depends on the proximity of stigmatic surface to anther cone (Karapanos *et al.,* 2008). The variations in the style length and anther length, brought about by the hormonal changes, can happen in two ways *viz:* by the shortening of stamens and by the lengthening of styles (Pan *et al.,* 2018). The Jasmonic acid and IAA are having differential functions in the pistil and stamen. In the pistil these phytohormones result in cell elongation. This is a physiological adaptation to protect the pistil from high temperature, thus resulting in stigma exertion (Pan *et al.,* 2018). Anther length in the rainy season is found to be less compared to the anther length in the summer season. Variable microclimate inside rainshelter and polyhouse was responsible for the changes in the style and anther length. Thus the selection of genotypes with direct relation between anther length and style length is promising.

Days to first fruit set is an important character determining the earliness of the crop. During summer evaluation under polyhouse days taken for first fruit set varied between 38.2 days (EC-538153) and 50.5 days (EC-620387), whereas inside rainshelter the range was between 33.2 days (EC-620395) and 45.8 days (EC-620417). Days to first fruit set largely depends upon the proper transition from vegetative to phenological and to reproductive phases (Garcia *et al*., 2011). The proper microclimate, for efficient photosynthesis and ensured photosynthate translocation, combined with the better pollen viability inside rainshelter could invariably ensure the proper morpho-phenological development of crop. In the rainy season under polyhouse, the days to first fruit set ranged between 44.2 days

(EC-151568) and 50.0 days (EC-165690), whereas inside rainshelter it ranged between 46.0 days (Akshaya) and 55.3 days (EC-528368). In the pooled mean, under polyhouse EC-620378 and inside rainshelter Akshaya, were the earliest to set fruit (42.5 days and 40.2 days, respectively) indicating varying response of the genotype to microclimate. The variations in the fruit set was a varietal response indicating their higher capacity to make available assimilates to the reproductive site during sensitive phase (Rana *et al.,* 2014). Similar results were also reported by Singh *et al.,* (2015) and Singh and Kumar (2017). Thus the genotype x environment interaction patterns help in the selection of genotype for particular structure (Ayenan *et al*., 2019)

5.1.1.3Fruit characters and yield

The fruit and yield characters studied in the present investigation were days from anthesis to fruit maturity, days to first fruit harvest, number of fruits per cluster, number of fruits per plant, locule number per fruit, pericarp thickness, average fruit weight, yield per plant and yield per plot.

The range for days from anthesis to fruit set and days to first fruit harvest were found to be less for rainshelter plants compared to polyhouse plants in summer seasons. During summer days from anthesis to fruit maturity for polyhouse plants were in the range between 38.4 days (EC-151568) and 49.3 days (Arka Saurabh), whereas, inside rainshelter, it was 36.1 days (EC-164670) and 47.0 days (EC-163605). During summer EC-164670 recorded earliest harvest (82.4 days) under polyhouse and, inside rainshelter EC-620429 recorded earliest harvest (74.7 days). Days from anthesis to fruit maturity and days to first fruit harvest play an important role in determining the earliness of the crop. Even a single day’s difference is crucial from marketing perspective for perishable vegetable crops (Parvej *et al.,* 2010). Early and late maturity is attributed largely by the genetic makeup of the plant and the extent is influenced by the environmental factors of the particular growing structure (Chapagain *et al*., 2011). The genotype which exhibited minimum number of days from anthesis to fruit maturity failed in early harvest. This could be due to delayed fruit ripening process associated with genotype. The delay in harvesting could be attributed to delayed flowering also (Omprasad *et al*., 2018).

In the rainy season evaluation, under polyhouse EC-620395 exhibited minimum days from anthesis to fruit maturity (39.1 days). Inside rainshelter, EC-528368 recorded minimum days from anthesis to fruit maturity (35.2 days). EC-620382 recorded earliest fruit harvest (83.9 days) under polyhouse and, inside rainshelter Arka Abha recorded earliest harvest (85.4 days). Polyhouse climate hastened the maturity of fruits by the advancement of required heat units or the thermal time of the crops grown inside the polyhouse in the prevailing climate (Fayaz *et al.,* 2007). There was a markable difference among the genotypes for earliness. Early varieties respond well to the congenial growth conditions of the polyhouse (Singh *et al.,* 2015).

In the pooled mean for number of fruits per cluster, under both the structures, EC-620401 exhibited highest number of fruits per cluster (4.2 and 4.4, respectively). The number of flowers per cluster was high inside rainshelter. The easy wind movement (Cheema *et al*., 2014) and more insect movement (Singh *et al.,* 2015) were noticed inside rainsheter. All these factors can contribute to the higher number of fruits per cluster. The genotype EC-620401 could maintain the highest number of fruits per cluster under both conditions. The genotype was also superior in the pollen viability, indicating the suitability for protected cultivation. The number of fruits per cluster and pollen viability can directly influence the yield potential of tomato, thus these traits could be considered as the criteria for selection of superior lines (Singh *et al.,* 2015).

The fruit set per cent was higher for rainshelter plants in the summer. Under polyhouse EC-164263 exhibited maximum fruit set per cent (62.4%) and inside rainshelter EC-620401 exhibited maximum value (68.4%) (Figure 11). The higher number of flowers per cluster and easy wind movement could improve the fruit setting inside rainshelter. In the rainy season polyhouse plants exhibited more fruit set. EC-165700 exhibited maximum fruit set under polyhouse and inside rainshelter (68.3% and 66.5%, respectively). The genotypes EC-620401, EC-620406 and EC-620410 consistently maintained their fruit set per cent over the condition and season (Figure 12). Fruit set per cent is a major important parameter for selecting a variety for summer or rainy season, since it determines the tolerance of a genotype to temperature and other environmental factors (Jones, 2008). The better performance of a genotype under different structures for consecutive seasons shows the better adaptability of the genotype to the given ecosystem (Singh *et al.,* 2015)

As a consequence of the high fruit set per cent, number of fruits per plant was observed to be higher for rainshelter plants in the summer evaluation. Polyhouse plants recorded the range between 10.6 and 23.2, whereas, rainshelter plants recorded a range of 13.6 to 71.9. The number of flowers per cluster, number of fruits per cluster and fruit set per cent were high for rainshelter plants in the summer resulting in higher number of fruits per plant (Meseret *et al*., 2012 and Jones, 2008). In the rainy season, the polyhouse plants recorded a range of 13.0 to 24.6, whereas rainshelter plants recorded a range of 11.3 to 67.0. There was no general trend for rainshelter plants in the rainy season. Inside rainshelter two genotypes, EC-165690 and EC-165395, performed exceptionally well for number of fruits per plant but failed in good performance under polyhouse. This indicates the suitability of genotype to particular structure. Screening under different structures speculates best genotypes for particular structure (Bannur *et al.,* 2019).

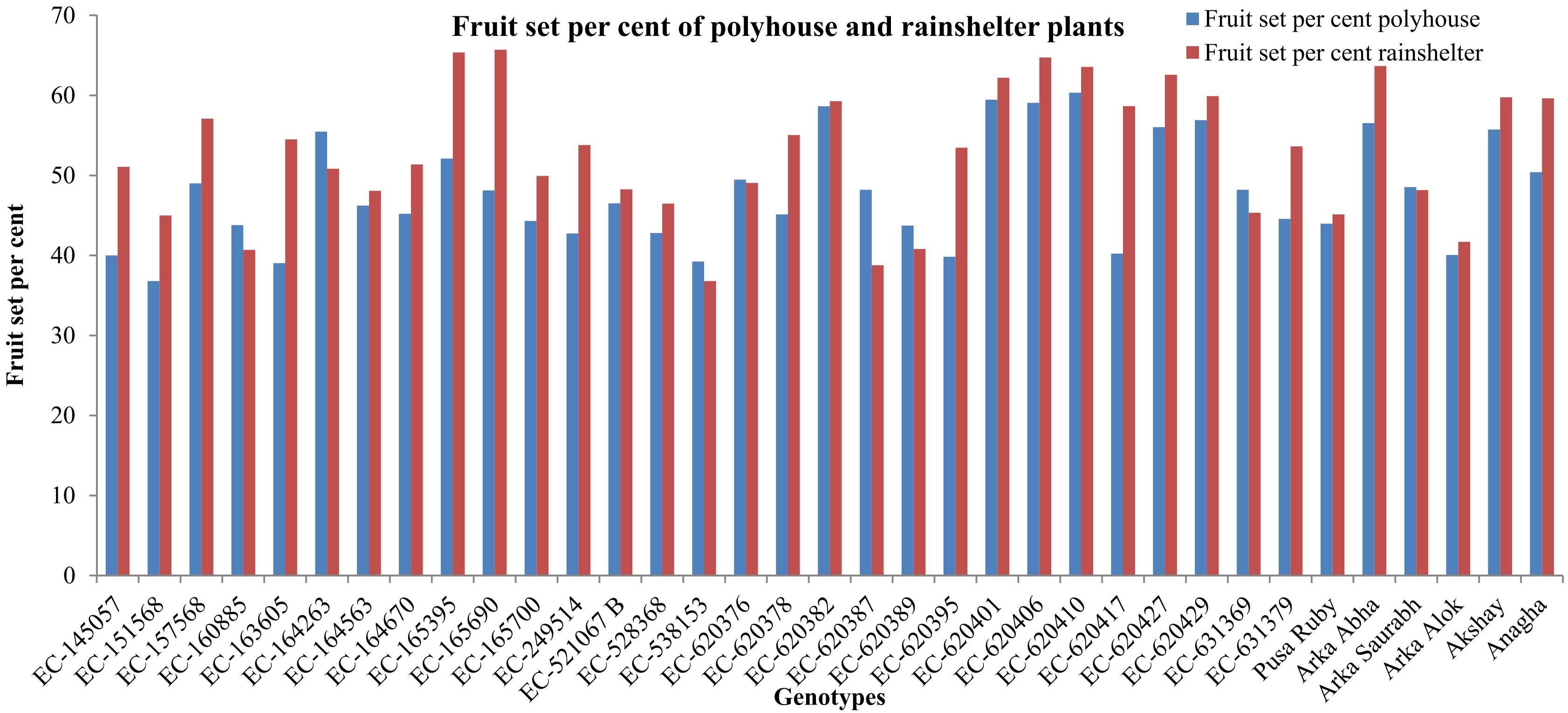


Figure 11: Fruit set per cent of (mean of three stages of flowering) polyhouse and rainshelter plants for summer season

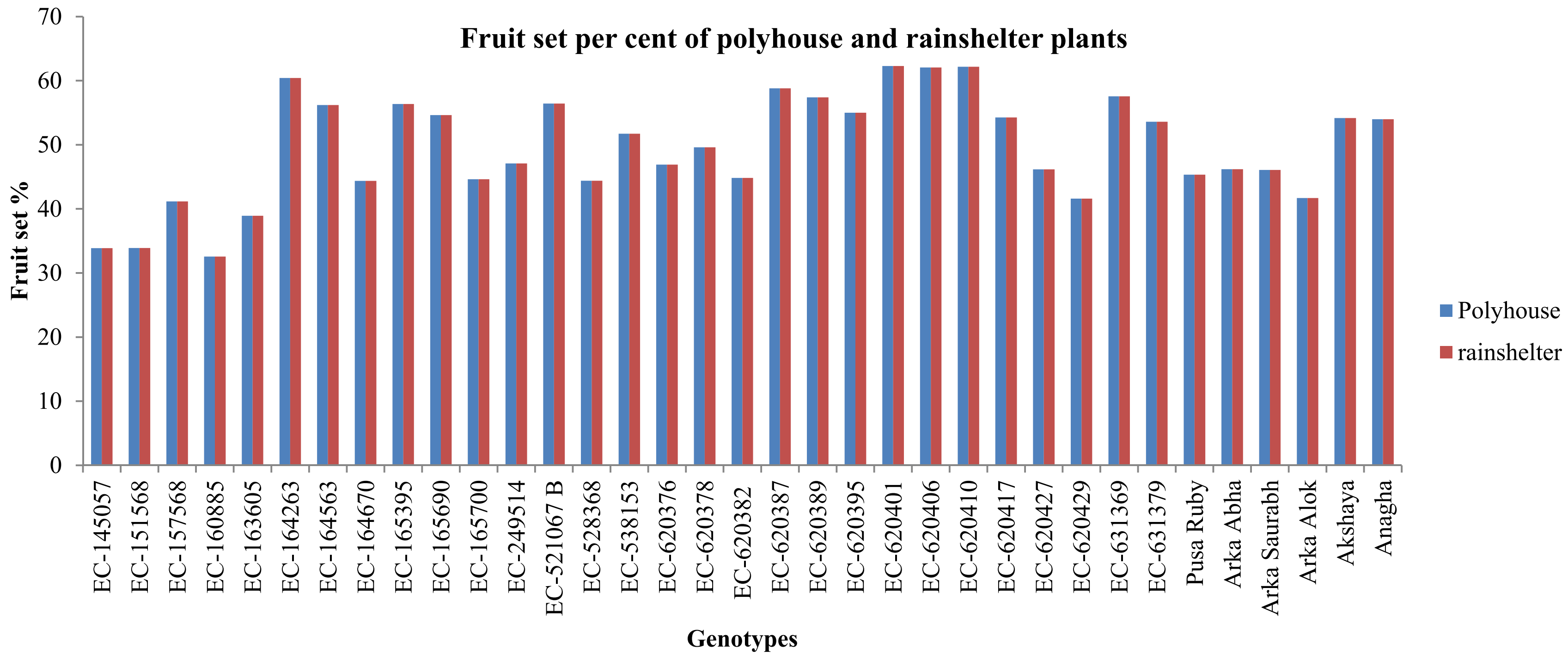


Figure 12: Fruit set per cent (mean of three stages of flowering) of polyhouse and rainshelter plants for rainy season

Locule number per fruit was observed to be less for polyhouse plants for both the seasons. In the pooled mean, under polyhouse EC-521067 B (2.3) and inside rainshelter EC-528368 (2.6), recorded minimum locule number per fruit. The pericarp thickness was observed to be more for polyhouse plants in both the seasons. In the pooled mean, under polyhouse EC-620427 (0.91 cm) and inside rainshelter EC-620406 (0.82 cm), recorded maximum pericarp thickness. Minimum number of locules with thick pericarp is a desirable character since it can provide firmness and better storability. The fruit with thick pericarp was also reported by Kanwar (2011) and Sharma and Singh (2015) under polyhouse condition. The genotypes with less locule and thick pericarp are suitable for selection for shelf life (Bharathkumar*et al.,* 2017). The genotypes EC-620417 (2.6 and 0.72) and EC-631379 (2.5 and 0.81) exhibited favourable combination of locule number per fruit and pericarp thickness under polyhouse having potential for distant market.

The average fruit weight was observed to be more for rainshelter plants in the summer evaluation. Under polyhouse the average fruit weight was in the range between 8.0 g (EC-528368) and 86.3 g (EC-620417), whereas inside rainshelter it was 10.9 g (EC-620376) and 94.2 g (EC-538153). The better photosynthesis under ensured light intensity has resulted in better accumulation of photosynthates available for growing sinks. The result was confirmed with the finding of Pooja and Hakkim (2017) inside rainshelter. In the rainy season evaluation the average fruit weight was high for polyhouse plants than for rainshelter plants. Fruit weight of polyhouse plants were in the range between 6.4 g (EC-528368) and 98.2 g (EC-631369), whereas rainshelter plants were in the range between 4.2 g (EC-165700) and 95.3 g (EC-538153). The rate of leaf initiation, its expansion and net photosynthesis are reduced with decrease in temperature. During rainy season the temperature inside the polyhoue was higher than that of rainshelter temperature (Parvej *et al*., 2010). The availability of photoasimilates to the developing fruit largely determines its weight. The genotypes with high average fruit weight inside rainshelter remained the same over the seasons. The average fruit weight is a varietal character with minor fluctuations with the variability in the microclimate (Singh and Kumar, 2017).

