EVALUATION OF HYBRIDS OF INDETERMINATE TOMATO (*Solanum lycopersicum* L.) UNDER PROTECTED CULTIVATION

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"EVALUATION OF HYBRIDS OF INDETERMINATE TOMATO (*Solanum lycopersicum* L.) UNDER 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.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AVRDC	Asian Vegetable Research and Development center
BP	Better parent
CD	Critical difference
cm	Centimeter
d.f	Degrees of freedom
et al	And co-workers /co-authors
g	Gram
ha	Hectare
ha^{-1}	Per Hectare
HB	Heterobeltiosis
i.e.	That is
KAU	Kerala Agricultural University
kg	Kilogram
m	Meter
m^2	Square meter
MP	Mid parent
No.	Number
NBPGR	National Bureau of Plant Genetic Resources
RH	Relative heterosis
SE	Standard error
SED	Standard error difference
SEM	Standard error mean
SH	Standard heterosis
sp.	Species
t	tone
TSS	Total Soluble Solids
UV	Ultra violet
viz.	namely
^0C	Degree Celsius
%	Per cent

INTRODUCTION

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the globally leading popular and versatile vegetable belonging to the nightshade family Solanaceae. 'Poor man's orange', 'love apple' and 'golden apple' are its appellations which captures an interest towards it. It is a native of Peru, Equador, Bolivian region of South America and the domestication took place in Mexico. Tomato is consumed as raw, cooked or green fruits as pickles and preserves and ripe fruits in processed form like sauce, ketchup, puree, paste, soup, juice and powder which adds its impetus in processing industry (Sharma *et al*., 2015).

Tomato is the world's most cultivated vegetable crop after potato with an annual production of 163.03 million tonnes in an area of 4.82 million ha and a productivity of 33.90 t ha^{-1} and it tops the list of processed vegetables. India is the second largest producer of tomato with a production of 19.40 million tonnes from an area of 1.20 million ha and a productivity of 16.10 t ha^{-1} in 2013- 2014. (NHB, 2015).

It is universally treated as protective food as it is a rich source of vitamin A (320 IU/ 100g), vitamin C (31 mg/100g), , minerals (680 mg/100g) and antioxidants like lycopene, phenolics and flavonoids (Anand and Sankari, 2015). Lycopene, the red pigment in tomato fruit, is a powerful antioxidant and has garnered much attention because of the linkage between lycopene- rich diets and lower risks of certain cancers, heart disease and age related diseases (Hanson *et al*., 2004).

Tomato has great demand throughout the year and arrival of huge quantity of produce at a time leads to glut during favourable seasons and scarcity during unfavourable seasons leading to an unrealistic hike in prices during the unfavourable season (Yadav *et al*., 2014). But the year around production is not possible in open field condition as it is highly sensitive to several biotic and abiotic stresses which affect the production and quality of tomato. The protected cultivation is the best alternative to overcome the situation. It 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 during their growth period (Mishra *et al*., 2010). It enables the farmers to realize greater returns per unit

area with other benefits like earliness, higher productivity and quality, reduced incidence of pest and diseases, efficient utilization of water and fertilizers and longer harvest duration ensuring off-season supply to the market and quality produce for export demand can be achieved (Sharma *et al*., 2011).

High yielding indeterminate tomatoes with long growing season are preferred for protected cultivation. Indeterminate types are characterized by continuous vegetative growth in which the terminal bud ends in leafy bud producing inflorescence at every third or more internodes and are best suited for protected cultivation owing to its long growing season.

Now a days farmers are very much inclined towards hybrids because of its higher yield and quality (Kumar and Singh, 2016). But the lack of good hybrids in public sector, forced them to depend on the private sector hybrids. Hence, the development of indeterminate tomato hybrids and their evaluation over different seasons is highly essential and it will be a boon to the farmers. Of the various genetic approaches, heterosis breeding is the puissant way for developing a high yielding variety or hybrid by exploitation of hybrid vigour. Heterosis breeding has extensively been explored in the past for boosting yield in determinate types, but indeterminate types, which are dominant over determinate and semi determinate types, is the priority area of research in improving the productivity (Rattan and Bindal 2014). By assessing the extent of heterosis, the breeder gets an idea of its genetic control and it helps in deciding whether the hybrids are of economic value and worthy of exploitation (Shankar *et al*., 2014). Moreover heterosis breeding makes possible the attainment of a given breeding task in the most precise, shortest, and surest way, by combining the valuable dominant characters of both parents.

Knowledge of the nature and magnitude of association of yield with various component characters is a pre requisite to bring improvement in the desired direction as yield is a complex character (Meena *et al*., 2015). So the yield components having direct or indirect bearing on yield deserves considerable attention in a breeding programme.

Evaluation of the hybrids developed over seasons is an important task as it reveals the actual potential of the newly produced hybrid at different growing conditions. If similar trends are found over seasons then the hybrid can be stated as stable.

In view of the above facts, the present investigation was carried out at the Department of Olericulture, College of Agriculture, Vellayani with the following objectives

1. To evaluate the yield and quality of indeterminate tomato hybrids under protected cultivation for two seasons.
2. To study the correlation of different characters under study.
3. To estimate the heterosis of the F_1 hybrids.

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REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Tomato (*Solanum lycopersicum* L.) is one of the most economically important vegetable in India and the world. It is a rich source of antioxidants, mainly lycopene and β-carotene, Vitamin A, Vitamin C and minerals like calcium, phosphorous and iron (Saleem *et al*., 2013). It is in constant demand throughout the year all over the world and is a very important off-season vegetable that fetches great returns to the farmers. In non-traditional areas open field cultivation is not very profitable because of unfavourable weather especially. Thus, there is a great scope of tomato cultivation under polyhouse conditions.

Indeterminate cultivars with prolonged growing period are ideal for raising tomatoes inside the polyhouses. Plastic house technology and arrival of hybrids have increased the possibility of tomato cultivation in India. The advantages of hybrid tomato cultivars are earliness, increased vigor, uniformity in shape and size, high yield and resistance to specific pests and pathogens. Therefore, development of hybrids through heterosis breeding can be a potential alternative for substantial increase in tomato production. The recent literature with respect to protected cultivation, correlation and heterosis in tomato were reviewed and presented in this chapter under the following headings.

2.1 Protected cultivation of tomato

2.2 Correlation

2.3 Heterosis

2.1 PROTECTED CULTIVATION OF TOMATO

Protected cultivation is an improved agro technique being used worldwide to register three to four times increase in production. Cultivation of tomato in protected environment has been a very important technological advancement and is gaining momentum, especially for off season cultivation. Performance of indeterminate tomato varieties under greenhouse condition was investigated by

Singh *et al*. (2002), Arora *et al.* (2006) and Parvej *et al.* (2010) reported that polyhoused plants had higher number of flower clusters plant^{-1}, fruit clusters plant^{-1}, fruit cluster $^{-1}$, fruit weight, fruit size, and yield over open field. Protected cultivation offers protection from adverse climate and weather which ultimately influences the overall productivity and quality of vegetables (Wani *et al.,* 2011). Under protected cultivation the natural environment is modified to the suitable conditions for optimum plant growth and this altered growing conditions especially light and temperature are known to influence both composition and quality of tomato fruits which ultimately helps in the production of quality tomatoes suitable for export and domestic consumption (Rana *et al*., 2014). Protected cultivation offers distinct advantages of earliness, higher productivity and quality particularly pesticide residue free produce, besides higher returns to growers.

2.1.1 Vegetative Characters

Vegetative characters like plant height, height at flowering, node to first inflorescence, internodal length, leaf length and leaf width are greatly influenced by protected cultivation.

Bhatt *et al*. (2004) evaluated 66 F_1 hybrids and found that the hybrid Sel-7 x Mani Leima had highest plant height (179.33 cm) inside the polyhouse than EC 386037 x Sel-7 in open field (76.33 cm). Hazarika and Phookan (2005) found that plants under plastic rain shelter had higher growth rate compared to open condition. Tomato plants grown under shade exhibited better growth in terms of plant height and dry matter production compared to those in open field (Thangam and Thamburaj, 2008). Kumar and Arumugam (2010) reported that the polyhouse grown tomato exhibited maximum plant height (215.68cm), internodal length (13.20cm). He also noticed that the polyhouse grown tomato performed well with regard to all the characters compared to open field condition. Chapagain *et al*. (2011) studied eight tomato varieties under plastic house condition and found that the variety Srijana was the tallest (268.7cm). The plant height, number of branches, number of leaves per plant, internodal length, leaf area and leaf area index were

influenced by growing environment. Cheema *et al*. (2013) also reported an increase in plant height inside the net house than open field.

Rajasekar *et al.* (2013) reported all these vegetative characters were higher under shadenet house than open field. Pintu (2014) reported an increased plant height and leaf area index in chilli under polyhouse condition than open condition. The plant height (140 cm) of the crop grown under protected condition was more in comparison to the field grown (90 cm) crop (Rana *et al*., 2014). In an investigation, Singh *et al*. (2014), reported that plant height differed significantly among the hybrids at maturity stage due to varied genetic makeup of different tomato hybrids and the mean value of this trait ranged from 106.00-315.00cm under protected cultivation. Also Sharma and Singh (2015), reported a maximum plant height of 315.00 cm in the hybrid Himraja in his study.

2.1.2 Flowering Characters

Flowering characters include days to first flowering, days to fruit set, fruit set (%) and pollen viability (%).

Tomato crops grown under polyhouse conditions were earlier to flower than those grown in open field (Nagalakshmi *et al*., 2001). Khalid *et al.* (2002) reported a range of 30-35 days for days to first flowering in tomato under protected condition. Fruit set percent of tomato varieties is one of the important parameters for summer and rainy season tomato production, which determines the resistance and tolerance of a variety to a particular temperature and environment. Pressman *et al*. (2002) found that the continuous exposure of tomato to elevated temperature markedly decreased the pollen viability and reduced the number of pollen grains per flower. The effect of heat stress on pollen viability was associated with alterations in carbohydrate metabolism in various parts of anther during its development. The fruit set percent was highly affected by the varieties. Out of all the 27 cultivars studied by Hazarika and Phookan (2005), Yash recorded maximum fruit set percent (83.96 %). In a study conducted by Pandey *et al*. (2006), the highest fruit set per cent (93.9%) was observed in NSITH-162. In tomato, when the ambient

temperature exceeds 35^0c, vegetative growth, flowering and fruit set are adversely affected (Wahid *et al*., 2007). Singh *et al*. (2010) assessed the difference among heat tolerant and heat sensitive cultivars for fruit setting ability and ability to produce viable pollen under high temperature.

Chapagain *et al*. (2011) studied eight tomato varieties under plastic house condition and found that the variety Srijana had the shortest period (31 days) for flowering. Out of the 16 F_1 hybrids studied by Sharma *et al*. (2011), US-285 was earliest (28.00 and 29.33 days) for first flowering during first and second season and BSS-366 recorded maximum fruit set (86.21%) during first year. Akhtar *et al*. (2012) revealed clearly that the reproductive characters were highly sensitive to high temperature stress. Flower production capacity, pollen viability, germination and fruit setting ability reduced severely in all the genotypes under high temperature stress condition. Most of the genotypes showed marginally increased style length under high temperature condition as compared to normal season. In his study the pollen viability was reduced from 87.90% under autumn-winter to 36.61 % under spring-summer. According to Singh *et al.* (2014), the mean number of days from transplanting to first flower intiation in tomato varied from 23.16-44.00 and the fruit set per cent varied from 50.65-84.09% inside the polyhouse.