The fruit yield per plant and fruit yield per plot were observed to be more for raishelter plants in both the seasons. Under polyhouse the yield per plant was in the range between 136.0 g (EC-620376) and 1373.9 g (EC-620401), whereas inside rainshelter, the range was between 146.7 g (EC-620376) and 1857.0 g (EC-620410), during summer. In the rainy season, under polyhouse, the range was between 128.1 g (EC-620376) and 1727.3 g (EC-620410). Inside rainshelter, the range was between 409.5 g (EC-620376) and 1875.0 g (EC-620410). The yield per plot under polyhouse, was in the range between 0.8 (EC-528368 and EC-620376) and 8.2 (EC-620406) during summer. Rainshelter plants exhibited the range between 2.5 (EC-620376) and 11.3 (EC-620410). In the rainy season polyhouse plants was in the range between 0.7 (EC-165700) and 10.4 (EC-620410) under polyhouse, and the range between 0.3 (EC-528368) and 11.1 (EC-620410) Yield is considered as a cumulative effect of fruit set per cent, number of fruits per cluster, number of fruits per plant, average fruit weight and number of harvest (Harel *et al.,* 2014). The contributing traits gave better value for rainshelter resulting in the better yield for rainshelter in the summer evaluation. The genotype EC-620410 exhibited superior performance under both the seasons. The yield of a genotype is determined by the genetic makeup of the genotype. But the expression is influenced by the environments (Cheema *et al.*, 2014). The light intensity and temperature which are conducive for balanced photosynthesis and respiration are important to make a better use of both these climatic parameters under protected conditions (Lekshmi and Celin, 2015). A genotype exhibiting a compensation point at low light intensity and temperature may have a high photosynthetic efficiency and such genotypes perform better under shade. The hotset genotypes perform well in the summer under tropical conditions (Alsamir *et al*., 2017, Singh and Kumar, 2017). The pooled data of fruit and yield traits revealed the genotypes EC-164263, EC-538153, EC-620387, EC-620389, EC-620395, EC-620401, EC-620406, EC-620410, EC-620417, EC-631369, Arka saurabh and Arka Alok as superior genotypes with acceptable average fruit weight, pericarp thickness and yield potential.

5.1.1.4 Incidence of pest and diseases

Bacterial wilt caused by *Ralstonia solanacearum* is a serious threat to the tropics and severely limit the production in many tropical and sub tropical regions (Pradeepkumar *et al.,* 2001). Bacterial wilt incidence was found to be more in the rainy season. In the summer evaluation under polyhouse the bacterial wilt incidence was 0% to 69.0%. The rainshelter also recorded a similar range 0% to 69.1%. Pusa Ruby recorded the highest wilt incidence in both the growing structures (69.0% and 69.1% for polyhouse and rainshelter respectively). In the rainy season evaluation also Pusa Ruby recorded highest wilt incidence in both the growing systems (74.6% and 71.4% for polyhouse and rainshelter respectively). The genotypes EC-165395, EC-165690, EC-165700, EC-620376, EC-620382, EC-620427, EC-620429, EC-631379, Arka Abha, Akshaya and Anagha exhibited stable resistant reaction to the pathogen during evaluation, thus categorised as resistant. The remaining genotypes were categorised into moderately resistant / moderately susceptible / susceptible / highly susceptible based on their reaction. Sharma *et al.* (2006) reported two lines *viz:* EC-369060 and BT-17 as resistant and CH-193 as moderately resistant after three year of evaluation trials. Kumar *et al.,* (2018) also categorised 11 tomato lines into highly resistant, resistant, moderately susceptible, susceptible, highly susceptible based on their performance at 100 days after planting.

The genotypes with susceptibility to fruit crack were found to have fruit cracking in both the seasons under polyhouse and rainshelter. EC-620378, EC-620395 and Arka Saurabh observed to have fruit cracking in both the growing systems. The fruit cracking was observed to be more for rainshelter. It is in accordance with the findings of (Abdel-Razzak *et al*., 2016). Rainy season crop recorded more incidence. Poole data showed that EC-145057, EC-151568, EC-157568, EC-160885, EC-163605, EC-164670, EC-165395, EC-165690, EC-165700, EC-538153, EC-620376, EC-620382, EC-620401, EC-620406, EC-

620410, EC-620417, EC-620427, EC-620429, EC-631369, EC-631379, Pusa Ruby, Arka Abha, Akshaya and Anagha were resistant to fruit crack. Irregular watering from very dry to very wet can play a major role in fruit cracking. During rainy season evaluation, towards the ripening of fruits, after a long spell of rain a dry spell was observed. This can alter the moisture levels of the soil resulting in fruit cracking (Abbott, 1998).

EC-620378, EC-620387 and EC-631379 were found to have blossom end rot in both the growing structures during summer. In the summer season polyhouse recorded four genotypes with blossom end rot *viz:* EC-164263, EC-620378, EC-620395, Arka Saurabh. Rainshelter recorded five genotypes *viz:* EC-538153, EC-164263, EC-620417, EC-151568 and Arka Saurabh with blossom end rot. In the rainy season polyhouse recorded five genotypes *viz:* EC-249514, EC-620378, EC-620395, EC-164563 and Arka Saurabh with blossom end rot, whereas inside rainshelter nine genotypes *viz:* EC-249514, EC-521067 B, EC-528368, EC-620387, EC-620395, EC-620378, EC-620389, Arka Saurabh and Arka Alok were observed with blossom end rot. These findings agree with the reports of Brubaker (2016). Millones-Chaname *et al.* (2019) reported that screening for blossom end rot under high temperature drought conditions is an effective tool for the selection of resistant genotypes, since the trait had a direct correlation with stomatal density.

Pest attack was found to be less under polyhouse than in rainshelter for both the seasons. The rainshelter allows easy passage of pests without compromising the yield potentials (Cheema *et al*., 2014). This is also supported by the finding of Lekshmi and Celin, 2015 and Singh and Kumar, 2017.

5.1.1.5 Biochemical / Quality characters

The quality aspects studied in the present experiment were TSS, lycopene, ascorbic acid, acidity and chlorophyll content.

Significant difference was observed for genotypes for both the season and system. During summer under polyhouse the TSS was in the range between 5.4 (EC-631369) and 6.2 (EC-164563 and Arka alok), whereas inside rainshelter the range was between 5.3 (EC-165395) and 6.4 (EC-164263, EC-164563 and EC-620406). In the rainy season, polyhouse plants were in the range between 5.5 (EC-151568, EC-620395, EC-620429, EC-631369 and Anagha) and 6.3 (EC-249514), and rainshelter plants were in the range between 5.3 (EC-160885, EC-631379 and Anagha) and 6.2 (EC-157568). Tomato TSS was due to reducing sugars thus, any factor affecting sucrose accumulation (photosynthetic activity) would affect the concentration of glucose and fructose and alter the TSS (Rana *et al.*, 2014). The ranges are in accordance with the earlier reports of Akhile *et al*. (2016).

Lycopene content was higher for polyhouse produced fruits. In the pooled mean, under polyhouse and inside rainshelter, Arka Abha recorded maximum lycopene content (13.0 mg / 100 g fresh fruit and 12.0 mg / 100 g fresh fruit respectively). Lycopene synthesis was severely affected by the intense solar radiation, and radiation injury was caused due to the overheating on the irradiated tissue (Tilahun *et al*., 2017). This is in consonance with Singh and Kumar (2017) that, the polyhouse grown tomato was uniformly red coloured with very good appearance.

The ascorbic acid content was found to be in the higher range for rainshelter plants in both the seasons. In the summer evaluation under polyhouse the ascorbic acid was in the range between 16.4 mg / 100 g fresh weight (EC-631379) to 24.6 mg / 100 g fresh weight (Pusa Ruby) whereas, inside rainshelter the ascorbic acid content was in the range between 20.0 mg / 100 g fresh weight (EC-164670) and 26.1 mg / 100 g fresh weight (EC-528368). In the rainy season under polyhouse the ascorbic acid content was in the range between 16.8 mg / 100 g fresh weight (EC-620378) and 21.7 mg / 100 g fresh weight (EC-620401) whereas, inside rainshelter the ascorbic acid content was observed to be in the range between 17.6 mg / 100 g fresh weight (EC-151568) and 25.2 mg / 100 g fresh weight (EC-620382 and EC-163605). There reported a direct correlation with temperature and light intensity with ascorbic acid biosynthesis (Raffo *et al.,* 2006). This might have favoured rainshelter plants in both the seasons. This is further supported by the findings of Rana *et al.*(2014), reporting the range for ascorbic acid between 10 to 30 mg per 100 g of the fresh weight under protected cultivation. The activity of ascorbate oxidase vary in different genotypes and this largely influences ascorbic acid content (Parvej *et al.,* 2019)

The titrable acidity was in the range between 0.12 per cent (EC-620406) and 0.24 per cent (Arka Alok) for polyhouse and 0.17 per cent (EC-620401) and 0.37 per cent (EC-157568) for rainshelter in the summer evaluation whereas, in the rainy season the range was observed to be 0.13 per cent (EC-157568) and 0.24 per cent (EC-249514), under polyhouse and between 0.21 per cent (EC-164670) and 0.46 per cent (EC-249514) inside rainshelter. The acidity per cent was observed to be more in the rainshelter crops. The major acid content of the tomato is citric acid (Tilahun *et al*., 2017). The higher photosynthetic activity and high availability of photosynthates could improve the acidity levels of tomato (Murkute *et al*., 2018). The genotype EC-249514 could perform well under both the structures clearly indicating the superiority of the genotype.

Chlorophyll a, chlorophyll b and total chlorophyll were found to be high for the polyhouse crops for both the seasons. In the pooled mean, under polyhouse EC-620378 (1.16 mg / 100 g plant tissue) and inside rainshelter EC-165690 (0.45 mg / 100 g plant tissue), recorded maximum chlorophyll a content. For chlorophyll b the pooled mean revealed, under polyhouse EC-163605 (1.08 mg / 100 g plant tissue) and inside rainshelter EC-620410 (0.47 mg / 100 g plant tissue), the maximum content. Likewise, under polyhouse EC-620387 (2.06 mg / 100 g plant tissue) and inside rainshelter Arka Saurabh (0.86 mg / 100 g plant tissue), recorded maximum total chlorophyll content. The maximum availability of PAR is 40% less under polyhouse (Rana *et al*., 2014) than in the open field. But it is only 10% reduction in the rainshelter. Of the total radiations received

10% is reflected and 10% is transmitted, and approximately 80% is absorbed. From this only a small proton, 5%, is used for the biological activities. The remaining large portion is dissipated by transpiration and convection (Tilahun *et al.*, 2017). So for capturing the maximum light more chlorophyll pigment molecules are required. Under polyhouse, the genotype EC-620387 recorded highest chlorophyll a and total chlorophyll. The higher chlorophyll content is a favourable feature for polyhouse genotypes, since the plants under polyhouse has to produce more chlorophyll to survive (Cheema *et al*., 2014).

The biochemical characters analysis revealed the genotypes EC-249514, EC-620387 and EC-620401 with favourable traits.

5.1.1.6 Shelf life

Shelf life was observed to be more for fruits of polyhouse plants than for rainshelter plants in both the seasons. During summer, shelf life for polyhouse grown tomato was recorded in the range between 3.1 days (EC-160885) and 11.5 days (EC-620395), whereas, for rainshelter the shelf life was in the range between 3.2 days (Pusa Ruby) and 9.2 days (EC-620387 and EC-620401). In the rainy season the shelf life of polyhouse tomatoes were recorded in the range between 2.7 days (EC-528368) and 10.2 days (EC-164263), whereas for rainshelter the range was between 3.8 days (Pusa Ruby) and 9.1 days (EC-620410). For shelf life, even one day difference can be significant in the distant marketing. The ripening was affected by minor mutations in the ripening genes (Regassa *et al.*, 2012 and Kumar and Gowda, 2016). The difference in the shelf life could also be due to the difference in the transpiration and nutritional factors at the time of harvest (Prakash *et al*., 2019). In the pooled mean EC-620410 recorded highest value for pericarp thickness. The high values of pericarp thickness and low values of locule number could impart firmness to the fruit, which in turn can extend the shelf life (Kanwar, 2011).

5.1.2 Qualitative characters

The qualitative characters observed in the present investigation are fruit size, fruit shape, immature fruit skin colour, presence of green shoulders, mature fruit colour, fruit surface and blossom end fruit shape. The qualitative characters are genetical in nature. Besides being influenced by the genotype, some characters are also affected by the environmental conditions. The alterations in the physiological processes and the production of certain photoassimilates may affect the qualitative characters of the plant (Rana *et al.,* 2014).

Among the various qualitative characters, fruit size and fruit shape are very much important. They are important not only for the consumer but also for the transportation. The fruit size in fact depends on the average fruit weight. In the present study there were very small, small, medium and medium large fruits. More than half of the genotypes gave medium sized fruits (individual fruit weight between 30 g and 80 g). Salim *et al.* (2020) also reported variations in the fruit size of tomato. Fruit shape was the most promising trait which could be visualized by naked eye. In the present investigation flat round, slightly flattened, round, oval, heart shaped, banana type and plum shaped fruits were observed. Bhattarai *et al*. (2018) recorded various fruit shapes like flattened, slightly flattened, round, heart-shaped and high round fruits. As this trait was stable and not influenced by environment, this is highly useful in varietal identification and selection (Salim *et al.,* 2020). Greenish white, light green, green and dark green colours were observed for immature fruits. The variation in the colour was due to the variations in the concentration of pigments like chlorophyll, carotenoids and xanthophylls (Khachick *et al*., 2002). This might be attributed to the genotypic variations as well as environmental factors (Bhattarai *et al*., 2018). The green shoulders were present only in three genotypes *viz*; EC-249514, Arka Abha and Akshaya. The disorder was not noticed under polyhouse. This is in consonance with the finding of Salim *et al*. (2020). There was wide variation for fruit colour among the genotypes. Also there was difference between polyhouse and rainshelter fruits. The fruit colour varied among yellow, orange, red, crimson, pink, tangarine, yellow and red, tangarine, red and yellow, tangarine and red. The fruits on the polyhouse grown plants were mostly red or combinations of red coloured. The polyhouse fruits were more uniform red coloured (Singh and Kumar, 2017). The fruit surface was either corrugated or smooth. The blossom end fruit shape was either indented or pointed or flat. Round shaped flat bottom fruits were observed predominant in the genotypes. The same result was also proposed by Maria *et al.* (2014).

5.1.3 Correlation of reproductive traits

The success of any hybridization programme depends on the selection of parental lines. The main aim of this study was to develop F_1 hybrids with hotset characters and bacterial wilt resistance, which is suitable for protected cultivation during summer months. A suitable genotype for summer cultivation in a protected structure should be indeterminate with high pollen viability and fruit set per cent and capacity to yield 2-3 kg per plant, also uniform red ripe fruits with average fruit weight ranging 60-100g.

Fruit set per cent exhibited moderately strong, positive and significant correlation with pollen viability and number of fruits per cluster during early, mid and late stages of flowering. Flowers with exerted stigma exhibited negative significant correlation with pollen viability during early, mid and late stages of flowering and with fruit set per cent at the early stage of flowering. Inside rainshelter the correlation of pollen viability with fruit set per cent was strong positive and significant at the mid stages of flowering and weak, positive and significant during early and late stages of flowering. Fruit set per cent exhibited moderately strong, significant and positive correlation with number of fruits per cluster. Khapte and Jansirani (2014) also recommend strong and significant correlation between pollen viability and fruit set per cent (0.617). So they suggested selection of these traits for the improvement in the yield. In a stressed environment the reproductive traits determining the performance of the genotype were pollen viability, fruit set per cent and number of fruits per plant (Singh and Kumar, 2017). Moderately strong positive correlation was recorded between number of flowers per cluster and number of fruits per cluster (0.547) (Rani *et al*., 2008). Islam *et al* (2010) suggest any character having a direct positive effect on number of fruits per cluster can be considered for genotype improvement. Hence, the traits selected were flowers with exerted stigma, pollen viability and fruit set per cent.

5.1.4 Genetic variation of tomato genotypes under polyhouse and rainshelter

5.1.4.1 Coefficient of variation

The basic tool of bringing improvement in a crop is by exploiting the available variability. If the variability available in a population is largely due to genetic cause with least environment effect, the probability of getting superior genotypes is more. The yield improvement is not a single entity but highly associated with agronomic, morphologic and physiologic traits. The progress of breeding is primarily contributed by magnitude, nature and interaction of genes, and environmental variation emphasising the importance to partitioning the observed variability into heritable and non-heritable traits with suitable genetic parameters such as heritability, genetic advance *etc.* The genotypic and phenotypic coefficient of variation are useful in detecting amount of variability present in the genotypes whereas, heritability and genetic advance would help in determining the influence of the environment on the expression and the extent to which improvement could be possible through selection.

Under polyhouse condition high genotypic and phenotypic variances were observed for plant height at flowering, plant height at harvesting, leaf area, days to first fruit harvest, average fruit weight, yield per plant and crop duration. Inside rainshelter, plant height at flowering, plant height at harvest, leaf area, number of fruits per plant, average fruit weight, yield per plant and crop duration recorded high ranges for phenotypic and genotypic variance. A close association of genotypic and phenotypic variances were observed for certain traits under both the growing structures. This indicates the less effect of environment on these characters.

In the case of reproductive traits higher genotypic and phenotyoic variance were recorded for flowers with exerted stigma, pollen viability and fruit set per cent under both the structures. The phenotypic variance was found to be higher and the difference between phenotypic and genotypic variance were larger for these characters indicating the influence of environment on these traits. Phenotypic variance were found higher for flowers with exerted stigma and pollen viability for polyhouse plants and for pollen viability and fruit set per cent for rainshelter plants. The analysis of variance revealed significant mean square estimates for all characters indicating sufficient genetic differences among the genotypes used in the study, thus helpful in the development of superior varieties (Saravanan *et al.,* 2019).

In the present study high values of GCV and PCV (>20) were recorded for leaf area, days to first fruit harvest, number of fruits per plant, locule number per fruit, pericarp thickness, average fruit weight, fruit yield per plant and fruit yield per plot. In the case of rainshelter plants, leaf area, number of fruits per plant, average fruit weight and fruit yield per plot exhibit high PCV. In all these characters PCV was found to be higher than GCV indicating the influence of environment on these characters. Hasan *et al*. (2016) reported high degree of variation for yield and yield related traits. Among the quality traits the polyhouse plants recorded high PCV and GCV values for acidity, cholorophyll a, b and total. Rainshelter plants recorded high PCV and GCV values for chlorophyll a, b and total. Chandola (2015) also reported high GCV and PCV values for chlorophyll. Higher values of GCV and PCV for these characters revealed the scope for selection (Khan *et al.,* 2017). In both the growing structures, high GCV and PCV values were recorded for shelf life.

Among the reproductive traits under polyhouse, only number of fruits per cluster recorded high GCV and PCV. Inside rainshelter, flowers with exerted stigma and number of fruits per plant recorded high GCV and PCV. Somraj *et al.* (2017) also reported high GCV and PCV values for stigma exertion.

Under polyhouse condition, moderate GCV and PCV was recorded for internodal length, intercluster distance and lycopene. Inside rainshelter, plant height at flowering, plant height at harvest, internodal length, intercluser distance, lycopene and ascorbic acid recorded moderate levels of GCV and PCV (10-20%). Many other workers also reported the same range (Shashikanth *et al.,* 2010, Mohamed *et al.,* 2012 and Shankar *et al.,* 2013). Inside rainshelter, the reproductive traits *viz:* pollen viability, length of the style, anther length and number of flowers per cluster recorded moderate GCV and PCV.

Plant height at flowering, internodal length, plant height at harvest, days from anthesis to fruit maturity, days to first fruit set, crop duration, TSS and ascorbic acid under polyhouse exhibit low GCV and PCV. Days from anthesis to fruit maturity, days to first fruit set, days to first fruit harvest, crop duration, TSS and acidity inside rainshelter also expressed similar trend.

In the case of reproductive traits under polyhouse, pollen viability exhibited low GCV and PCV estimates, while length of the style and anther length showed low GCV and moderate PCV, indicating the influence of environment on these traits. The results were in consonance with the findings of Kumar and Thakur (2007). Wide range of variability could be observed among the traits studied, indicating the scope for selection of better genotypes.

5.1.4.2 Heritability and genetic advance

According to Johnson *et al.* (1955) and Panse and Sukhatme (1967) with the help of GCV and PCV it is not possible to determine the variability in a population. The total variability in a population can be due to heritable and non-heritable components. Hence, the magnitude of heritability is an important aspect of the genetic constitution of a breeding material. Heritability magnitude clearly indicates the reliability with which the genotype can be clearly recognized through its phenotypic expression. Heritability along with genetic advance is more meaningful and helps in predicting the effect of selection on phenotypic expression.

In the present study, under polyhouse condition high heritability was recorded for all traits except days to first fruit set, TSS, ascorbic acid and chlorophyll a and chlorophyll b. In the case of reproductive traits, high heritability was recorded for all traits except for flowers with exerted stigma, pollen viability and number of flowers per cluster. Inside rainshelter, high heritability was recorded for all traits except, days to 50% flowering, days from anthesis to fruit maturity, days to first fruit set, days to first fruit harvest, pericarp thickness and lycopene. Among the reproductive traits only flowers with exerted stigma recorded medium heritability. Saravanan *et al*. (2019) reported high heritability for plant height, number of fruits per plant, number of branches per plant, number of locules per fruit, average fruit weight and number of fruits per cluster.

Under polyhouse, days to first fruit set, ascorbic acid, chlorophyll a and chlorophyll b recorded medium heritability. Among the reproductive traits, flowers with exerted stigma, pollen viability and number of flowers per cluster recorded medium heritability. Inside rainshelter the traits *viz:* days from anthesis to fruit maturity, days to first fruit set, pericarp thickness and lycopene recorded medium heritability. These results agree with that of Mohamed *et al.* (2012). They recorded medium heritability for pericarp thickness, TSS, lycopene, ascorbic acid, acidity and chlorophyll content. Under polyhouse, low heritability was recorded only for TSS. Inside rainshelter low heritability was observed for days to 50% flowering and days to first fruit harvest.

Under polyhouse high genetic advance was recorded for locule number per fruit, pericarp thickness, fruit yield per plot, acidity, chlorophyll a, chlorophyll b, total chlorophyll and shelf life. Low genetic advance was recorded for plant height at flowering, days to 50% flowering, leaf area, days from anthesis to fruit maturity, days to first fruit set, days to first fruit harvest, number of fruits per plant, average fruit weight, fruit yield per plant and ascorbic acid. In the reproductive traits all characters except flowers with exerted stigma and pollen viability recorded high genetic advance. These traits recorded low genetic advance. Inside rainshelter all traits except plant height at flowering, days to 50% flowering, plant height at harvest, leaf area, intercluster distance, days from anthesis to fruit maturity, days to first fruit set, days to first fruit harvest, pericarp thickness, fruit yield per plant, crop duration, lycopene and ascorbic acid recorded high genetic advance. Low genetic advance was recorded for plant height at flowering, days to 50% flowering, plant height at harvest, leaf area, days from anthesis to fruit maturity, days to first fruit set, days to first fruit harvest, pericarp thickness, and ascorbic acid. In the reproductive traits flowers with exerted stigma and pollen viability recorded high genetic advance. These finding are in accordance with the reports of Mohamed *et al.* (2012) and Saravanan *et al*. (2019).

High heritability will be efficient in making selection based on good phenotypic performance but not necessarily mean high genetic gain of the character. High heritability coupled with high genetic advance will be more useful and efficient in selecting a genotype. In the present study high heritability along with high genetic advance was recorded for locule number per fruit, pericarp thickness, yield per plot, acidity, total chlorophyll and shelf life under polyhouse. In the reproductive traits, except pollen viability, all other traits recorded high heritability along with high genetic advance. Inside rainshelter internodal length, number of fruits per plant, locule number per fruit, average fruit weight, fruit yield per plot, TSS, acidity, chlorophyll a, b and total and shelf life recorded high heritability coupled with high genetic advance. In the reproductive traits, except flowers with exerted stigma and pollen viability, all other traits recorded high heritability with high genetic advance. This indicates the predominance of additive gene action for these characters (Saravanan *et al.,* 2019). Selection for the improvement could be achieved by simple methods like pure line selection, mass selection, SSD or bulk method following the hybridization and selection. High heritability with low genetic advance is recorded for plant height at flowering, days to 50% flowering, plat height at harvest, leaf area, days to first fruit harvest, number of fruits per plant, average fruit weight, fruit yield per plant and crop duration under polyhouse. In the reproductive traits, pollen viability recorded high heritability coupled with low genetic advance. Inside rainshelter, plant height at flowering, days to 50% flowering, plant height at harvest, leaf area and ascorbic acid recorded high heritability with low genetic advance. In the reproductive traits, pollen viability and flowers with exerted stigma recorded high heritability with low genetic advance. These characters may be governed by non-additive gene action (Saravanan *et al.,* 2019). Environment has least influence for the characters with high heritability and there could be greater correspondence between phenotypes and breeding value while selecting individuals.

Thus it can be concluded that simultaneous selection based on multiple characters having high estimates of heritability (> 60 %) coupled with genetic advance may be useful for the crop. These traits which exhibited high heritability in broad sense and high genetic advance as per cent mean are largely governed by additive gene action and hence there is further scope for effective improvement through selection.

5.1.5 Multivariate analysis (D^2 statistics)

Mahalanobis's generalized distance (D^2) can effectively measure genetic divergence. This measures the force of differentiation at the intra-cluster and inter-cluster levels and can provide a reasonable basis for the effective selection of genetically divergent parents for the hybridization programme. Hybridization between genetically divergent parents can bring wide variability and chance of transgressive segregation in the heterotic population (Singh *et al*., 2006; Ara *et al*., 2007). This will provide better scope to isolate superior recombinants. D^2analysis also quantifies the redundancy of accessions with respect to a particular trait or combination of traits (Lekshmi and Celin, 2015).

In the present study, 35 genotypes of tomato were subjected to D^2analysis based on the characters *viz*: flowers with exerted stigma, pollen viability, days to first fruit set, number of fruits per cluster, fruit set per cent, average fruit weight, pericarp thickness, number of fruits per plant and yield per plant. The analysis was done separately for polyhouse and rainshelter. Under polyhouse the genotypes were divided into seven clusters and inside rainshelter the genotypes were grouped into five clusters. The more number of clusters indicated the wide range of genetic diversity among the genotypes as suggested by Basavaraj *et al.* (2010), Evgenidis *et al.* (2011), Thamir *et al.* (2014) and Dar *et al.* (2015). Under polyhouse condition Cluster III included maximum number of genotypes (14) and inside rainshelter Cluster II included maximum number of genotypes (15). The heterogenous composition of the clusters indicate that there was no parallelism between genetic diversity and genetic divergence between growing structures. Yashavantakumar *et al*. (2009) grouped 70 tomato genotypes into seven clusters, Chernet *et al*. (2014) clustered 36 genotypes into six distinct clusters and Kiran *et al.* (2017) clustered 44 tomato genotypes into nine clusters.

Inter- cluster values were higher than intra-cluster values under both the conditions. This indicates the heterogenous nature of clusters among them. Lekshmi and Celin (2015) suggest homogenous nature within and heterogenous nature between the clusters from the clustering of 40 tomato genotypes into eight clusters. Under polyhouse condition, the inter-cluster distance was maximum between Cluster IV and Cluster V (2506.24), followed by Cluster II and Cluster IV (1678.56). Inside rainshelter, the inter-cluster divergence ranged between 937.87 (between Cluster III and Cluster V) and 3758.17 (between Cluster II and Cluster V). Under polyhouse, the intra-cluster divergence ranged from 0.0 to 123.96, the least being for Cluster VII including only EC-620429. Cluster IV had the highest intra-cluster divergence including EC-620401, EC-631369, EC-538153, EC-620406, EC-620417, EC-620410, EC-631379 and EC-620387. Inside rainshelter, the intra-cluster divergence ranged from 0.0 to 400.63. Cluster IV recorded maximum intra-cluster value. Cluster II containing fifteen genotypes followed. This indicates the heterogenous nature of genotypes even within the clusters. Kumar *et al.* (2016) also suggested comparatively higher intra-cluster values.

Depending on the breeding objective, the line selection differs in the clusters. This could be based on the genetic distance and mean value. Hazra *et al.* (2010) and Meena and Bahadur (2015) reported that the clustering pattern could be utilized in choosing parents for crossing. The higher intra cluster distance allows the selection from the same cluster since the divergence can promote the heterotic effect (Kumar *et al.,* 2016).

The cluster mean value also points to the degree of genetic diversity among the genotypes. Under polyhouse, the hotset characters *viz*: higher pollen viability and fruit set per cent and lower stigma exertion were recorded for Cluster IV. The same cluster also recorded higher average fruit weight and yield per plant. In the same manner hotset characters of higher pollen viability and fruit set per cent and lower stigma exertion were exhibited by Cluster II inside rainshelter. Hence, the lines were selected from these clusters. Under both the systems the testers were selected from three different clusters. Bacterial wilt resistant testers were selected based on the divergence and mean value. Reliable conformity is known on the basis of cluster mean value (Lekshmi and Celin, 2015). Inter-crossing among genotypes with better mean value will be effective for further crop improvement in tomato. Selection of the divergent parents based on their cluster distances would be useful in formulating comprehensive breeding strategy for developing superior hybrids or segregants (Kumar *et al.,* 2016 and Kiran *et al.,* 2017).

5.1.5 Selection index

Improvement of yield and other related traits is a basic objective in any breeding programme. Intercrossing of genotypes with better mean performance will be effectual for further crop improvement in tomato (Kumar *et al.* 2013). The reliable conformity for this can be known from the cluster means. Selection index provides appropriate weight age to the phenotypic values of two or more characters to be used simultaneously for the selection. It involves the discriminant function analysis meant for isolating superior genotypes (Fisher, 1936). Selection index formulation aids to increase the efficiency of selection of suitable genotypes by taking into account the important hotset characters along with yield attributes. Litty (2015) recommended selection index formulation for cowpea genotypes under polyhouse conditions of Kerala. Ghosh *et al.* (2018) recommended a selection based on suitable index, and commend it as more efficient than individual selection, based on individual characters, in 30 tomato genotypes in order to recommend for farmers.

In the present study selection indices were formulated based on five characters *viz:* pollen viability, fruit set per cent, flowers with exerted stigma, number of fruits per plant and average fruit weight. Sherpa *et al.* (2014) recommended fruit number and fruit weight as most important selection indices of tomato. Ruggieri *et al.* (2019) suggested for selection of hotset types, fruit setting, pollen viability, number of fruits and average fruit weight were important yield related traits. Selection indices were calculated separately for two structures. The result from two structures revealed the genotypes EC-164263, EC-538153, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369, which secured ranks within ten under both the structures could be considered as hotset high yielding genotypes among the thirty five genotypes screened. These promising candidates with hotset traits along with high yield potential could be functionally validated and can be involved in breeding programme to improve its performance under high temperature (Ruggieri *et al.*, 2019).

5.2 SCREENING FOR BACTERIAL WILT

Tomato is one of the most important solanaceous vegetable crops grown worldwide due to its acclimatization to wide variety of climatic regimes and high nutritive and economic value. Tomato crop suffers from several biotic and abiotic stresses. Among these bacterial wilt caused by *Ralstonia solanacearum* is one of the most devastating and wide spread disease of tomato especially in the humid tropics and the pathogen also attack more than 200 crop species including the high value vegetable crops like eggplant, chilli, capsicum, pepper and tobacco (Tiwari *et al.,* 2012). The yield loss from this disease can be in the range of 4.24 to 86.14%, while in tropics it can cause up to 100% (Kumar *et al*., 2018). The disease is widely spread in all states of India, but is a serious cause of yield loss in high rainfall and coastal areas like Kerala. Kerala is considered as a hot spot for this disease, due to high acidity, resulting in total yield loss.

Ralstonia solanacearum is an aerobic, non-sporing, gram-negative, soil borne plant pathogenic bacterium. It colonises in the xylem, causing bacterial wilt in a very wide range of potential host plants. Different number of races and biovars of this pathogen exist in the world but in India race 2 and 3 are more dominant. The first symptoms appear on leaves. During hottest part of day, youngest leaves start wilting. The wilted leaves remain green. Later on, wilting and yellowing of foliage leads to entire plant death.

Integrated management including crop rotation and use of chemicals have given only limited success (Vanitha *et al.,* 2009). Use of resistant varieties can be considered as a potentially possible method to overcome the disease (Tiwari *et al*., 2012). A thorough knowledge regarding the pathogen, pathogenicity, source of resistance and inheritance of resistance becomes most important to develop such stable resistant varieties. The screening for bacterial wilt by root dip was done for identifying the stable resistant lines from the screened accessions. The screening was used to identify the genotypes with stable resistance by several workers *viz:* Sharma *et al.* (2006) and Dutta and Rehman (2012) for bacterial wilt in tomato. Kim *et al.* (2016) evaluated disease severity of tomato accessions in 289 tomato accessions from 7 days to 14 days after inoculation of *R. solanacearum* under greenhouse conditions and suggested artificial screening as a successful method for the selection of parents in the resistance breeding programme. Kumar *et al.* (2018) reported line AR-4 with no wilting symptoms as highly resistant line and suggested as a promising parent for breeding experiments from artificial inoculation screening.

Several exotic collections from NBPGR *viz*., EC -179906, EC- 179908, EC -179909, EC- 191535 and EC- 191538 were suitable for heterosis breeding and development of open pollinated varieties through conventional breeding (Sharma *et al*., 2006). This is found to be in accordance with the finding of this work since most of the resistant genotypes of this study are from the collections of NBPGR. Arka Abha, earlier reported as moderately resistant (Sharma *et al.,* 2006), was found to be resistant in this study. The Line CH-195 (Sonali), CHDT-1 (EC-386021) and CHDT-4 (EC-339074) were promising and exhibited resistance in some years and moderate resistance in others (Sharma *et al.,* 2006). Environmental conditions and locations also influence bacterial wilt resistance (Aslam *et al.,* 2017). These lines with stable resistance and field performance can be used in the breeding programmes.

The testers for the breeding programme in the present study were selected from the highly resistant and resistant lines, *viz*: EC-165395, EC-165700, EC-521067 B, EC-620376, EC-620378, EC-620382, EC-620427, EC-620429, Arka Abha, and Anagha which was confirmed through root dip method.