In a study conducted by Sharma and Singh (2015), the hybrid Lakshmi (23.16 days) and Apoorva (28.50 days) were earliest to flower and the hybrid Himraja exhibited maximum fruit set (84.09 %) under polyhouse conditions. According to the results of Kumar *et al*. (2015), he suggest that a major effect of heat stress due to high temperature (37/27°C) on pollen development is the reduction in starch concentration before anthesis, which leads to a decreased soluble sugar concentration in the mature pollen grains at anthesis and these events results in decreased pollen germination, pollen viability and ability to fruit set in tomato. He also observed a reduction in starch content was maximum in heat sensitive tomato genotype Floradade (68.4%) followed by H-86 (65.4%) at high temperature. Also the highest reduction of pollen viability and pollen germination was found in Floradade (87.8 and 85.1%) and H-86 (75.3 and 31.1%) respectively.

2.1.3 Fruit Characters and Yield

Fruits plant $^{-1}$, fruits truss $^{-1}$, fruit length, fruit girth, fruit weight, yield plant $^{-1}$ and yield plot $^{-1}$ are the characters reviewed here.

Nagalakshmi *et al*. (2001) stated that the tomato crops grown under polyhouse conditions had higher yield than those grown in open field. Khalid *et al.* (2002) conducted a study under plastic tunnel and observed that the cultivar Torquessa recorded highest fruit yield of 20.4 kg/m^2 followed by cultivar Jacinta (12.34 kg/m^2). Chaudhry *et al*. (2003) evaluated 12 indeterminate tomato hybrids along with Moneymaker for yield and quality aspects and the highest fruit yield m $^{-2}$ was recorded in Jiafen No. 15. According to Bhatt *et al*. (2004) the cross Azad T-2 x DARL-64 (3.700) had highest yield plant $^{-1}$(kg) inside the polyhouse than Mechin x EC 386023(2.480) outside and the cross Hawaii-7998 x EC 386037 had 191.67 and 134.67 number of fruits plant $^{-1}$ inside the polyhouse and open field respectively. Out of all the 27 cultivars studied by Hazarika and Phookan (2005), Yash recorded the the maximum yield plant $^{-1}$ (1.76kg/plant). Singh *et al*. (2005) evaluated the performance of six tomato cultivars under greenhouse condition for two years and reported that the cv. R-144 (Daniela) had the maximum number of fruits truss $^{-1}$ (5.6 and 5.4) and highest yield (5.8 and 5.6 kg/plant) during first and second year respectively and the heaviest average fruit weights (145 and 140g) was given by cv. FA-574.

Chaudhry *et al*. (2006) evaluated five exotic tomato hybrids along with a cultivar Moneymaker and the maximum yield of 13.16 kg m $^{-2}$ was recorded in Mamotaroyork hybrid and it was recommended to be grown under plastic tunnel to get an early tomato crop. Farooq *et al.* (2006) also reported highest fruit yield of 13.16 kg m^{-2} in cultivar Mamotoroyork and 9.44 kg m^{-2} in cultivar Chinese Hybrid. In a study conducted by Pandey *et al*. (2006), the highest number of fruits (6.8) was observed in NSITH-162. Sudhakar and Purushotham (2009) evaluated different F_1 hybrids of tomato for higher yield. In his study, all the growth characters varied significantly among different tomato hybrid and the early maturing hybrid Lakshmi

produced the highest number of fruits plant $^{-1}$(20.13). In the case of tomato, number of fruits plant $^{-1}$ (43.49), average fruit weight (99.43 g) and fruit yield plant $^{-1}$ and total yield was the highest (4.32 and 45.67 kg) in polyhouse (Kumar and Arumugam, 2010). Chapagain *et al*. (2011) reported that the fruits of the US-04 were largest (5.78cm) among the tested varieties, however, average fruit weight was higher in Manisha (61.94gm) and the variety All Rounder produced the highest marketable fruit yield (86.5 t ha^{-1} yield). Cultivation of tomato under the polyhouse produced 136.12 per cent more yield ha^{-1} and 188.93 per cent more fruits plant^{-1} compared to open field cultivation (Kanwar, 2011). In an investigation, Sharma *et al*. (2011) found that BSS-366 recorded maximum average number of fruits cluster^{-1} (9.53 and 10.12) and fruits plant^{-1} (160 and 169) during both the years of study and Naveen 2K+ recorded highest fruit weight (73.33 and 74.17 g) and yield plant $^{-1}$ (3.23 and 3.81 kg).

Cheema *et al*. (2013) evaluated 26 indeterminate tomato hybrids and found that number of fruits cluster $^{-1}$, number of fruits plant $^{-1}$, average fruit weight, and total fruit yield plant $^{-1}$ were higher inside the net house than open field. Farooq *et al*. (2013) studied 17 indeterminate tomato hybrids in plastic tunnel and observed that the check Sahel had maximum number of fruits plant^{-1} (30.26) and fruit length (7.89 cm) and NTT-01-08 had maximum fruit diameter (8.85 cm).Two local hybrids NTT-04-08 and NTT-12-08 were the highest yielder (2.77 kg plant $^{-1}$) but the maximum individual fruit weight of 170.63 g was recorded in NTT-05-08.

The tomato plants grown in polyhouse climate produced about 50% higher fruit yield (90 t ha-1) than the tomato plants grown in open field conditions (54 t ha-1).The significantly higher yield in the plants grown under polyhouse condition was associated with the production of higher number of fruits (38) with greater length (4.4 cm) and diameter (5.4 cm) and fruit weight (68 g) than over the plants grown in the open field (Rana *et al*., 2014). Sharma and Singh (2015) evaluated 14 fresh tomato hybrids under polyhouse and observed that maximum number of marketable fruit plant $^{-1}$ (58.53) and maximum fruit yield ha $^{-1}$ (1080.00 q). Apoorva recorded maximum fruit diameter (5.00 cm) and fruit girth (17.26 cm). Rupali

produced the highest individual fruit weight of 71.010 g and the hybrid Hill Sona maximum fruit length (8.91 cm). He also noted that many folds increase in fruit yield might be due to the hybrids and growing condition in polyhouse.