5.3 PRODUCTION OF F_1 HYBRID SEEDS

Improved varieties and quality seeds are the most viable ways of improving agricultural production in a sustainable manner. Due to high fruit production potential of F_1 hybrids, due attention has been given in developing F_1 hybrids in crops. Hybrid technology is widely adapted in tomato due to the easiness of emasculation and pollination of tomato flowers. Since single pollination of tomato can produce many seed, the hand emasculation and pollination is commercially exploited technique in tomato (Joshi *et al.,* 2011). Developing F_1 hybrids is the best way to combine disease resistance and fruit qualities from breeding lines. A sound proposition of the selection of parents is based on the knowledge of gene action including the combining ability. The combining ability is estimated in three biometrical techniques, *viz.,* diallel, partial diallel and line × tester analysis. Line x tester is one best technique that provides information about general and specific combining ability of the parent, at the same time helpful in estimating heterosis and understanding gene action (Singh and Asati, 2011). The technique can identify the best combiners which could be utilised either to exploit heterosis in the F_1 or for accumulation of fixable genes for evolving a variety (Dar and Sharma, 2011). The first step of evaluating the potentials of new inbred lines to cross with a common parent, provides guidelines for the assessment of relative breeding potential of a parent (Singh, 2013).

Line x tester design crossing was performed using three lines and four testers. Three hotset genotypes with high yield potential were selected as lines and bacterial wilt resistant high yielding genotypes were selected as testers. The lines selected were 1 (EC-620401), 2 (EC-620406) and 3 (EC-620410). The testers selected were 4 (EC-620382), 5 (EC-620427), 6 (EC-620429) and 7 (Arka Abha).

5.4 EVALUATION OF F_1 HYBRIDS

Improved varieties and quality viable seeds are the most viable ways of improving crop production in a sustainable manner. F_1 hybrid seed production ensures high production potential in many crops. Due to easiness of emasculation and pollination of tomato flowers, developing F_1 hybrids is widely adopted in tomato and single pollination can produce many seeds. Hybrids are best way to combine disease resistance, fruit quality and higher yield from breeding lines.

The approach of line x tester analysis proposed by Kempthorne (1957) is based on the estimates of combining ability variances and effects. Line x tester analysis was carried out to evaluate the seven parents (three lines and four testers) and 12 F_1 hybrids on the basis of mean performance, general combining ability of parents and specific combining ability of hybrids. The three lines used in the study were EC-620401, EC-620406 and EC-620410, and four testers as EC-620382, EC-620427, EC-620429 and Arka Abha. The leading hotset hybrid Abhilash and leading rainshelter variety Akshaya were used as checks. Significant variation was observed among the genotypes as revealed from ANOVA.

5.4.1 Evaluation of parents

Combining ability is a good measure of genotype ability of crossing to produce superior hybrids. Combining ability provides information regarding cross combination for better heredity. The parents chosen in a cross could be assessed based on their mean performance and their general combining ability effects. The general combining ability effects represent the additive nature of gene action. A good general combiner parent could be characterized by its better breeding value when crossed with a number of other parents. In this study, the performance of the parents was studied based on mean value and *gca* effects.

5.4.1.1 Evaluation of parents under polyhouse

gca estimates under polyhouse condition revealed that among the lines 1 (EC-620401) was good general combiner for crop duration, days to 50% flowering, intercluster distance, days to first fruit set, days from anthesis to fruit maturity, days to first fruit harvest, locule number per fruit, TSS and ascorbic acid. 2 (EC-620406) was a good general combiner for plant height at flowering, leaf area, days to first fruit harvest, average fruit weight, yield per plant, yield per plot, TSS, lycopene, and chlorophyll b content. 3 (EC-620410) proved to be good for plant height at flowering, internodal length, plant height at harvest, locule number, pericarp thickness, average fruit weight, yield per plant, yield per plot, lycopene, cholorophyll a content and shelf life. In the case of testers, 4 (EC-620382) was a good combiner for intercluster distance, locule number per fruit, lycopene, chlorophyll a, b and total contents. 5 (EC-620427) was a good combiner for plant height at flowering, internodal length, plant height at harvest, leaf area, crop duration, days to 50% flowering, days to first fruit set, days from anthesis to fruit maturity, days to first fruit harvest, pericarp thickness, average fruit weight, TSS and shelf life. 6 (EC-620429) was a good combiner for crop duration, yield per plant, yield per plot, lycopene, ascorbic acid and shelf life. 7 (Arka Abha) was proved to be good combiner for the traits days to 50% flowering, intercluster distance, days from anthesis to fruit maturity, days to first fruit harvest, number of fruits per plant, locule number, pericarp thickness, average fruit weight, yield per plant, yield per plot, ascorbic acid, acidity and chlorophyll a and b content. Metwally *et al*., (2015) estimated the effects of six lines and six testers under polyhouse and reported that none of the parents was a good combiner for all traits. They reported positive significant *gca* effects for plant height, yield per plant, fruit number, fruit firmness, TSS, ascorbic acid and chlorophyll. Estimation of combining ability revealed significant *gca* estimates for internodal length, plant height at harvest, leaf area, crop duration, days to 50% flowering, days to first fruit set, locule number, pericarp thickness, average fruit weight, yield per plant and yield per plot (Kumar *et al.,* 2015). Similar results were also reported by Saleem *et al.,* (2009), Narasimhamurthy and Ramanjini (2013) and El-Gabrt *et al.,* (2014).

In the case of reproductive traits, *gca* estimates of 2 (EC-620406) and 3 (EC-620410) were proved to be good for pollen viability. 1 (EC-620401) and 2 (EC-620406) were good combiners for length of the style. 3 (EC-620410) was a good combiner for anther length. 1 (EC-620401) and 2 (EC-620406) were good combiners for flowers with exerted stigma. 1 (EC-620401) and 3 (EC-620410) were good combiners for number of flowers per cluster and number of fruits per cluster. 3 (EC-620410) was a good combiner for fruit set per cent. For the reproductive traits among testers, 4 (EC-620382), 6 (EC-620429) and 7 (Arka Abha) were good combiners for pollen viability. 6 (EC-620429) and 7 (Arka Abha) were good combiners for length of the style and 4 (EC-620382) and 5 (EC-620427) were good combiners for anther length. 5 (EC-620427) and 6 (EC-620429) were good combiners for flowers with exerted stigma. 4 (EC-620382) and 7 (Arka Abha) were good combiners for number of flowers per cluster and number of fruits per cluster. 7 (Arka Abha) proved to be good combiner for fruit set per cent. Sarvanana *et al*., (2019) reported positive significant *gca* effects for pollen viability and number of flowers per cluster under polyhouse. Dharmatti *et* *al*., (1997), Sekhar *et al*., (2010) and Shankar *et al*., (2013) also reported similar results for summer tomato crop.

From the above results 2 (EC-620406) proved to be a good combiners for fruit and quality characters and 3 (EC-620410) could be regarded as a good general combiner for vegetative, fruit and yield characters, quality characters and shelf life. 3 (EC-620410) also proved to be a good combiner for pollen viability, number of flowers per cluster, number of fruits per cluster and fruit set per cent. So the line 3 (EC-620410) could be regarded as a good general combiner for vegetative, reproductive, fruit and yield, quality characters and shelf life. In the case of testers, 5 (EC-620427) proved to be a good combiner for vegetative, fruit characters and shelf life, whereas 7 (Arka Abha) could be considered as a good general combiner for fruit and yield characters and quality traits. 5 (EC-620427) was a good general combiner for anther length and flowers with exerted stigma. 7 (Arka Abha) could prove to be a good general combiner for pollen viability, length of the style, number of flowers per cluster, number of fruits per cluster and fruit set per cent. Hence, 5 (EC-620427) and 7 (Arka Abha) are good general combiner for fruit and yield, quality and reproductive traits.

5.4.1.2 Evaluation of parents inside rainshelter

Inside rainshelter the line 1 (EC-620401) proved to be a good general combiner for days to 50% flowering, intercluster distance, days to first fruit set, days to first fruit harvest, number of fruits per plant, locule number and ascorbic acid. 2 (EC-620406) was a good combiner for plant height at flowering, plant height at harvest, leaf area, days from anthesis to fruit maturity, number of fruits per plant, locule number, average fruit weight, yield per plant, yield per plot, TSS and shelf life. 3 (EC-620410) was a good combiner for plant height at flowering, internodal length, plant height at harvest, leaf area, crop duration, locule number per fruit, pericarp thickness, average fruit weight, yield per plot, lycopene, chlorophyll content (a and total) and shelf life. Among the testers 4 (EC-620382) was a good combiner for plant height at harvest, intercluster distance, locule number, lycopene, acidity and cholophyll content (a,b and total). 5 (EC-620427) was a good combiner for plant height at flowering, internodal length, plant height at harvest, leaf area, crop duration, days to 50% flowering, days to first fruit set, days from anthesis to fruit maturity, days to first fruit harvest, locule number, pericarp thickness, average fruit weight, yield per plant, yield per plot, TSS and shelf life. 6 (EC-620429) was a good combiner for plant height at harvest, crop duration, intercluster distance, number of fruits per plant, pericarp thickness, average fruit weight, yield per plant, yield per plot, lycopene, ascorbic acid and shelf life. The tester 7 (Arka Abha) was a good combiner for plant height at flowering, leaf area, days to 50% flowering, intercluster distance, days from anthesis to fruit maturity, days to first fruit harvest, number of fruits per plant, locule number per fruit, pericrap thickness, average fruit weight, TSS, ascorbic acid and chlorophyll b. Kumari *et al*. (2007) reported positive significant *gca* effects for average fruit weight, number of fruits per plant, locule number per fruit, TSS, lycopene and shelf life in different protected structures. Gautham *et al*. (2018) reported positive significant *gca* effects for vegetative, fruit and yield traits for a 6 x 6 diallel cross of tomato under net house.

In the case of reproductive traits 2 (EC-620406) was a good combiner for pollen viability. 1 (EC-620401) and 2 (EC-620406) were good combiners for length of the style and flowers with exerted stigma. Among the lines 2 (EC-620406) was a good combiner for anther length, number of fruits per cluster, number of flowers per cluster and fruit set per cent. Among testers, for the reproductive traits, 5 (EC-620427) and 7 (Arka Abha) were good combiners for pollen viability. 6 (EC-620429) and 7 (Arka Abha) were good combiners for length of the style and 4 (EC-620382) was a good combiner for anther length. 4 (EC-620382) and 7 (Arka Abha) were good combiners for flowers with exerted stigma. For number of flowers per cluster and number of fruits per cluster 7 (Arka Abha) was a good combiner. 4 (EC-620382) and 7 (Arka Abha) were good combiners for fruit set per cent. Kumari *et al*. (2010) reported positive significant *gca* estimates for pollen viability, stigma exertion and fruit set per cent inside shade net house. Narasimhamurthy and Ramanjini (2013) suggested the combination of parents with positive significant *gca* estimates for pollen viability, number of flowers per cluster, number of fruits per cluster and fruit set per cent for yield attributing traits improvement.

In the case of lines 2 (EC-620406) and 3 (EC-620410) could be considered as good general combiners for vegetative, fruit and yield characters and shelf life. In the reproductive traits 3 (EC-620410) was a good combiner for anther length, number of fruits per cluster, number of flowers per cluster and fruit set per cent. Hence, 3 (EC-620410) could be regarded as a good combiner for vegetative, reproductive, fruit and yield characters and shelf life. The above results reveal 4 (EC-620382) was a good combiner for quality traits. 5 (EC-620427) and 6 (EC-620429) are good combiners for vegetative, fruit and yield characters and shelf life. 7 (Arka Abha) is a good combiner for vegetative, fruit and quality traits. In the reproductive traits 7 (Arka Abha) was a good combiner for all traits except anther length.

The comprehensive assessment of the parents by considering *gca* estimates for various characters studied revealed that among lines 2 (EC-620406) was a good general combiner for vegetative and fruit and yield characters and 3 (EC-620410) could be regarded as a good general combiner for vegetative, reproductive, fruit and yield, quality characters and shelf life. Among the testers 5 (EC-620427) and 6 (EC-620429) were good combiners for vegetative, fruit and yield characters and shelf life. 7 (Arka Abha) was a good combiner for vegetative, reproductive, fruit characters and shelf life.

None of the parents revealed significant and desirable *gca* effect for all traits studied simultaneously. Different parents exhibited significant *gca* effect for different traits. Singh *et al.* (2005), Muttappanavar *et al.* (2014) and Lekshmi and Celin (2015) also reported the same results for characters in tomato. As none of the parents proved to be good general combiner for all the traits studied simultaneously, the parents with desirable *gca* estimates for maximum traits could be selected for use in further breeding programme.

5.4.2 Evaluation of hybrids

5.4.2.1 Quantitative characters

Heterosis breeding has been used as a tool for genetic improvement in tomato. In tomato both relative heterosis (RH) and heterobeltiosis (HB) have been observed for plant height, total number of fruits per plant, average fruit weight, yield per plant, TSS *etc.* (Amin *et al.,* 2001, Sekhar *et al.,* 2010 and Metwally *et al*., 2015). Heterosis effect could be utilized in the creation of hybrids. The nature and direction of heterosis in crossing could provide information in the choice of potential parents to get the desired results. Better hybrids could be generally identified based on their mean performance, *sca* effect and standard heterosis expression. The hybrids obtained can be either used as F_1 hybrid to exploit heterosis or advanced to further generations for selecting superior recombinants with desirable gene combinations from the segregating populations (F_2 and others).

The mean performance, heterosis and *sca* effects of the hybrids were studied and the results are discussed below.

5.4.2.1.1 Vegetative characters

Vegetative characters are good signs of better growth in the early stages of crop. Under polyhouse condition for the trait plant height at flowering, the hybrid 3 x 7 recorded highest value. 3 (EC-620410) recorded highest significant positive *gca* for plant height at flowering. The same hybrid also recorded highest significant positive RH and HB. Eight hybrids recorded significant positive standard heterosis. Inside rainshelter also the same hybrid recorded highest mean performance. Highest significant *sca* effect was observed for 1 x 5 inside rainshelter. Similar results were also reported by earlier workers Sekhar *et al.* (2010), Muttappanavar *et al.* (2014) and Leskhmi (2015).

Under polyhouse condition, 3 x 7 recorded highest mean performance for internodal length. 2 x 4 and 3 x 5 recorded highest significant positive RH and HB. Six hybrids recorded significant positive SH and the highest was for 3 x 7.

EC-620410 recorded significant positive *gca* effect. Significant positive *sca* was also recorded for the same hybrid. Inside rainshelter three hybrids, 2 x 4, 3 x 5 and 3 x 7, recorded significant positive RH and two hybrids, 2 x 4 and 3 x 5, recorded significant positive HB. High mean performance of the crosses among poor general combiners are attributed to gene effects (Lekshmi, 2015).

Only one hybrid, 3 x 7, recorded significant positive RH and HB for plant height at harvest under polyhouse. Among the parents only 3 (EC-620410) and 5 (EC-620427) recorded significant positive *gca* effect. Significant positive *sca* effect was observed for four hybrids. Inside rainshelter significant positive RH and HB were not observed. All hybrids except one, 1 x 7, recorded significant positive standard heterosis. Five hybrids recorded significant positive *sca* effect.

Leaf area is an important factor in determining the photosynthetic efficiency of the crop. Under polyhouse, 2 x 5 and 2 x 7 recorded highest leaf area. Only one hybrid 2 x 7 recorded significant and positive SH. All hybrids except two recorded significant positive RH, indicating the clear dominance of better parent (Metwally *et al.,* 2015). 2 (EC-620406) and 5 (EC-620427) recorded highest significant positive *gca* effect among lines and testers respectively. 2 x 7 also recorded significant positive *sca* effect. Inside rainshelter also 2 x 7 recorded highest mean value among the hybrids. 2 x 7 and 3 x 5 recorded significant positive HB indicating the dominance of better parent (Saravanan *et al.,* 2019). The parents *viz:* 2 (EC-620406), 3 (EC-620410), 5 (EC-620427) and 7 (Arka Abha) recorded significant positive *gca* effect and the hybrid recorded highest significant *sca* effect. This indicates the dominant gene action involved and these traits could be improved by hybrid breeding. These results were also supported by Sekhar *et al*. (2010) and Shankar*et al.* (2013).

Among the hybrids 1 x 6, 3 x 6 and 2 x 6 recorded highest crop duration. 1 x 6 recorded significantly high RH and HB. Five hybrids recorded insignificant positive value indicating the dominance of better parent (Yadav *et al.,* 2013). Significant positive SH was not observed. 2 x 6 recorded significant positive *sca* effect. Inside rainshelter, 2 x 5 recorded highest mean value among the hybrids. Three hybrids recorded significant positive RH and HB, indicating the over dominance of better parent (Saravanan *et al.,* 2019). 2 x 5 and 3 x 7 recorded significant positive *sca* effect and 3 (EC-620410) and 2 (EC-620406) recorded significant *gca* effect.

In vegetative characters, 3 x 7 exhibited significant and positive RH and HB for plant height at flowering, plant height at harvest and significant RH for leaf area. The same hybrid recorded significant positive *sca* effect for plant height at flowering, internodal length and plant height at harvest, and for these traits 3 (EC-620410) recorded significant and positive *gca* effect. Inside rainshelter, 3 x 7 recorded significant and positive RH, HB and SH for plant height at flowering and plant height at harvesting and significant RH and SH for internodal length and significant SH for crop duration. The same cross recorded significant and positive *sca* effect for all traits except leaf area.

5.4.2.1.2 Flowering characters

Earliest flowering among hybrids was recorded for 1 x 7 both under polyhouse and inside rainshelter. Under polyhouse, significant negative RH was observed for three hybrids and HB was observed for two hybrids. Significant negative SH was not observed. Three hybrids recorded significant negative *sca* effect. Inside rainshelter significant negative RH and SH were observed for 1 x 7 and 2 x 5. Both the hybrids recorded significant negative *sca* effect. The g*ca* effect of 1 (EC-620401) and 7 (Arka Abha) under polyhouse and inside rainshelter were significant negative indicating additive x additive gene action (Fasahat *et al.,* 2016).

The minimum intercluster distance was recorded for 1 x 7 in both the growing structures. The hybrid also recorded significant negative RH, HB and SH in both the growing structures. Parents recorded maximum significant negative g*ca* effect in both the growing structures. In the earlier studies, Leskhmi (2015) reported the similar results.

Under polyhouse minimum flowers with exerted stigma was observed for 1 x 4, 3 x 7 and 2 x 7. RH and HB were not observed for flowers with exerted stigma. Inside rainshelter 1 x 4 and 3 x 6 recorded minimum flowers with exerted stigma. HB was observed for 2 x 4. Under polyhouse 1 x 4 and inside rainshelter 2 x 4 recorded significant and negative s*ca* effect. Under both the growing system significant negative g*ca* effect was observed for 4 (EC-620382).

For pollen viability 3 x 6 recorded significant positive RH and positive significant s*ca* effect under polyhouse. Inside rainshelter, 3 x 5 and 3 x 7 recorded significant and positive RH, HB and SH and three hybrids 2 x 5, 3 x 5 and 3 x 7 recorded significant and positive RH, HB and SH. Only 3 x 5 recorded significant positive s*ca* effect.

For length of the style 6 (EC-620429) and 7 (Arka Abha) recorded significant negative g*ca* effect under polyhouse, and significant negative s*ca* effect was observed for 1 x 7 and 3 x 7. Significant SH was observed only for 1 x 7 and 3 x 6. Inside rainshelter significant negative g*ca* effect was observed for 7 (Arka Abha) and significant negative s*ca* effect was observed for 1 x 5. Significant negative RH was observed for 1 x 5, 1 x 6, 1 x 7 and 2 x 6. SH was observed only for the crosses 1 x 5, 2 x 6 and 2 x 7.

Many hybrids recorded significant positive SH for anther length under both the growing structures. Significant and positive s*ca* effect was observed for 1 x 4 and 3 x 7 under polyhouse and for 3 x 7 inside rainshelter.

The number of flowers per cluster was maximum for 1 x 6 and 1 x 7 under polyhouse. None of the hybrids exhibited positive significant s*ca* effect under polyhouse. 3 x 5 and 3 x 7 recorded maximum number of flowers per cluster, and 3 x 5 recorded significant and positive HB inside rainshelter. Two hybrids, 1 x 6 and 2 x 5, recorded positive significant s*ca* effect inside rainshelter. 3 (EC-

620410) and 7 (Arka Abha) recorded positive significant g*ca* effect inside rainshelter.

The hybrid, 1 x 7 recorded the earliest fruit set under both the growing structures. The hybrid also recorded significant negative RH, HB and SH under both the growing structures. 1 (EC-620401) recorded significant negative g*ca* effect under both the growing structures. 1 x 7, 2 x 5 and 3 x 6 recorded significant negative s*ca* effect under both the growing structures. Saleem *et al.* (2009) reported at least one parent with significant negative g*ca* effect could improve the flowering traits.

In the flowering characters under polyhouse 2 x 5 recorded significant negative s*ca* effect for days to 50% flowering, intercluster distance and days to first fruit set under polyhouse. The same hybrid also recorded significant negative HB for days to 50% flowering and days to first fruit set indicating the over dominance of better parent. Inside rainshelter, 1 x 7, recorded significant negative s*ca* effect for days to 50% flowering, intercluster distance and days to first fruit set and 2 x 5 recorded significant negative s*ca* effect for days to 50% flowering and days to first fruit set. 2 x 5 recorded significant negative RH, HB and SH for days to 50% flowering and days to first fruit set. The same hybrid also recorded positive significant s*ca* effect for pollen viability and negative significant s*ca* effect for flowers with exerted stigma. Similar results were also reported by Premalakshme *et al.,* (2005), Duhan *et al.,*(2005) Yadav *et al*. (2013) and Saravanan *et al.,* (2019)

5.4.2.1.3 Fruit and yield characters

Under both the growing structures, days from anthesis to fruit maturity was minimum for 2 x 5. Negative significant s*ca* effect was also recorded for the same hybrid under polyhouse. SH was not observed under both the growing structures and 2 x 7 recorded significant negative RH and HB under both the structures. These finding were in agreement with Kansouh (2013).

For number of fruits per cluster, none of the hybrids recorded significant positive s*ca* effect under polyhouse. 1 x 6 and 1 x 7 recorded significant positive RH and HB. The hybrids, 1 x 7 and 3 x 5, recorded significant positive s*ca* effect inside rainshelter. 3 x 5 was also superior in mean performance over three stages inside rainshelter with significant positive RH. Maximum HB and SH were also observed for the same hybrid. This result was in accordance with the findings of Bhatt *et al*. (2004) in a 6 x 6 line x tester. Four crosses showed HB suggesting the over dominance. They were also observed with positive significant s*ca* effect. Yadav *et al*. (2013) and Saravanan *et al.,* (2019) also reported more crosses with HB and preponderance of over dominance.

The hybrids 1 x 5 and 3 x 6 recorded significant positive s*ca* effect under polyhouse for fruit set per cent. 1 x 5 was also superior in mean performance under polyhouse. The same hybrid could also record significant positive RH and SH under polyhouse. Inside rainshelter, positive significant s*ca* effect was recorded for 1 x 5. But the hybrid 2 x 5 was superior in mean performance. 3 (EC-620410), 4 (EC-620382) and 7 (Arka Abha) recorded significant positive g*ca* effect. 2 x 5 and 3 x 7 recorded RH, HB and SH. Narasimhamurthy and Ramanjini (2013) reported, from 24 crosses four crosses showed significant and positive HB and SH suggesting over dominance for number of flowers per cluster, number of fruits per cluster and fruit set per cent.

Days to first fruit harvest was minimum for 2 x 5 with maximum negative significant g*ca* effect under polyhouse. 1 x 7 and 2 x 5 recorded significant negative RH, HB and SH under polyhouse. Inside rainshelter, 1 x 7 was the first to harvest fruit with maximum negative significant g*ca* effect. The same hybrid recorded significant negative RH, HB and SH. Metwally *et al*. (2015) observed over dominance of better parent for this trait.

Under polyhouse, the hybrid 2 x 7 recorded maximum number of fruits per plant under polyhouse. s*ca* effect was maximum for 3 x 5. Significant positive RH, HB and SH were not observed. 1 x 4 was the best performer in the mean value with maximum s*ca* effect inside rainshelter. 1 x 4 and 3 x 7 recorded significant positive RH, HB and SH inside rainshelter. This result was supported by the finding of Al-Daej (2018).

Under polyhouse, 1 x 5 was superior in mean value and s*ca* effect with significant negative RH, HB and SH for locule number per fruit. Inside rainshelter, 1 x 5 and 3 x 7 were superior in mean performance with maximum significant negative s*ca* effect. These two hybrids also recorded significant negative RH, HB and SH. Premalakshme *et al.,* (2005), Duhan *et al.,* (2005) and Kumar *et al*., (2017) also reported the same for locule number per fruit.

2 x 5 and 3 x 7 recorded highest significant positive s*ca* effect for pericarp thickness under polyhouse. The same hybrids was also superior in mean performance and recorded significant positive RH, HB and SH. Inside rainshelter, 3 x 5, 3 x 7, 2 x 5 and 1 x 5 were better performing in mean value. Only 2 x 5 reported significant positive s*ca* effect. 2 x 5 and 3 x 5 recorded significant positive RH, HB and SH. This result was supported by Kumari *et al.* (2010), Kumari and Sharma (2011) and Gautham *et al.,* (2018).

Under polyhouse, 1 x 7 recorded highest mean average fruit weight and maximum significant positive s*ca* effect under polyhouse. 1 x 7, 2 x 5 and 3 x 4 recorded significant positive RH, HB and SH. 1 x 7 also recorded highest mean performance for yield per plant and yield per plot. s*ca* effect of yield per plant and yield per plot was highest for 3 x 4. 1 x 7 and 2 x 5 recorded significant positive RH and SH for yield per plant. Significant positive RH, HB and SH was not observed for yield per plot.

Inside rainsheter, 3 x 5 recorded maximum average fruit weight and 3 x 7 recorded maximum yield per plant and yield per plot. But the same hybrids failed to record significant positive s*ca* effect. 3 (EC-620410) and 7 (Arka Abha) recorded significant positive g*ca* effect for average fruit weight and 5 recorded significant positive g*ca* effect for yield per plant. Similar results were also reported for tomato under protected cultivation by Kumari *et al.* (2010), Kumari and Sharma (2011), Gautham *et al.,* (2018) and Saravanan *et al.,* (2019).

In the fruit and yield characters, 2 x 5 was better performing under polyhouse. Inside rainshelter, 3 x 5 and 3 x 7 were better performing. 2 x 5 was also superior in fruit set per cent, pericarp thickness and average fruit weight.

5.4.2.1.4 Biochemical characters

Tomato is universally treated as a protective food and there is a need to formulate breeding programme to develop high quality fruits. Under polyhosue condition, eight hybrids recorded RH, five hybrids recorded HB and four hybrids recorded SH for TSS. Exploitation of hybrid vigour for the improvement of TSS was suggested by Kumar *et al.* (2013). All hybrids except one, 1 x 5 recorded higher TSS than the lower TSS among the parents. Significant positive g*ca* effect was observed only for 2 (EC-620406) and 5 (EC-620427) and significant positive s*ca* effect was observed only for four hybrids. Inside raishelter, only 1 x 6 recorded TSS lower than the TSS of parents. 2 x 4 and 2 x 5 recorded significant positive RH, HB and SH. Most of the hybrids recorded insignificant negative value indicating the complete dominance of the poor parent (Agarwall *et al.,* 2014). Significant positive s*ca* effect was observed only for 2 x 4, 2 x 5 and 3 x 6.

Significant positive HB was not observed for hybrids for lycopene in both the growing structures. 2 x 4 and 3 x 6 recorded significant positive SH and 3 x 6 recorded significant positive RH under polyhouse. Considering s*ca* effect 3 x 6 was superior for both lycopene and ascorbic acid. Inside rainshelter, only significant positive SH was observed. Considering mean value, 3 x 4 was superior for lycopene and 3 x 6 was superior for ascorbic acid and considering s*ca* effect 2 x 7 was superior for both lycopene and ascorbic acid. Similar results were also proposed for lycopene and ascorbic acid by Singh and Asati (2011), Lekshmi (2015) and Gautham *et al.,* (2018).

Only two hybrids, 3 x 6 and 3 x 7, recorded significant positive RH under polyhouse for acidity. Three hybrids recorded significant positive s*ca* effect. Inside rainshelter, significant positive RH, HB and SH were not observed. Five hybrids recorded significant positive s*ca* effect. 3 x 7 exhibited significant positive RH and HB in both the growing structures for chlorophyll a. 2 x 4 and 3 x 7 expressed significant positive RH, HB and SH in both the growing structures for chlorophyll b. Both the hybrids recorded significant positive s*ca* effect for chlorophyll a, chlorophyll b and total chlorophyll in both the growing structures. These hybrids exhibited hybrid vigour and over dominance to their better parent (Metwally *et al.,* 2015).

In biochemical traits, 2 x 5 recorded significant positive s*ca* effect for TSS, ascorbic acid, acidity and cholorophyll b under polyhouse. The same hybrid also recorded significant positive RH, HB and SH for TSS. Inside rainshelter none of the hybrid was superior in all traits. However 3 x 6 recorded significant positive s*ca* effect for TSS, ascorbic acid and acidity. The hybrid also recorded significant positive RH, HB and SH for ascorbic acid. 3 x 7 recorded significant positive RH, HB and SH for cholorophyll a and cholorophyll b.

5.4.2.1.5 Incidence of pests and diseases

Among the 12 hybrids, bacterial wilt incidence was observed for four hybrids. Under polyhouse three hybrids *viz:* 1 x 6, 2 x 4 and 3 x 6 were categorized moderately susceptible. Inside rainshelter, 1 x 6, 2 x 5 and 3 x 6 exhibited moderately susceptible reaction and 2 x 4 exhibited susceptible reaction. The crosses involving bacterial wilt resistant parents generated bacterial wilt resistant progenies. This was in consonance with the findings of Yadav (2011) and Jyothi *et al.,* (2013). Resistance was ensured when both R protein and cognate *Avr* effectors were present in the plant immune system. Disease susceptibility occurs when one or both R/*Avr* partners were absent. An incomplete resistance results in the reduction rather than the eradication of the disease (Huet, 2014). Fruit cracking was observed for two hybrids 1 x 6 and 2 x 4. Mustafa *et al.* (2017) suggested the selection criteria for resistance to fruit cracking involve fruit diameter, thickness of the flesh, fruit hardness, fruit cracking index and water content of the fruit. Leaf minor and fruit borer infestations were not recorded under polyhouse, but observed inside rainshelter. The infestations observed were less than 20 per cent.

5.4.2.1.5 Shelf life

In both the growing system 3 x 6 was superior in mean performance. The hybrid recorded significant positive RH and SH under polyhouse and significant positive RH, HB and SH inside rainshelter. Significant positive s*ca* effect was also observed in both the growing structures. Thus the cross reflected over dominance towards better parent indicating the hybrid vigour. Kumar and Gowda (2016) observed the mean for shelf life of fruit was significantly different from parents in a cross involving five lines and two testers.

In the present study none of the hybrid was superior for all traits studied under both the growing structures. Increase in the yield is mainly due to increase in the number of fruits and average fruit weight (Ahmad *et al.,* 2011). Under polyhouse 2 x 5 recorded significant positive RH and SH for average fruit weight and yield per plant. The same hybrid recorded negative s*ca* effect and significant negative HB for days to 50% flowering and days to first fruit set. The same hybrid also exhibited significant positive s*ca* effect and significant positive RH, HB and SH for biochemical traits. The hybrid 3 x 5 recorded significant positive RH and HB for average fruit weight and number of fruits per plant inside rainshelter. The hybrid, 3 x 7, recorded significant positive RH and SH for average fruit weight. These two hybrids recorded significant positive RH, HB and SH for yield per plant, and 3 x 7 recorded significant positive RH and SH for yield per plot. 3 x 7 recorded significant positive RH, HB and SH and significant positive *sca* effect for most of the vegetative traits. Hence, the hybrid, 2 x 5 was found to be better performing under polyhouse and 3 x 5 and 3 x 7 were found to be better performing inside rainshelter.

5.4.2.2 Qualitative characters

. Variation in the fruit morphology is a prevalent characteristic among domesticated tomato. Morphological characters are important in the identification of individual plant at the same time helps in promoting the economic relevance. In the present study, the morphological features studied were fruit size, fruit shape, immature fruit skin colour, presence of green shoulders, fruit colour, fruit surface and blossom end fruit shape.

In the present study either medium or medium large fruits were observed. The parents selected for crossing also recorded medium large and large fruits. Brewer *et al.* (2007) recommended high heritability (> 60%) for fruit size. A prevalent morphological distinguishing feature of tomato is fruit shape. In the present study majority of the hybrids were observed with elongated fruits. Only two hybrids gave round fruits. Elongated fruit shape is a distinguishing feature of domesticated tomato from wild forms (Brewer *et al,*. 2007). The blossom end fruit shape was either flat or pointed in the study. Only three hybrids recorded pointed blossom end. Ku *et al.* (2008) reported high correlation coefficients between fruit shape index and other fruit traits. This recommended the presence of overlapping QTLs at *sun locus* including the joint multitrait OTL, and supported the notion that this locus has its role in controlling several fruit traits.

Immature fruit colour and mature fruit colour do not show much variation from the parents. The immature fruit colour was either greenish white or light green or green. Only three hybrids recorded green colour. Mature fruit colour varied from red, orange, tangerine, yellow and red and yellow, tangerine and red.

Lycopersocon species has been investigated by several workers (Sardon *et al.,* 2013 and Osei *et al.,* 2014) for fruit colour and they concluded simple inheritance and relatively fewer genes controlling fruit skin colour. The presence of more variability was evident from the variability of the initial material taken.