2.1.4 Quality Characters

In the last decades, quality concerns have become increasingly important worldwide and many investigations were conducted to improve theses aspects. The important quality characters include Total Soluble Solids (TSS), lycopene and ascorbic acid. Total soluble solids content is one of the most important quality parameters in processing tomato cultivars. Tomatoes having higher TSS content are better suited for the preparation of processed products. Total solids content of cultivated tomato amount to 4.5 to 8.5% of its fresh weight, though this percentage can be much higher in some wild species (Bertin *et al*., 2000). The antioxidant potential of tomato is contributed by a group of antioxidant biomolecules including lycopene, ascorbic acid and flavonoids. (Kaur *et al*., 2004). The red pigment in tomato (lycopene) is now being considered as the "world's most powerful natural antioxidant" (Ilahy *et al*., 2011) and ascorbic acid content determines the nutritional status of tomato varieties.

Ahluwalia *et al*. (1996) reported that quality of tomato obtained from greenhouse condition was better compared to open field condition. Zhu, *et al.* (2003) observed that the tomato cultivar Puhong 909 had maximum TSS content (4.5%) under the multispan greenhouse. In an investigation, Bhatt *et al*. (2004) reported that the highest TSS, lycopene (mg/100g) and ascorbic acid (mg/100g) were 07.60 (BL·342 x Sel-7); 6.33 (EC 386032 x BL-342), 09.50 (EC 386037 x BL-342); 7.70 (EC 386037 x BL-342) and 37.11 (BL-342 x EC 386023); 35.56 (Hawaii-7998 x Sel-7) inside and outside the polyhouse respectively. Hazarika and Phookan (2005) observed that Pusa Ruby and Arka Shreshta recorded the maximum TSS and the cultivar DRD-8014 exhibited the highest ascorbic acid (16.56 mg/100 g). He also noted that this higher TSS in these cultivars may be due to enhanced deposition of solids and more conversion of organic acids to sugar. Experiments conducted by Singh *et al*. (2005) under poly tunnel revealed that Sel-11 had

maximum TSS (5.02%), Sel-4 had maximum ascorbic acid (35.204 mg/100ml of juice) and Punjab Kesri recorded maximum lycopene content (2.491mg/100g).

Mahajan and Singh (2006) conducted a study on tomato under low cost naturally ventilated greenhouse and this greenhouse tomato fruits were superior to fruits of open field crop for fruit size, TSS content, ascorbic acid content and p^H. He also reported a significant variation in TSS among the cultivars ranging from 4.24 to 6.54 per cent. Dar and Sharma (2011) studied 60 genotypes and observed maximum ascorbic acid content in genotype CGNT-14 (37.80 mg/100g) which was on par with CGNT-10 (36.53mg /100 g). The mean value of the population for ascorbic acid content was 27.04 mg/100g. Purkayastha and Mahanta (2011) reported that the total soluble solids content ranged from 3.60 to 5.40 ^{0}Brix inside the polyhouse. In a study conducted by Sharma *et al*. (2011) the hybrid BSS-366 exhibited maximum total soluble solids (5.43 and 5.37 ^{0}B), ascorbic acid (28.39 and 32.43 mg/100g) and lycopene content (3.19 and 3.24 mg/100g) during both the years under low cost plastic greenhouse. The observations recorded by Cheema *et al*. (2013) revealed that the TSS content (6.25%), ascorbic acid content (21.25mg/ 100ml of fruit juice) and lycopene content (6.40mg/100g were higher inside the net house than the open field. Singh *et al*. (2014) reported a range of 4.90-7.98^0 Brix for the TSS content. In a study conducted by Sharma and Singh (2015) the hybrid Heemsohna had the highest Vitamin C content (15.63 mg/100g) and the hybrid Himraja had highest total soluble solids (7.98 ^{o}Brix) under polyhouse condition.

2.1.5 Pest and Disease Incidence

Under open field coditions, vegetables were highly susceptible to insect (white fly, mites, aphid, fruit fly, borers, cutworm, hoppers and beetle) attack, which caused about 30-40 per cent loss in vegetable yield (Satparthy *et al*., 1998; Singh, 1998). Protected structures act as physical barrier and play a key role in integrated pest management by preventing spread of insect pests and viruses causing severe damage to the crop (Singh *et al*., 2003). Kittas *et al*. (2009) studied the influence of shade on disease incidence on tomato, and observed a reduction of about 50 per cent incidence of disease than that under open field condition. Singh

et al. (2009) reported a minimal incidence of fruit borer and vector white fly in tomato plants grown under polyhouse structure.

Singh *et al*. (2012) conducted an experiment on insect-pest incidence in tomato and capsicum under open field and polyhouse conditions. The results revealed that the incidence of insect-pest was minimum under polyhouse condition as compared to open field condition. Sringarm *et al.* (2013) also reported that insect infestation was lowest inside greenhouses than outside.

2.1.6 Physiological disorders

The major physiological disorders of tomato inside the polyhouse include blossom end rot, fruit cracking and stigma exertion. Blossom end rot is the appearance of brown water soaked lesion at the blossom end mainly because of calcium deficiency and sudden change in rate of transpiration. Fruit cracking occur due to irrigation after long dry spell or exposure of fruit to sun or boron deficiency or genetic factor which is to be inherited polygenically. Singh *et al*. (2003) and Singh *et al*. (2006) reported variation in blossom end rot incidence among tomato varieties grown under greenhouse condition. Stigma exertion occurs mainly due to high temperature during flowering stage. Singh *et al*. (2010) reported 11.31% to 80.67% stigma exertion in his study.

2.2 CORRELATION

Improvement in yield based on multiple traits is always better than based on yield alone. Adequate knowledge about the magnitude and degree of association of yield with its attributing characters or components is of great importance to breeders. Correlation coefficient is statistical measure which is used to find out the degree and direction of relationship between two or more variables. Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for generic improvement in yield (Nagariya *et al.*, 2015).