The result of differential growth process which occur probably in the formation of ovary or after anthesis during the formation of fruit can make changes in the fruit surface and fruit cross sectional shape (Brewer *et al,.* 2007). In the present study fruit surface was either corrugated or smooth. Tomato fruit quality and metabolites biosynthesis were affected by plant growing conditions (Diouf *et al.,* 2018). The high temperature reduced the formation of pigments. In the parents only the tester 7 (Arka Abha) observed to have green shoulders inside rainshelter. But none of the crosses involving 7 (Arka Abha) observed with green shoulders. The intensity of sunlight and foliage cover might have affected the presence of green shoulders.

5.4.2.3 Screening for bacterial wilt

The soil born bacterial wilt disease is the most devastating and wide spread disease of solanaceous vegetables in Karnataka, Kerala, Maharashtra, Orissa and West Bengal (Ambresh *et al.,* 2017). In the present study, all the twelve F_1 hybrids showed resistance to bacterial wilt on challenge inoculation. Kim *et al.* (2018) observed that use of resistant cultivars in the breeding program results in the resistant progenies. They observed the colonization of pathogen in the tap root and collar region 14 days after inoculation with no difference in the density of pathogen between resistant and susceptible lines. But the pathogen spread to aerial parts was reduced in the resistant cultivars. Acharya *et al.* (2018) suggested the disease was conditioned predominantly by single dominant gene in tolerant × susceptible crosses. Duplicate epistasis was also suggested in complex inheritance pattern of tolerance. Area under disease progress-curve suggested that cumulative disease progress was less in resistance or tolerant segregating population of tomato. In this situation they recommended modified bulk method of selection.

5.4.3 Gene action

Gene action measured by g*ca* and s*ca* variance is useful in deciding the inheritance of characters and there by helps in the selection of breeding method. The characters with greater g*ca* variance reflects the additive gene action for the trait involved. If s*ca* variance is greater non-additive gene action plays the role. For the characters with additive gene action simple selection can be employed and the characters with non-additive gene action heterosis breeding is useful as it is non-fixable. Griffing (1956) reported that the analysis of combining ability is a potential tool for identifying productive parents in the development of F_1 hybrids.

Information on the relative importance of general combining ability (*gca*) and specific combining ability (*sca*) are of great values in the breeding programme for the species which are amenable to the development of F_1 hybrids. The *gca* effects can be used for the choice of parents and for the isolation of elite germplasm. The *sca* effects represent the relative betterness and worseness that would be expected in the hybrid. Further it tantamount to consequence of intra-allelic (dominance) and inter-allelic interaction (epistasis) (Sprague and Tatum, 1942).

In the present study analysis of variance for combining ability with respect to yield revealed that *sca* variance was greater than g*ca* variance for all traits except internodal length, plant height at harvest, locule number per fruit, pericrap thickness, TSS, acidity and chlorophyll b under polyhouse, and lycopene, ascorbic acid, acidity and chlorophyll a inside rainshelter. Higher *sca* variance compared to *gca* variance indicated the predominance of dominance gene action (Angadi *et al.,* 2012).

Among the reproductive traits the *sca* variance was greater than g*ca* variance for all traits except, length of the style at late stage of flowering and anther length at early and mid stages of flowering under polyhouse, and for all traits except length of the style and anther length at the mid stage of flowering inside rainshelter. The reproductive traits *viz:* pollen viability, fruit set per cent and flowers with excerted stigma, occupies a special importance in hotset traits of tomato. Hanna *et al.* (1982) reported significant positive *sca* variance for fruit set per cent under high temperature growing condition. Metwally *et al.* (1996) reported both *sca* variance and g*ca* variance were highly significant for pollen viability and fruit set per cent suggesting both additive and non-additive genetics were important under high temperature conditions. Similar results were also reported by Ahmad *et al.* (2009). The variance components due to *sca* were higher in magnitude than *gca* indicating the predominance of non-additive gene action for all traits except number clusters per plant and number of fruits per cluster in a cross involving two heat tolerant and four susceptible tomato genotypes in a half diallel mating design (Habu *et al*., 2016). Hence, they suggested that selection will bring no or slow genetic improvement for heat stress. The result of the present was also in agreement with the finding of Zengin *et al.* (2015), Dagade *et al.* (2015) and Aiysha et al. (2016)

Under polyhouse for all traits except internodal length, plant height at harvest, locule number per fruit, pericrap thickness, TSS, acidity and chlorophyll b dominance variance was found to be higher than the additive variance. The average degree of dominance revealed the characters *viz:* plant height at flowering, leaf area, crop duration, intercluster distance, days to first fruit harvest, number of fruits per plant, lycopene, ascorbic acid, total chlorophyll and shelf life exhibit dominance gene action. Pericarp thickness, TSS, acidity and chlorophyll b exhibited partial dominance. For other traits the estimated value of dominance variance or the additive variance was negative. The negative value indicates more of recessive genes controlling the trait (Bhattarai *et al.,* 2016). This gives an increase in the mean at inbreeding (Yadav *et al*., 2017). Thus average degree of dominance could not be calculated.

Among the reproductive traits, dominance variance was found to be higher than the additive variance for flowers with excerted stigma at mid stage of flowering, anther length at late stage of flowering, number of flowers per cluster and number of fruits per cluster in the early, mid and late stages of flowering and fruit set per cent at the mid stage of flowering. The average degree of dominance revealed over dominance for flowers with exerted stigma at mid stage of flowering, anther length at late stage of flowering, number of flowers during early and late stage of flowering and number of fruits per cluster at early, mid and late stages of flowering. Partial dominance was exhibited by flowers with exerted stigma at late stage of flowering, length of the style at late stage of flowering, anther length at early and mid stages of flowering, number of flowers per cluster at the mid stage of flowering and fruit set per cent at the early stage of flowering. For other traits the estimated value of dominance variance or the additive variance was negative. Thus average degree of dominance could not be calculated. Similar results under polyhouse were unfolded by Dharmatti (1995), Kulkarni (2003), Lekshmi (2015), Goutham *et al.,* (2018) and Saravanan *et al.,* (2019) for vegetative, flowering, fruit and yield and biochemical characters. Non-additive gene action was proposed for biochemical characters by Mondal *et al.* (2010) and Shankar *et al.* (2013).

Inside rainshelter, higher additive variance than dominance variance was observed for TSS, lycopene and chlorophyll a. Inside rainshelter complete dominance was observed for pericarp thickness. Plant height at flowering, plant height at harvest, leaf area, days to 50% flowering, inter-cluster distance, days from anthesis to fruit maturity, locule number per fruit, average fruit weight, number of fruits per plant, yield per plant, yield per plot, chlorophyll b, total chlorophyll and shelf life were observed with over dominance. Crop duration, ascorbic acid and chlorophyll a were observed with partial dominance. For other traits the estimated value of dominance variance or the additive variance was negative. Thus average degree of dominance could not be calculated. In the case of reproductive traits, flowers with exerted stigma and pollen viability during early and mid stages of flowering and style and anther length at the early and late stages of flowering, number of flower per cluster at the late stage of flowering and fruit set per cent at the early stage of flowering exhibited over dominance. Style length and anther length at the mid stage of flowering exhibited partial dominance.

For other traits the estimated value of dominance variance or the additive variance was negative. Thus average degree of dominance could not be calculated. Non-additive gene action was reported for yield and related traits in tomato by Dutta *et al.* (2013). Bhattarai *et al.* (2016) suggested heterosis breeding to utilize dominant gene action for heat tolerance traits including pollen viability and total chlorophyll content in tomato. Yadav *et al.,* (2017) suggested over dominance for plant height and ascorbic acid and partial dominance for pericarp thickness. Similar results were also proposed by Yadav *et al.,* (2013), Amin *et al.,* (2017) and Chouhan *et al.,* (2019).

Hence it is concluded that heterosis breeding would yield better results in the improvement of traits involved since preponderance of non-additive gene action has been reported for most of the traits.

Hence, the present study revealed SCA variance components were higher than GCA variance for the major vegetative, flowering and reproductive traits, fruit and yield characters and biochemical traits. This indicated the preponderance of non-additive gene action. Considering GCA to SCA ratio and degree of dominance values, hybrid vigour could be exploited to develop high yielding heat tolerant tomato for off-season production.

The present study revealed that genotypes EC-620401, EC-620406 and EC-620410 can be chosen as hotset genotypes. Based on the mean performance RH, HB and SH, *sca* effects and disease tolerance, the cross combinations 2 x 5 was found suitable under polyhouse cultivation and 3 x 5 and 3 x 7 were suitable inside rainshelter cultivation under the prevailing weather conditions of Kerala (Plate 26 and 27).

5.5GENOMIC DNA EXTRACTION AND PCR ASSAY

The productivity and quality of the crop is affected by plant diseases in the different growth stages. The main limiting factor for the cultivation of tomato in the hot and humid tropics is the incidence of bacterial wilt caused by *Ralstonia solanacearum*. The pathogen invades through the wounds or the natural openings

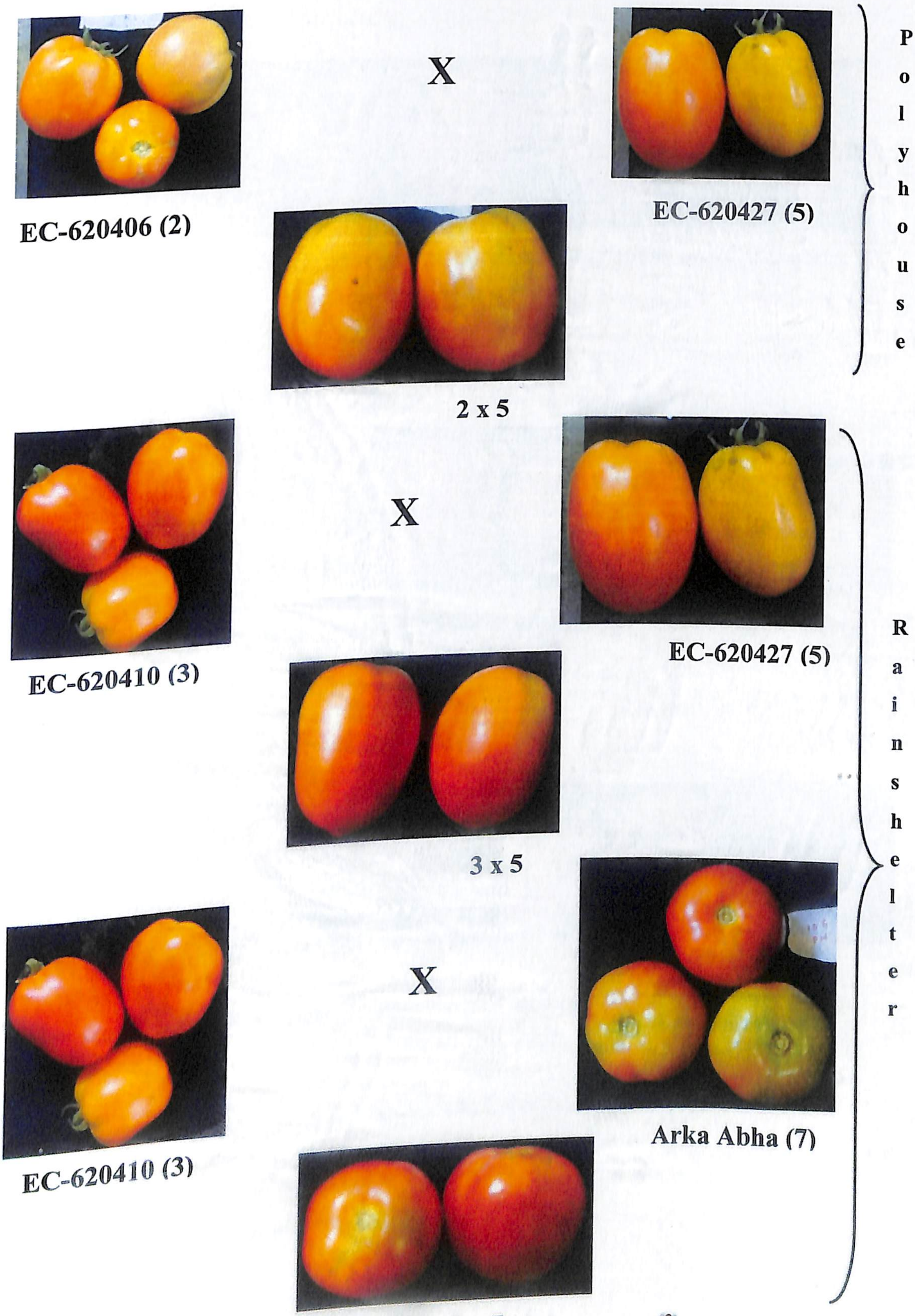


Plate 26: Promising crosses - parents and progenies

2 x 5: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

3 x 5: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

3 x 7: The plant, fruit from rainshelter and polyhouse and transverse section of the fruit

Plate 27: Better performing crosses

of the roots occurring while lateral roots grow horizontally from the taproot (Kim *et al.,* 2018). The pathogen continues to infect the xylem tissue resulting in the blockage of water flow from the vascular system of infected plant. The symptoms include rapid and complete wilting of the plants at any stage of the growth. Even though diverse strategies, like chemical and biological controls, are used to control this devastating disease, the best strategy is the use of resistant cultivars (Kim *et al.,* 2018).

The cultivar Hawaii 7996 has stable resistance to *Ralstonia solanacearum* established with a set of recombinant inbred derived from the cross between Hawaii 7996 and West Virginia 700 (Kim *et al.,* 2018). Using SSR markers in the mapping population two major QTLs, *Bwr-6* and *Bwr-12* located on the chromosome number 6 and 12 respectively, delimited by SSR markers were found to be closely associated with bacterial wilt disease (Wang *et al*., 2013). Such developments have provided opportunity for the selection of genotypes based on the markers rather than field evaluation.

SSR markers require only small amounts of DNA and the quality of DNA need not be as high as for most other advanced DNA assays (Gupta and Varhsney, 2000). In addition they provide an ideal tool for diversity studies due to their high information content, ease of genotyping through PCR, co-dominant and multi allelic nature and high discriminating power (Saravana *et al.,* 2014). In this study, the utility and reproducibility of the reported SSR markers were analysed for bacterial wilt resistance in tomato using the genotypes collected from NBPGR.

Eleven SSR primers were screened using bulked genomic DNA from five resistant and five susceptible sources to select the primers showing good amplification and polymorphism between resistant and susceptible cultivars. The number of bands obtained using SSR primers ranged from 1 to 4. Chandrakanth (2014) also reported 1 to 4 bands for SSR primers. Among the 11 primers only two primers produced polymorphism between resistant and susceptible genotypes.

The primers SLM6124 and SLM6-110 produced two distinct bands for resistant genotypes and four bands (two distinct and two fainted) for susceptible genotypes. Thus for primer SLM6124 bands at 400bp and 950bp and for primer SLM6-110 bands at 500bp and 700bp were found to be polymorphic between resistant and susceptible genotypes. All other primers gave monomorphism among the genotypes used in the study. Different sources of resistance and linkage of markers with the QTL may be the reason for not obtaining polymorphism to characterise genotypes with all the reported markers used in the study (Dheemanth *et al*., 2018).

Thus the SSR primers SLM6124 and SLM6-110 could be suggested for the validation of genotypes for bacterial wilt susceptibility and could be exploited for early elimination susceptible genotypes from a segregating population.

Summary

6. SUMMARY

The present investigation entitled "Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation" was conducted at the Department of Vegetable Science, College of Agriculture, Vellanikkara from 2018 January to 2020 January with the objective of identifying superior hotset and bacterial wilt resistant tomato genotype and developing hotset bacterial wilt resistant indeterminate F_1 hybrids suitable for protected cultivation. The study also tried to assess the suitability of available molecular markers linked to bacterial wilt resistance in tomato.

The investigation was completed in five experiments. In the first experiment 35 tomato genotypes, were evaluated for two seasons, one summer and one rainy season, under two structures, *viz:* polyhouse and rainshelter in RBD design with two replications. The aim of the experiment was to identify high yielding genotypes with hotset traits. The extent of variability, heritability and genetic advance of the genotypes were assessed from the pooled data for two structures. The relationship among the hotset associated traits was also worked out. Genetic divergence among the genotypes was studied using D^2 statistics. The selection indexing effectively ranked the genotypes for combined effect of hotset and high yield potential. In the experiment II the bacterial wilt resistant genotypes were confirmed with true resistance by challenge inoculation. In the experiment III the selected lines (hotset types with high yield potential) were crossed with selected testers (bacterial wilt resistant). The experiment IV was the field evaluation of F_1 hybrids along with parents and checks in RBD design with two replications under polyhouse and rainshelter. The experiment V was conducted to assess the linkage of available molecular markers with bacterial wilt résistance. The salient results of the investigation are summarized below.