In a study on 24 tomato genotypes, Dhankar *et al.* (2011) observed a positive correlation between number of fruits plant $^{-1}$ and fruit yield. Harer *et al.* (2003) reported very high and significant correlation coefficient between yield and fruit weight. Kumar *et al.* (2003) reported that number of fruits plant $^{-1}$ was positively correlated with the yield and the pericarp thickness has positively and significantly correlated with plant height, fruit number plant $^{-1}$ and yield in tomato. Singh *et al.* (2004) after evaluation of 92 genotypes of tomato found that number of fruits plant^{-1} and number of fruits cluster^{-1} was highly significant positive correlation with yield. Fruit weight showed significant positive association with fruit yield (Asati *et al*., 2008). Prashanth *et al*. (2008) studied 67 genotypes and reported that total yield plant $^{-1}$ was positively and significantly associated with early yield plant $^{-1}$, fruit volume, average fruit weight, polar diameter of the fruit, number fruits plant $^{-1}$ and fruit set percent. Rani *et al.* (2008), also reported that the yield contributing traits like plant height, fruit weight and quality traits such as lycopene, pericarp thickness, acidity, and ascorbic acid had positive association with yield.

Rani *et al*. (2010) conducted a study in 23 hybrids of tomato and reported that pericarp thickness, fruit weight, acidity, lycopene and ascorbic acid were positively and significantly associated with yield plant $^{-1}$, while number of fruits plant $^{-1}$ was associated negatively. Islam *et al.* (2010) reported very high and significant correlation coefficient between yield and fruit weight. Dar *et al*. (2011) reported that yield ha $^{-1}$ was positively correlated with number of fruits plant $^{-1}$, fruit yield plant $^{-1}$, average fruit weight, lycopene content, fruit pH, total soluble solid, pericarp thickness and number of locules fruit $^{-1}$. However negative correlation was observed with β-carotene and ascorbic acid at genotypic as well as phenotypic level. The correlation analysis revealed that total fruit yield plant $^{-1}$ was correlated significantly and positively with number of fruits plant $^{-1}$, fruit weight and total sugar (Kumar and Dudi, 2011). Tiwari and Upadhyay (2011) reported that the days to first flowering showed positive and significant correlation with days from transplanting to fruit set and fruit yield.

Correlation studies revealed that fruit yield had significant positive correlation with number of fruits plant $^{-1}$, fruit length, fruit diameter and fruit weight

and negative correlation of days to flowering and days to first harvest on yield plant $^{-1}$ suggested indirect selection for earliness for yield improvement. (Khan and Samadia, 2012). Kumar *et al*. (2013) reported that the number of fruits cluster^{-1}, number of seed fruit^{-1}, average fruit weight and number of fruits plant^{-1} had significantly positive correlation with fruit yield plant $^{-1}$. Patel *et al*. (2013) reported a significant positive correlation of fruit yield plant $^{-1}$ with harvesting duration, number of harvesting, number of fruits plant $^{-1}$, fruit length, fruit width, average fruit weight and total soluble solids also a negative significant correlation was observed with days to initiation of flowering, days to 50% flowering and days to first harvest.

Fruit yield plant^{-1} was positively and significantly associated with number of fruits plant^{-1} fruit width and yield plot $^{-1}$. However, fruit yield plant $^{-1}$ was negatively and significantly correlated with days to last fruit harvest and shelf life. (Reddy *et al*., 2013). Fruit yield had positive and significant correlation with plant height, number of primary branches plant $^{-1}$, number of flower clusters plant $^{-1}$, number of fruits plant $^{-1}$, fruit width, fruit length, average fruit weight, pericarp thickness, number of locules fruit $^{-1}$, and fruit yield plant $^{-1}$ (Mahapatra *et al*., 2013). Correlation analysis revealed that, fruit yield plant $^{-1}$ (g) exhibited significant and positive correlation with number of fruits plant $^{-1}$, fruit set per cent, fruit weight and polar diameter of fruit (Meena and Bahadur, 2014). Yield and contributing characters had significant positive association with the harvest duration, plant height, number of fruits per cluster (Sharma and Jaipaul, 2014). Khapte and Jansirani (2014) reported that fruit set per cent, number of primary branches, number of flower trusses plant $^{-1}$, number of fruits plant $^{-1}$, fruit length average fruit weight, fruit firmness, total soluble solids and pericarp thickness were positively and significantly associated with yield plant $^{-1}$.

Fruit yield had positive and significant correlation with plant height, number of secondary branches plant^{-1}, days to 50% flowering, days to 50% fruit setting, days to first flowering, days to fruit maturity, average fruit weight and T.S.S and it was observed that with increase in plant height, there was corresponding increase in number of primary branches plant^{-1} and number of flowering clusters plant^{-1}

(Prajapati *et al*., 2015). Twenty parental genotypes of tomato were studied by Ullah *et al*. (2015) and observed a significant correlation of fruits plant $^{-1}$, fruit weight, fruit diameter and locule number fruit $^{-1}$ with fruit yield plant $^{-1}$. Plant height showed non-significant negative association with individual weight of fruit and fruit cluster^{-1} disclosed non-significant negative association with length of fruit and individual weight of fruit but non-significant positive association with plant height, shelf life of tomato and yield plant $^{-1}$ (Rahman *et al*., 2015).

2.3 HETEROSIS

Heterosis in tomato was first observed by Hedrick and Booth (1968) for higher yield and more number of fruits. Since then, heterosis for yield, its components and quality traits were extensively studied. Choudhary *et al.* (1965) emphasized the extensive utilization of heterosis to step up tomato production.

2.3.1 Vegetative Characters

In a study conducted by Hannan *et al.* (2007), the heterosis for plant height at 60 days after transplantation varied from 47.6 to 56.9 over standard parent, 40.8 to 63.9 over mid parents and 44.29 to 78.19 over better parents. Among the 24 F_1 crosses studied by Himanshu *et al*. (2008), the cross combinations Hisar Anmole x WIR-5032 and Kashi Anupam x WIR-5032 exhibited high and positive heterosis for plant height. Singh *et al*. (2008) studied 65 F_1 hybrids and reported that the cross combinations Sikkim Local x EC-521 080, Vaibhav x EC-521080 exhibited high and positive heterobeltiosis for plant height.