Two genotypes EC-151568 and EC-165690 recorded taller plants with long internodes under both the structures. Thus, suitable for vertical space utilization under protected structures. Leaf area was observed to be more for EC-

631369 (136.4 mm^2) and Arka Saurabh (89.5 mm^2), under polyhouse and rainshelter, respectively. Under polyhouse, EC-620410 (140.9 days) and inside rainshelter EC-620406 (133.8 days) recorded the longest crop duration. In the pooled mean polyhouse plants exhibited better values for vegetative traits, plant height, leaf area and crop duration.

More conducive microclimate for the proper morpho-phenological transition of tomato was noted inside rainshelter, since earlier flowering was observed, EC-620378 (39.3 days) under polyhouse and EC-620429 (38.8 days) inside rainshelter. Under both the structures, Akshaya recorded the shortest intercluster distance (8.0 cm and 7.4 cm, respectively for polyhouse and rainshelter).

The pooled mean for polyhouse and rainshelter revealed less variation between structures for stigma exertion, indicating the presence of either of the stress (temperature or light), under both the structures. Under polyhouse EC-620401 (16.9%) and inside rainshelter EC-620410 (16.8%) exhibited minimum stigma exertion. The pooled mean also revealed the suitability of EC-620387, EC-620401, EC-620406, EC-620410 and EC-620395 for hotset characters, since they exhibited less stigma exertion under both the structures.

The number of flowers per cluster and pollen viability were observed to be more for rainshelter plants in the pooled mean. Under polyhouse EC-620410 exhibited maximum number of flowers per cluster (7.0). Inside rainshelter two genotypes, EC-165395 and EC-165690, exhibited exceptionally superior performance, 8.2 and 7.8, flowers per cluster respectively. EC-620476, EC-620401, EC-620406, EC-620410 and EC-620417 exhibited better flower production under both the structures. EC-164263 exhibited highest pollen viability (57.4%) under polyhouse, and EC-165690 exhibited highest pollen viability (61.5%) inside rainshelter. The genotypes *viz:* EC-165700, EC-528368, EC-

620376, EC-620395, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369 could maintain higher levels of pollen viability under both the structures.

The genotype EC-145057 exhibited short style under both the conditions, irrespective of season, indicating the hotset feature of the genotype. The genotype EC-164563 produced longest anthers for all three stages of flowering under both the conditions.

Fruit set was earlier inside rainshelter. In the pooled mean, under polyhouse EC-620378 and inside rainshelter Akshaya, were the earliest to set fruit (42.5 days and 40.2 days, respectively).

Rainshelter took less time for fruit maturation. In the pooled mean, under polyhouse EC-151568 (40.2 days) and inside rainshelter EC-164670 (36.6 days), recorded minimum days from anthesis to fruit maturity. Under polyhouse EC-164670 and Arka Abha (85.0 days) and inside rainshelter EC-620427 (81.6 days), recorded minimum days to first fruit harvest.

For number of fruits per cluster and fruit set per cent rainshelter plants recorded better values. For number of fruits per cluster under polyhouse EC-620401 and EC-620410 recorded highest value (4.1). Inside rainshelter EC-165690 recorded 4.5 fruits per cluster. The genotype EC-620401 could maintain the highest number of fruits per cluster under both the conditions (4.1 and 4.4, respectively). Under polyhouse, EC-620410 recorded maximum fruit set per cent (62.9%), whereas inside rainshelter, EC-620406 exhibited 63.4% fruit set per cent. The genotypes EC-164263, EC-620387, EC-620401, EC-620406 and EC-620410 consistently maintained high fruit set per cent irrespective of season and growing structure.

Under polyhouse, EC-151568 exhibited maximum number of fruits per plant (22.4). Inside rainshelter EC-165395 and EC-165690 exhibited exceptionally high number of fruits per plant (66.6 and 69.5, respectively). EC-620401, EC-

620406, EC-620410, EC-620417, EC-631369 and Akshaya maintained high number of fruits per plant under both the structures.

Less locule number per fruit and thick pericarp were observed for polyhouse plants for both the seasons. From the pooled mean, under polyhouse EC-521067 B (2.3) and inside rainshelter EC-528368 (2.6), recorded minimum locule number per fruit. Under polyhouse EC-620427 (0.91 cm) and inside rainshelter EC-620406 (0.82 cm), recorded maximum pericarp thickness. The genotypes EC-620417 (2.6 and 0.72) and EC-631379 (2.5 and 0.81) exhibited favourable combination of locule number per fruit and pericarp thickness.

The average fruit weight was observed to be more for rainshelter plants. under polyhouse EC-620387 (90.8 g) and inside rainshelter EC-538153 (94.8 g), recorded maximum average fruit weight. For yield per plant rainshelter plants recorded better values. Under polyhouse and inside rainshelter, EC-620410 recorded maximum fruit yield per plant (1525.2 g and 1866.0 g, respectively). The same genotype also exhibited highest yield per plot for both the structures (9.2 kg and 11.2 kg, respectively).

The pooled data of fruit and yield traits revealed the superiority of genotypes *viz;* EC-164263, EC-538153, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369 with acceptable average fruit weight and yield potential.

Under polyhouse EC-249514 and EC-521067 B (6.2) and inside rainshelter EC-164263 (6.3), recorded maximum TSS. Lycopene content was observed to be more for polyhouse produced fruits. In the pooled mean, under polyhouse EC-528368 and EC-538153 (12.9 mg / 100 g fresh fruit) and inside rainshelter Anagha 12.0 mg / 100 g fresh fruit respectively), recorded maximum lycopene content.

Irrespective of the season the ascorbic acid was recorded higher for rainshelter produced fruits. In the pooled mean, under polyhouse Pusa Ruby (22.6 mg / 100 g fresh weight) and inside rainshelter EC-163605 (24.9 mg / 100 g fresh weight), recorded maximum ascorbic acid content. The acidity per cent was observed to be more in the rainshelter produced fruits. In the pooled mean, under polyhouse Arka Alok (0.22 per cent) and inside rainshelter Arka Abha (0.41 per cent), recorded maximum acidity per cent.

Chlorophyll a, chlorophyll b and chlorophyll total were found to be high for the polyhouse plants in both the seasons. Under polyhouse EC-620378 (1.16 mg / 100 g plant tissue) and inside rainshelter EC-165690 (0.45 mg / 100 g plant tissue), recorded maximum chlorophyll a content. For chlorophyll b content, under polyhouse EC-163605 (0.36 mg / 100 g plant tissue) and inside rainshelter EC-620410 (0.12 mg / 100 g plant tissue), recorded maximum. Under polyhouse, EC-620387 (2.06 mg / 100 g plant tissue) and inside rainshelter Arka Saurabh (0.86 mg / 100 g plant tissue), recorded maximum chlorophyll total content.

Pest attack noted more inside rainshelter. Under polyhouse twenty genotypes were resistant to bacterial wilt, whereas inside rainshelter only ten genotypes exhibited resistance reaction to bacterial wilt. Twenty nine genotypes recorded no fruit crack infestation under polyhouse, whereas inside rainshelter it was twenty five.

Shelf life was observed to be more for fruits from polyhouse plants. In the pooled analysis, under polyhouse and inside rainshelter, EC-620395 recorded maximum shelf life (13 days and 10.3 days, respectively).

More than half of the genotypes gave medium sized fruits. Round shaped flat bottom fruits were observed to be predominant among the genotypes. The fruit colour varied among yellow, orange, red, crimson, pink, tangarine, yellow and red, tangarine, red and yellow, tangarine and red.

The present study revealed the suitability of rainshelters for the summer, and suitability of both polyhouse and rainshelter for the rainy season cultivation of tomato in Kerala.

The correlation analysis revealed strong significant and positive correlation among flowers with exerted stigma pollen viability and fruit set per cent under both the structures. Hence it is concluded that most critical characters for identifying the hotset genotypes were flowers with exerted stigma pollen viability and fruit set per cent.

High GCV and PCV values were observed for leaf area, number of fruits per plant, locule number per fruit, average fruit weight, fruit yield per plant, fruit yield per plot, chlorophyll a, chlorophyll b, chlorophyll total and shelf life under both the growing system. In the reproductive traits, flowers with exerted stigma, number of flowers per cluster and number of fruits per cluster exhibited high GCV and PCV values.

High heritability combined with high genetic advance was observed for locule number per fruit, yield per plot, acidity, chlorophyll total and shelf life and among reproductive traits for length of the style, anther length, number of flowers per cluster, number of fruits per cluster and fruit set per cent under both the growing structures.

The 35 genotypes of tomato were subjected to D^2 analysis based on the characters *viz*: flowers with exerted stigma, pollen viability, days to first fruit set, number of fruits per cluster, fruit set per cent, average fruit weight, pericarp thickness, number of fruits per plant and yield per plant. Under polyhouse the genotypes were divided into seven clusters and inside rainshelter the genotypes were grouped into five clusters. Under polyhouse, Cluster IV and inside rainshelter Cluster II included more of hotset types and considered for line selection. Testers were selected based on the cluster divergence, average fruit weight and bacterial wilt resistance.

In the present study selection indices were formulated based on five characters *viz:* pollen viability, fruit set per cent, flowers with exerted stigma, number of fruits per plant and average fruit weight. The result from two structures revealed that the genotypes EC-164263, EC-538153, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-631369, which secured ranks within ten under both the structures as hotset and high yielding genotypes.

The study revealed the genotypes EC-165395, EC-165700, EC-521067 B, EC-620376, EC-620378, EC-620382, EC-620427, EC-620429, Arka Abha, and Anagha exhibited either highly resistant or resistant reaction in artificial inoculation of wilt pathogen.

Line x tester design mating was performed between three hotset genotypes with high yield potential as lines (EC-620401 (1), EC-620406 (2) and EC-620410 (3)) and four bacterial wilt resistant genotypes as testers (EC-620382 (4), EC-620427 (5), EC-620429 (6) and Arka Abha (7)). The seven parents (three lines and four testers) and 12 hybrids were evaluated on the basis of mean performance, general combining ability of parents and specific combining ability of hybrids with check hybrid Abhilash and check variety Akshaya.

The comprehensive assessment of the parents by considering *gca* estimates revealed that among the lines 3 (EC-620410) and among the testers 7 (Arka Abha) could be regarded as a good general combiner for vegetative, reproductive, fruit and yield, quality characters and shelf life.

In vegetative characters, the cross 3 x 7 exhibited significant and positive RH and HB for plant height at flowering and harvest. The same hybrid recorded significant positive *sca* effect for plant height at flowering and harvest and internodal length under both the structures.

For the flowering characters, the cross 2 x 5, recorded significant negative HB for days to 50% flowering and days to first fruit set and negative s*ca* effect for days to 50% flowering, intercluster distance and days to first fruit set under polyhouse. Inside rainshelter also, 2 x 5 recorded significant and negative s*ca* effect for days to 50% flowering, days to first fruit set and flowers with exerted stigma. 2 x 5 recorded significant and negative RH, HB and SH for days to 50% flowering and days to first fruit set.

Under polyhouse the hybrid 3 x 6 exhibited significant positive RH in the for pollen viability with positive significant s*ca* effect. Inside rainshelter three hybrids 2 x 5, 3 x 5 and 3 x 7 exhibited significant positive RH, HB and SH for pollen viability. The cross, 3 x 5 recorded positive significant s*ca* effect.

In the fruit and yield characters, 2 x 5 was better performing under polyhouse. Inside rainshelter, 3 x 5 and 3 x 7 were better performing cross combinations.

For biochemical traits, 2 x 5 recorded significant positive RH, HB and SH for TSS and significant positive s*ca* effect for TSS, ascorbic acid, acidity and cholorophyll b under polyhouse. However 3 x 6 recorded significant positive RH, HB and SH for ascorbic acid and significant positive s*ca* effect for TSS, ascorbic acid and acidity inside rainshelter.

Results revealed that 4 (EC-620382), 5 (EC-620427), 6 (EC-620429), 7 (Arka Abha), 1 x 4, 1 x 5, 1 x 7, 2 x 5, 2 x 6, 2 x 7, 3 x 4, 3 x 5, 3 x 7, Akshaya and Abhilash were resistant to bacterial wilt under polyhouse. Inside rainshelter 2 x 5 exhibited wilting.

For shelf life the cross 3 x 6 was superior in mean performance in both the growing system (12.0 and 10.1 days, respectively). 3 x 6 recorded significant positive RH and SH under polyhouse and significant positive RH, HB and SH inside rainshelter and significant positive s*ca* effect in both the growing structures.

The hybrid, 2 x 5 was found to be better performing under polyhouse and 3 x 5 and 3 x 7 were found to be better performing inside rainshelter based on mean performance, heterosis, s*ca* effect and disease resistance.

In the present study either medium or medium large fruits were observed for hybrids. Majority of the hybrids were observed with elongated fruits. Mature fruit colour varied from red, orange, tangerine, yellow and red and yellow, tangerine and red.

In the present study, all the twelve F_1 hybrids showed resistance reaction to bacterial wilt on challenge inoculation in the seedling stage.

Analysis of variance for combining ability with respect to yield revealed that *sca* variance was greater than g*ca* variance for all traits except internodal length, plant height at harvest, locule number per fruit, pericarp thickness, TSS, acidity and chlorophyll b under polyhouse and lycopene, ascorbic acid, acidity and chlorophyll a inside rainshelter indicating the predominance of dominance gene action. Among the reproductive traits the *sca* variance was greater than g*ca* variance for all traits except, length of the style and anther length under polyhouse and for pollen viability, fruit set per cent and flowers with exerted stigma inside rainshelter, indicating the predominance of non-additive gene action.

Under polyhouse, plant height at flowering, leaf area, crop duration, inter-cluster distance, days to first fruit harvest, number of fruits per plant, lycopene, ascorbic acid, chlorophyll total and shelf life exhibited dominant gene action. Pericarp thickness, TSS, acidity and chlorophyll b exhibited partial dominance.

Among the reproductive traits over dominance was observed for flowers with exerted stigma, anther length, number of flowers per cluster and number of fruits per cluster. Partial dominance was exhibited by flowers with exerted stigma, length of the style, anther length, number of flowers per cluster and fruit set per cent.

Inside rainshelter complete dominance was observed for pericarp thickness. Plant height at flowering, plant height at harvest, leaf area, days to 50% flowering, intercluster distance, days from anthesis to fruit maturity, locule number per fruit, average fruit weight, number of fruits per plant, yield per plant, yield per plot, chlorophyll b, chlorophyll total and shelf life were observed with over dominance. Crop duration, ascorbic acid and chlorophyll a were observed with partial dominance. In the case of reproductive traits, flowers with exerted stigma and pollen viability and style and anther length, number of flowers per cluster and fruit set per cent exhibited over dominance.

It was observed that the cross 2 x 5 was suitable under polyhouse cultivation and the crosses 3 x 5 and 3 x 7 were suitable inside rainshelter cultivation under the prevailing weather conditions of Kerala.

The study also indicated the potential of SSR primers SLM6124 and SLM6-110 for the validation of genotypes for bacterial wilt susceptibility.

As a future line of work, the identified hotset genotypes can be used in the further breeding programmes for heat tolerance in tomato. Combined stress tolerance studies can be done for the development of genotypes with combined stress tolerance. Multilocation trials of identified hotset lines and crosses are to be done. Molecular markers can be exploited for early elimination of susceptible genotypes, thus exploiting gene pyramiding. Furthermore, molecular markers are to be validated for hotset.