Ahmad *et al*. (2011) recorded a range of 0.70 to 70.16 percent heterosis for plant height at last harvest and highest positive heterosis percent were observed in the cross $P_1 \times P_2$ followed by $P_1 \times P_4$. In a study, Chattopadhyay and Paul (2012), highest positive significant heterosis towards plant height was registered in cross combination (P_8 x P_2) over mid- parent (79.45 %) and better- parent (50.57 %). Kumar *et al*. (2012) studied 15 hybrids and in his study, the heterosis for plant height at 60 days after transplantation varied from -45.78 % to 5.36 % over better parents and 34.79 % to -16.49% over standard check. Short internode length

indicates high fruit yield in tomato. So negative heterosis is desirable. Gul *et al*. (2013) studied 28 tomato hybrids and reported that the negative heterosis occurred in 10 hybrids and only hybrid 'P_{45}' × 'P_{54}' had negative heterosis over the mid-parent and nine hybrids had negative heterosis over the better parent. Among the 28 F_1 hybrids, the cross combination P_2 x P_5 (36.72 %) exhibited the maximum positive heterosis for plant height (Patwary *et al*., 2013).

Yadav *et al*. (2013) studied 30 F_1 cross combinations and found that, the cross LCT-6 × Arka Vikas displayed maximum standard heterosis (50.50 %) and heterobeltiosis (45.94 %) for plant height. Mali and Patel (2014) studied 20 F_1 hybrids and observed that the heterosis for plant height exhibited by F_1s over GT2 ranged from 29.96 % to 184.67 % and over JT 3 ranged from 33.24 % to 191.85 %. Kaushik *et al*. (2016) reported a high heterosis for leaf size in brinjal hybrids over its parents.

2.3.2 Flowering Characters

Negative heterosis for early flowering is considered as a desirable feature for early yield. Hannan *et al.* (2007) observed that the heterosis varied from -31.43 % to 4.39 % over standard parent, -26.32 % to 36.12 % over mid parents and -20.95 % to 40.05 % over better parents for days to first flowering. Negative and significant heterosis was recorded in cross combination Hisar Anmole x EC520061 and Punjab Chhuhara x EC520061. (Himanshu *et al*., 2008). Singh *et al*. (2008) studied 65 F_1 hybrids and in his study negative and significant heterosis for days to first flowering ranged from 4.13 % (Tura local x H-88-78-1) to - 37.5 % (H-24 x DVRT-2). Abdullateef *et al.* (2012) reported high heterosis of brinjal hybrid for pollen viability over its parents.

In a study, Chattopadhyay and Paul (2012), reported that for days to 50 % flowering, most of the crosses showed significant and negative heterosis over the mid parent and better parent. Among the 28 F_1 hybrids, P_3 x P_5 (20.65 %) exhibited the maximum positive heterosis for pollen viability (Patwary *et al*., 2013). Mali and Patel (2014) studied 20 F_1 hybrids and reported that the range of heterosis for days to 50 per cent flowering over the commercial check (GT 2) ranged from -29.55 % to -3.03 % and over commercial check (JT 3) ranged from - 21.85 % to 7.56 %.

2.3.3 Fruit Characters and Yield

Positive heterosis for number of fruits plant $^{-1}$, fruit weight and yield plant $^{-1}$ were reported by Baishya *et al*. (2001). Kurian *et al*. (2001) studied 15 hybrids and identified Sakthi x Fresh Market 9, Sakthi x HW 208F as heterotic hybrid for average fruit weight and Sakthi x TH 318, Sakthi x Fresh Market 9 as heterotic hybrids for yield plant $^{-1}$. Rai et *al.* (2003) were found significant and positive heterosis over better parent up to 214.28% in cross combination KS-17 x Agata for yield plant $^{-1}$. Positive heterosis for number of fruits plant $^{-1}$, fruit weight and yield plant $^{-1}$ was also given by Premalakshmi *et al*. (2005). Rana and Vidyasagar (2005) evaluated 30 F_1 hybrids along with their parents and found that the cross EC 191538 x LE 79-5 (264.91 %) recorded highest heterosis for marketable yield plant $^{-1}$.

Hannan *et al*. (2007) evaluated 45 single cross hybrids and reported that significant positive useful heterosis for number of fruits plant $^{-1}$ was observed in P_1 x P_4 (20.74).and it also had Significant positive heterosis over standard parent for fruit weight plant $^{-1}$. Useful significant positive mid parent heterosis for total fruit weight plant $^{-1}$ was observed in P_5 x P_6 (189 %), P_3 x P_8 (94.7 %), P_5 x P_8 (96.9 %) respectively. Himanshu *et al*. (2008) studied 24 F_1 hybrids and found that maximum fruit set (%) was recorded in cross combination Hisar Anmole x EC521080 and Kashi Vishesh x EC521080, whereas, number of fruits plant $^{-1}$ was the highest in Kashi Vishesh x EC520049 and highest heterosis for yield plant $^{-1}$ was observed in cross combination Hisar Anmole x EC520049. Number of fruits plant $^{-1}$ is one of the major component for yield and for this trait, positive heterosis over better parent was highest in cross combination PKM-l x EC521080(165.43 %) and the highest heterosis for yield plant $^{-1}$ was observed in cross combination H-88-87 x H-88-78-2 (210.45 %) (Singh *et al*., 2008). Highly significant heterosis of positive nature was found for fruits cluster^{-1} (38.9 % and 32.0 %), fruit length (32.7 % and 15.5 %), fruit weight (48.7 % and 45.0 %) and yield plant^{-1} (34.9 % and 14.7 %) over the mid and better parents, respectively (Gul *et al*., 2010).

Kumari *et al*. (2010) studied 10 F_1 hybrids and reported that, out of ten crosses, the heterosis was shown by nine crosses over superior parents and ten crosses over mid parent for weight fruit $^{-1}$, six crosses over superior parent & nine crosses over mid parent for fruit length, all the ten crosses over superior & .mid parent for total number of fruits plant $^{-1}$ and six crosses over both superior & mid parent for total yield. Ahmad *et al*. (2011) estimated the heterosis of 21 tomato cross combinations and reported that maximum positive heterosis for fruits plant $^{-1}$ (83.88 %) and yield plant $^{-1}$ (62.31 %) was shown by $P_4 \times P_7$, individual fruit weight by $P_1 \times P_7$, fruit length by $P_3 \times P_4$ (24.11 %) and fruit diameter by $P_1 \times P_2$ (15.49 %). Also eight crosses showed significant positive better parent heterosis for fruits cluster $^{-1}$ while highest heterosis was 23.73 percent.

Kumari and Sharma (2011) reported that the cross Sioux x FT-5 had highest heterosis over the check Naveen for fruits cluster $^{-1}$ (10.10 %), the number of fruits plant $^{-1}$ (16.33 %) and fruit yield (3.95 %). Heterosis over better parent was highest in S-1001 x Solan Vajr (24.98 %). Significant positive heterobeltiosis was exhibited by eleven crosses and only two cross combinations S-1001 x Solan Vajr (9.83 %) and Sioux x Solan Vajr (4.58 %) showed significant positive increase over the check Naveen. Chattopadhyay and Paul (2012) studied 12 F_1 hybrids and reported that the cross $P_5 \times P_7$ and $P_{13} \times P_4$ recorded highest heterosis (25 %) and heterobeltiosis (25 %) for fruits cluster $^{-1}$. Highest positive significant heterosis for number of fruits plant^{-1} was given by $P_9 \times P_7$ over mid- parent and better parent. Heterosis over mid parent for fruit weight varied from-43.56 % to 92.76 % and -53.37 % to 62.79 % over mid parent and better parents respectively. Out of twelve cross combinations studied, eleven of them exhibited significant and positive heterosis for fruit yield plant^{-1} over the mid parent, while significant positive heterosis over better parent was exhibited by nine hybrids.

Kumar *et al*. (2012) evaluated 15 F_1 hybrids and found that the heterosis varied from -16.48 % to 29.95 % over standard parent and -26.45 % to 34.13 % over better parent for fruits plant $^{-1}$. H-24 x Kashi Sharad showed highly significant heterosis over standard check (23.53 %) and for fruit diameter, the estimate of heterosis varied from -25.49 % to 16.96 % over better parent and -27.85 % to 16.96

% over standard parent, H-24 x Azad T-5 (14.71 %) hybrid showed highly significant positive heterosis over better parent for the number of fruits per cluster. High fruit yield plant $^{-1}$ is the ultimate goal of any breeding programme and so requires higher consideration. Heterosis for fruit yield plant $^{-1}$ varied from -8.54 % to 31.83 % over standard parent and - 26.57 % to 32.06 % over better parent. Singh *et al*. (2012) studied the heterotic effect in 7 x 7 half diallel cross and observed that, heterosis over superior parent was to the extent of 102.08 % in Marglobe Supreme x Sutton Roma for number of fruits plant $^{-1}$, 98.70 % in Ox-Heart x Sutton Roma for fruit weight, 110.98 % in Marglobe Supreme x Money Maker for fruit size and 163.20 % in Ox-Heart x Sutton Roma for yield plant $^{-1}$.

Patwary *et al*. (2013) conducted an experiment to study heterosis using eight parents and among the 28 hybrids produced, the highest heterotic effect for fruit set and fruits plant $^{-1}$ was found in the cross $P_6 \times P_7$ (62.59 % ;105.69 %). High average fruit weight is of prime importance in breeding high yielding cultivars. The highest positive heterosis for fruit weight was observed in the hybrid P_4 x P_5 (66.38 %). The cross combination P_4 x P_7 showed the maximum significant positive heterosis for fruit yield plant $^{-1}$ (282.63 %) and P_4 x P_6 (14.12 %) and $P_5 \times P_6$ (21.22 %) had maximum significant positive heterosis for fruit length and fruit diameter. In the study Yadav *et al*. (2013), reported that the cross Azad-T-5 × VR-20 displayed the maximum standard heterosis for number of fruits plant $^{-1}$ (58.50 %) and maximum extent of standard heterosis and heterobeltiosis for fruit length and average fruit weight was recorded in crosses KS-229 × Arka Vikas and the cross CO-3 × Arka Vikas displayed highest standard heterosis for fruit yield plant $^{-1}$ (29.57 %).

Chauhan *et al*. (2014) studied 28 F_1 hybrids and reported that, for number of fruits plant $^{-1}$ Pusa Gaurav x Cherry Orange exhibited highest significant positive heterosis over mid parent (30.07 %) and Pusa Rohini x Cherry Orange exhibited highest significant positive heterosis over standard check (309.81 %). The extent of heterosis for average fruit weight varied from 9.96 % to 14.79 % and 13.19 % to 28.01 % over mid parent and standard check respectively. The extent of heterosis for average fruit length varied from -42.97 % to 15.56 % over mid parent, -65.00 % to 13.92 % over better parent while the fruit diameter, ranged from -56.43 % to

14.38 % over mid parent, -72.15 % to 14.19 % over better parent and maximum heterosis for fruit size over mid parent recorded in Pusa Gaurav x Taiwan (29.23 %) and Pusa Gaurav x Selection-1 (52.43 %) over standard parent .With respect to yield plant $^{-1}$ Pusa Rohini x N-5 exhibited highest significant positive heterosis over mid parent (78.90 %), Pusa Rohini x Roma exhibited highest significant positive heterosis over better parent (73.41 %).