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Appendices

Appendix I

Weather data during summer evaluation (January 2018 - May 2018)

Standard week no.	Air temperature (˚C)				Soil temperature (˚C)			
	At 9 00 am		At 2 00 pm		At 9 00 am		At 2 00 pm	
	PH	RS	PH	RS	PH	RS	PH	RS
3	26.5	27.0	33.0	37.2	26.8	27.5	29.5	32.8
4	26.5	27.6	33.8	37.2	26.5	27.5	29.5	32.5
5	27.8	28.2	34.5	37.5	27.1	27.6	30.6	33.4
6	28.1	28.7	35.4	38.2	27.6	27.9	31.2	33.7
7	29.6	30.2	36.2	38.7	28.7	29.6	35.2	34.2
8	29.8	31.3	37.2	39.9	29.0	30.2	33.1	34.8
9	31.6	33.2	37.5	39.8	30.1	30.8	33.8	35.1
10	32.2	34.7	37.6	40.7	30.2	30.5	34.5	36.0
11	32.5	34.3	36.4	39.7	30.5	30.7	32.6	35.4
12	30.8	31.3	34.5	37.8	28.7	29.2	30.2	33.5
13	31.3	33.2	37.5	39.6	30.3	30.8	33.5	35.7
14	31.2	32.8	36.1	40.5	30.3	30.4	32.6	36.2
15	31.8	33.6	37.0	41.2	29.8	30.5	31.8	35.4
16	32.3	34.3	37.1	40.2	30.2	30.5	33.7	36.8
17	32.8	35.2	37.6	41.3	30.8	31.2	34.3	37.0
18	33.2	36.4	37.5	40.7	30.2	31.8	34.2	36.4
19	33.7	36.2	36.9	39.5	30.6	32.2	32.8	35.7
20	33.4	35.8	36.5	38.9	30.1	31.4	33.4	34.2
21	33.7	36.1	36.4	39.2	30.6	32.0	32.6	35.2
22	31.5	32.3	35.2	38.1	28.8	29.7	30.2	33.8

Appendix I : Continued

Standard week no.	Relative humidity (%)				Light (µmol/m^2/sec)	
	At 9 00 am		At 2 00 pm		At 12 00 noon	
	PH	RS	PH	RS	PH	RS
3	70.5	66.4	42.1	60.5	526.0	894.0
4	71.5	67.5	43.8	59.7	612.0	920.0
5	71.2	67.2	43.1	59.2	626.0	984.0
6	72.5	66.5	45.5	58.6	542.0	846.0
7	79.7	67.4	43.4	57.5	621.0	980.0
8	73.3	68.1	44.7	56.3	436.0	942.0
9	68.5	63.5	49.2	61.2	420.0	886.0
10	74.2	65.7	47.5	59.8	382.0	743.0
11	74.5	68.5	49.5	57.5	447.0	823.0
12	78.8	76.2	45.2	59.3	347.0	679.0
13	73.6	68.4	46.4	58.2	412.0	783.0
14	79.2	68.7	48.5	56.7	457.0	726.0
15	73.5	68.5	47.3	59.5	392.0	871.0
16	74.5	69.2	47.5	60.3	454.0	742.0
17	74.3	68.5	46.3	57.4	387.0	623.0
18	75.7	70.3	45.2	58.5	467.0	847.0
19	75.2	64.6	48.7	57.5	421.0	732.0
20	75.5	67.5	46.3	59.2	379.0	626.0
21	80.2	74.2	59.2	66.7	452.0	712.0
22	86.7	75.5	64.5	68.2	411.0	689.0

Appendix I : Continued

Month	Rainfall (mm)
January	0.0
February	5.2
March	33.2
April	28.9
May	483.6

Appendix II

Weather data during rainy season evaluation (July 2018 - December 2018)

Standard week no.	Air temperature (˚C)				Soil temperature (˚C)			
	At 9 00 am		At 2 00 pm		At 9 00 am		At 2 00 pm	
	PH	RS	PH	RS	PH	RS	PH	RS
27	25.8	23.8	28.4	25.5	22.5	21.0	27.5	24.0
28	25.8	23.8	28.7	25.9	22.7	21.5	27.2	23.5
29	25.8	24.2	28.3	25.5	23.2	22.3	27.3	23.7
30	26.2	24.5	28.7	25.2	24.2	22.5	26.7	23.2
31	25.5	24.7	29.2	25.7	25.1	22.0	27.4	23.8
32	26.6	25.2	29.3	25.8	25.4	23.6	27.5	23.5
33	24.7	22.8	27.4	23.6	23.2	21.7	26.3	22.4
34	26.2	24.7	29.7	25.6	25.1	22.8	28.2	23.6
35	26.4	23.2	30.2	24.7	25.5	21.8	27.5	23.1
36	27.3	25.1	31.3	28.6	25.2	23.5	30.8	25.3
37	27.5	26.3	32.4	30.8	24.6	23.5	30.5	26.4
38	27.5	28.4	31.7	32.7	25.2	24.2	28.7	27.5
39	27.7	28.5	31.4	33.4	24.2	25.3	27.7	27.6
40	27.8	26.1	31.8	31.6	24.3	22.5	28.1	28.0
41	27.8	27.3	32.3	32.8	25.4	23.6	29.1	28.7
42	28.9	27.8	31.4	32.3	25.5	23.7	28.5	27.6
43	27.5	26.7	30.3	31.6	22.8	21.3	27.5	26.4
44	27.5	27.7	31.8	32.7	25.5	23.7	27.8	26.8
45	27.5	28.2	31.5	33.6	25.6	25.8	27.9	28.9
46	27.9	28.5	32.6	34.2	25.3	25.4	27.8	29.2
47	27.2	27.9	32.5	35.6	24.8	25.4	28.3	30.6
48	27.8	26.6	32.4	36.2	22.6	21.5	27.5	30.5
49	27.5	26.2	33.2	37.5	24.3	21.5	28.2	31.2
50	28.7	26.5	33.8	37.7	24.5	21.0	28.4	30.8

Appendix II: Continued

Standard week no.	Relative humidity (%)				Light (µmol/m²/sec)	
	At 9 00 am		At 2 00 pm		At 12 00 noon	
	PH	RS	PH	RS	PH	RS
27	82.7	90.0	73.2	88.5	225.0	387.0
28	83.6	89.4	74.5	87.5	214.0	287.0
29	80.5	89.5	72.3	86.7	287.0	313.0
30	81.2	88.4	73.2	87.5	276.0	312.0
31	82.3	90.7	72.5	89.3	298.0	326.0
32	82.7	91.3	73.6	89.7	282.0	317.0
33	86.4	91.2	77.5	89.4	206.0	287.0
34	87.2	92.4	76.5	90.5	234.0	256.0
35	86.4	91.3	74.2	89.6	218.0	237.0
36	84.2	88.8	71.6	77.3	287.0	327.0
37	81.3	82.4	68.3	72.1	342.0	486.0
38	80.4	79.6	66.4	69.7	357.0	521.0
39	77.5	76.4	63.7	65.8	338.0	613.0
40	74.3	75.4	66.5	67.4	292.0	586.0
41	76.5	74.3	62.5	63.4	326.0	643.0
42	79.2	75.6	66.7	61.4	247.0	487.0
43	78.6	73.2	67.5	62.8	314.0	587.0
44	74.3	70.5	61.5	59.6	328.0	593.0
45	76.8	71.3	57.6	61.3	384.0	612.0
46	74.8	73.5	53.2	59.7	412.0	693.0
47	75.2	72.3	52.6	59.5	322.0	554.0
48	79.4	83.5	55.7	54.6	427.0	674.0
49	74.2	84.2	53.5	55.0	394.0	728.0
50	72.5	83.8	51.8	55.4	426.0	756.0

Appendix II : Continued

Month	Rainfall (mm)
July	793.2
August	928.0
September	290.0
October	393.0
November	66.6
December	0.0

Appendix III

Weather data during F_1 hybrid evaluation (March 2019 - August 2019)

Standard week no.	Air temperature (˚C)				Soil temperature (˚C)			
	At 9 00 am		At 2 00 pm		At 9 00 am		At 2 00 pm	
	PH	RS	PH	RS	PH	RS	PH	RS
11	27.5	30.7	32.5	38.7	27.4	29.2	30.8	33.8
12	28.7	31.2	32.7	38.9	27.7	30.1	30.3	34.2
13	28.6	32.6	32.8	39.6	26.8	29.5	29.2	34.6
14	29.2	33.8	33.2	40.4	27.2	29.2	30.3	35.7
15	29.5	32.4	33.8	39.9	26.7	28.3	30.5	33.4
16	30.6	34.2	34.6	41.6	26.7	30.2	30.6	34.8
17	29.5	33.5	36.8	43.2	27.6	29.8	32.4	35.8
18	29.8	33.4	36.2	42.8	26.4	29.7	32.7	35.5
19	30.3	33.8	37.4	42.6	27.5	30.6	32.5	35.7
20	31.2	34.4	36.2	41.2	27.9	31.2	32.5	35.1
21	29.7	31.5	34.8	39.2	26.2	29.6	29.8	34.5
22	28.2	28.9	32.6	36.5	26.4	27.8	28.7	32.6
23	27.5	27.2	33.6	34.9	25.2	26.1	28.5	29.6
24	27.3	26.4	33.5	31.2	25.2	24.8	26.7	27.2
25	27.1	25.6	32.4	30.8	24.2	23.5	25.7	24.2
26	26.9	25.2	30.8	29.7	24.5	22.8	25.1	23.5
27	26.8	24.7	29.7	29.2	24.1	22.3	25.4	22.9
28	25.8	24.2	30.1	28.6	23.2	22.0	25.6	22.6
29	25.9	23.5	29.8	28.2	23.7	22.4	25.5	22.7
30	24.7	23.2	28.7	27.3	22.6	21.7	24.9	22.5
31	24.3	22.7	29.1	25.2	22.4	21.6	25.1	22.8
32	24.8	23.3	30.2	27.5	22.5	21.5	26.4	23.2
33	24.6	20.2	29.6	24.3	22.7	22.0	26.0	23.5
34	24.0	20.0	30.2	23.7	22.5	21.8	26.8	24.0
35	25.9	21.2	30.5	23.5	23.0	22.0	27.5	24.6

Appendix III: Continued

Standard week no.	Relative humidity (%)				Light (µmol/m^2/sec)	
	At 9 00 am		At 2 00 pm		At 12 00 noon	
	PH	RS	PH	RS	PH	RS
11	76.8	68.7	56.7	66.7	387.0	895.0
12	74.5	64.3	52.4	65.2	438.0	920.0
13	77.2	67.5	51.8	66.4	472.0	848.0
14	76.5	65.4	49.7	64.3	527.0	944.0
15	77.8	68.2	46.4	65.8	614.0	985.0
16	76.5	64.7	45.7	66.2	522.0	1237.0
17	77.2	65.8	43.2	63.2	635.0	1005.0
18	76.2	67.3	47.8	62.8	628.0	940.0
19	75.4	66.2	44.8	64.7	630.0	948.0
20	76.3	65.7	47.2	62.7	587.0	1145.0
21	77.2	68.5	54.3	62.7	623.0	987.0
22	79.2	68.5	57.8	65.8	648.0	922.0
23	79.6	67.5	58.7	66.8	528.0	833.0
24	82.4	76.5	64.2	72.5	413.0	735.0
25	85.7	84.5	69.2	80.6	315.0	621.0
26	83.7	89.7	74.5	86.5	285.0	488.0
27	85.2	91.2	73.6	89.2	327.0	511.0
28	86.6	90.4	77.4	89.7	335.0	326.0
29	84.8	92.1	76.2	90.1	245.0	387.0
30	86.1	91.5	75.6	89.6	233.0	315.0
31	84.2	90.2	76.1	89.4	216.0	248.0
32	82.3	88.5	74.2	87.3	225.0	265.0
33	86.5	92.3	76.5	88.6	217.0	289.0
34	84.2	89.6	75.4	82.4	288.0	343.0
35	80.7	85.4	70.5	79.5	328.0	530.0

Appendix III : Continued

Month	Rainfall (mm)
March	0.0
April	76.4
May	48.8
June	324.4
July	654.4
August	977.5

Abstract

Breeding hotset indeterminate tomato (*Solanum lycopersicum* L.) resistant to bacterial wilt suitable for protected cultivation

By

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ABSTRACT OF THE THESIS

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Doctor of Philosophy in Horticulture

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DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

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Abstract

The present investigation was undertaken to develop an indeterminate hotset tomato with bacterial wilt resistance through line × tester analysis. The experiment was conducted at the Department of Vegetable Science, College of Agriculture, Vellanikkara, Kerala Agricultural University, during the year 2018-2020.

The first experiment was the performance evaluation of 35 tomato genotypes for two seasons in the year 2018, summer evaluation from January 2018 and rainy season evaluation from July 2018, in two protected structures viz., polyhouse and rainshelter. Genotypes exhibited significant variation for vegetative, flowering, fruit, yield and biochemical traits under both growing structures across season. Under polyhouse during summer the genotypes EC-164263, EC-620387, EC-620401, EC-620406, EC-620410, and EC-620417 performed better for hotset traits (flowers with exerted stigma, pollen viability and fruit set per cent) and yield traits (average fruit weight, number of fruits per plant and yield). In rainshelter, the genotypes EC-165395, EC-165690, EC-538153, EC-620401, EC-620406, EC-620410 were superior. During rainy season, EC-164263, EC-538153, EC-620401, EC-620406, EC-620410, EC-631369 were superior under polyhouse, and EC-620395, EC-620401, EC-620406, EC-620410, EC-631369 and EC-631379 inside rainshelter, for hotset traits and yield traits. The pooled data of flowers with exerted stigma, pollen viability, fruit set per cent, number of fruits per cluster, days to first fruit set, average fruit weight, pericarp thickness, number of fruits per plant and yield per plant were subjected to multivariate analysis for discrimination of genotypes into clusters. Under polyhouse seven clusters and inside rainshelter five clusters were observed. The selection index was also applied for ranking of genotypes based on the hotset distinctions and yield attributes. The hotset genotypes with high yield potential, identified suitable for protected cultivation were EC-164263, EC-538153, EC-620387, EC-620389, EC-620401, EC-620406, EC-620410, EC-620417 and EC-

631369. The genotypes EC-620401 (1), EC-620406 (2) and EC-620410 (3) were selected as hotset line for the line × tester analysis.

In the second experiment the genotypes were tested for bacterial wilt resistance. The 35 tomato genotypes were sown in 98 well pro-trays holding sterilised soil medium. Another set of pro-trays holding the same medium were drenched with bacterial suspension with OD adjusted 0.8 to 1.3 at 600 nm and kept as the sick pro-trays. The twenty-one days old seedlings were used for inoculation through root dip method. With the help of sterilized scissors the tertiary roots of the seedlings were sectioned. The root clipped seedlings were dipped in bacterial suspension for thirty minutes. The inoculated seedlings were transplanted in the sick pro-trays. The entire experiment was conducted inside rainshelter with three replications. Each replication had five plants per genotype. Periodical observation on bacterial wilt symptom expression was taken from third day onwards. The disease index has revealed EC-620382 (0.20) and Arka Abha (0.20) as highly resistant. Nine genotypes *viz:* EC-165395 (0.24), EC-165700 (0.25), EC-521067 B (0.25), EC-620376 (0.30), EC-620378 (0.28), EC-620427 (0.21), EC-620429 (0.23), Akshay (0.21), Anagha (0.28) were resistant. From these EC-620382 (4), EC-620427 (5), EC-620429 (6) and Arka Abha (7) were selected as testers.

In the third experiment, the identified lines and testers were crossed and seeds were collected for twelve cross combinations. The fourth experiment was the evaluation of F_1 hybrids from third experiment during summer in two protected structures viz., polyhouse and rainshelter. The cross combinations were laid along with the parents and two checks viz., one check hybrid (Abhilash) and one check variety (Akshaya). The mean performance, relative heterosis (RH), heterobeltosis (HB), standard heterosis (SH) and combining ability studies were conducted. For vegetative traits, the cross combination 3 × 7 exhibited superiority in the mean performance with significant positive *sca* effects in both the structures. For flowering traits, the cross 2 × 5 exhibited significant positive *sca* effects for pollen viability and significant negative *sca* effects for flowers with exerted stigma with significant RH, HB and SH in both the structures. In the case of fruit and yield traits, the cross combination 2 × 5 exhibited negative significant *sca* effects for days to first fruit set and positive significant *sca* effects for pericarp thickness, average fruit weight and yield per plant with significant RH, HB and SH. Inside rainshelter, 3 × 5 and 3 × 7 noted significant *sca* effects and positive significant heterosis for fruit and yield traits. For biochemical traits, the cross combination 2 × 5 exhibited positive significant *sca* effects and positive significant RH, HB and SH for TSS, ascorbic acid and acidity under polyhouse. In the seedling stage, all cross combinations exhibited resistance reaction to bacterial wilt in the challenge inoculation. Depending on the mean performance, heterosis and *sca* effects, the cross combination 2 × 5 was recommended for polyhouse and the crosses 3 × 5 and 3 × 7 were recommended for rainshelter.

None of the parents revealed significant and desirable *gca* effect for all traits studied. The comprehensive assessment of the parents by considering *gca* estimates revealed that among lines EC-620406 is a good general combiner for vegetative, fruit and yield characters under polyhouse, and EC-620406 and EC-620410 could be regarded as good general combiners for vegetative, reproductive, fruit and yield, quality characters and shelf life inside rainshelter. In the case of testers EC-620427 and Arka Abha were good combiners for vegetative, reproductive, fruit characters and shelf life in both the growing structures.

Dominant gene action was observed predominantly for characters studied under both the structures. Plant height at harvest, days to 50% flowering, days to first fruit set, days to first fruit harvest, number of fruits per plant, average fruit weight, yield per plant, yield per plot, lycopene, ascorbic acid, shelf life, flowers with exerted stigma, pollen viability, number of flowers per cluster, number of fruits per cluster and fruit set per cent exhibited dominant gene action under both the structures. Pericarp thickness exhibited complete dominance inside rainshelter.

In the fifth experiment, available SSR markers were validated for bacterial wilt resistance. Two SSR markers, SLM6124 and SLM6-110, produced polymorphism between resistant and susceptible genotypes, two distinct bands for resistant genotypes and four bands (two distinct and two fainted) for susceptible genotypes.

In conclusion, the work indicates the change in the behaviour of genotypes under different protected structures in different seasons. Hence the selection of genotype and structure depending on the season is important. The heterosis breeding is effective in improving hotset traits in tomato. The hybridisation involving one resistant parent can generate bacterial wilt resistant off-springs. The application of molecular markers can effectively reduce the time and labour intensive field evaluation.