Mali and Patel (2014) studied 20 F_1 hybrids and reported that the heterosis for number of fruits plant $^{-1}$ ranged from -13.75 % to 53.61 % over GT 2 and -11.92 % to 56.89 % over JT 3. For average fruit length, heterosis varied from -15.71 % to 28.54 % over commercial check GT 2 and -11.29 % to 35.28 % over commercial check JT 3. The heterosis for average fruit length and fruit girth ranged from -15.71 % to 28.54 % and 14.19 % to 54.29 % over commercial check GT 2 and -11.29 % to 35.28 % and 21.72 % to 64.47 % over commercial check JT 3. The highest heterosis over both the checks for average fruit weight was given by NTE 1 x NTE 2. NTE 2 x NTE 3 exhibited highest heterosis over both the checks for fruit yield plant $^{-1}$.

2.3.4 Quality Characters

Total soluble solid directly influences flavour of tomato and is an important quality parameter in the processing industry. High lycopene content is the most important desirable quality parameter for increasing marketing value and consumer prefer the good colour of tomato. Ascorbic acid content is nutritionally an important constituent. Small fruited genotypes are generally richer in ascorbic acid content.

TSS content of fruit results in a 20 % increase in recovery of processed product (Berry and Uddin, 1991). In a study conducted by Rana and Vidyasagar (2005), out of 30 F_1 hybrids nine hybrids showed positive heterosis over better parent for TSS. The highest heterosis for total soluble solids was recorded in Kashi Vishesh x WIR-3957 (Himanshu *et al*., 2008). Fifteen F_1s out of 21 crosses showed significant positive heterosis ranging from 3.93 to 31.89 percent. Highest positive heterosis was observed in the cross P_1 X P_7 followed by $P_1 \times P_6$ (24.70), $P_5 \times P_6$

(20.65). Higher brix percent is responsible for sweetness of tomato (Ahmad *et al*., 2011).

Kumari and Sharma (2011) reported highest heterobeltiotic effect in EC-521051 x Solan Vajr (28.49 %) and only five crosses showed significant positive increase over check Naveen, the highest increase being in EC- 521051 x Solan Vajr (11.92 %). The heterosis over better parent was maximum in EC 1914 x EC-15998 (23.49 %). Cross EC-13736 x Solan Vajr showed highest positive increase of 29.47 percent over check Naveen for ascorbic acid content. Of 28 hybrids, 18 had significant heterosis over the mid-parent as well as the better parent. Maximum heterosis over the midparent as well as the better parent occurred in hybrids 'E-02' × 'P28', 'P28' × 'P30', 'P28' × 'P59', 'P38' × 'P54', and 'P28' × 'P38' (Gul *et al*., 2013). Kumar *et al*. (2013) studied 30 tomato cross combinations and reported that top five crosses *viz.*; H-24 × Arka Abha (43.59), Sel-7 × Arka Abha (33.89), CO-3 × Arka Abha (32.60), Fla- 7171 × Arka Abha (32.54) and Sel-7 × Kashi Sharad (29.91 %) exhibited significant positive heterosis for TSS over the better parent and none over standard check. For ascorbic acid, the heterobeltiosis ranged from -19.50 to 10.28 % and standard heterosis ranged from -26.52 to -6.08 % and for lycopene, the extent of heterosis exhibited by the F_1s over their corresponding better parent and standard check ranged from -29.03 (D-2 × Kashi Sharad) to 46.35 (Flora Dade × BT-12) and –42.86 (ATL-239 × Arka Abha) to -8.27 (Punjab Upma × Arka Abha), respectively.

Among the 28 F_1 hybrids studied, the highest positive heterosis for TSS was observed by the cross P4 x P6 (11.49 %) (Patwary *et al*., 2013). Yadav *et al*. (2013) studied 30 cross combinations and found that the cross LCT-6 × NDT-5 exhibited highest standard heterosis and heterobeltiosis for T.S.S (37.50 % and 27.92 %, respectively). For total soluble solids, out of 20 crosses, three showed significant positive heterosis over the commercial check (JT 3). None of the crosses showed positive significant heterosis over commercial check GT 2. The magnitude of heterosis for ascorbic acid content revealed that out of 20 crosses, twelve and five crosses showed significant positive heterosis over both checks *viz.,* GT 2 and JT 3, respectively. (Mali and Patel, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Evaluation of hybrids of indeterminate tomato (*Solanum lycopersicum* L.) under protected cultivation." was conducted at the Department of Olericulture, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, during 2015 - 2016. The objective of the study was to evaluate the yield and quality of F_1 hybrids of indeterminate tomato under protected cultivation.

3.1 EXPERIMENTAL SITE

The experiment was conducted in a saw tooth type naturally ventilated polyhouse of size 480 m^2 (30 m x 16 m) attached to the Department of Olericulture. Vellayani. The framework was made of GI pipes and the roof was made of 200 micron UV stabilised polythene sheet. The sides were made of 40 mesh insect proof net (Plate 1).

The experiment comprised of two parts.

Part 1: Production of F_1 hybrids

Part 2: Evaluation of F_1 hybrids for two seasons

3.2 PART I: PRODUCTION OF F_1 HYBRIDS

3.2.1 Materials

Ten superior F_1 hybrids with respect to yield and quality selected based on specific combining ability and *per se* performance in the previous research programme were selected for the study.

The seeds of the selected ten F_1 hybrids were produced in a crossing block. The seven parents of the ten crosses (Table 1) were raised in a crossing block and were crossed to produce the hybrid seeds (Plate 8 and 9).

Table.1. Details of parents used for hybridization.

Code. No.	Accession Number	Name of accession	Source
P_1	LE 2	EC-775046	AVRDC, Taiwan
P_2	LE 16	EC 608244	NBPGR, New Delhi
P_3	LE 17	EC 608288	NBPGR, New Delhi
P_4	LE 20	EC 608365	NBPGR, New Delhi
P_5	LE 39	Akshaya	KAU, Thrissur
P_6	LE 38	Manulakshmi	KAU, Thrissur
P_7	LE 1	EC-775045	AVRDC, Taiwan

Table.2. Details of F_1 hybrids and the checks selected for the study

SI. No.	Cross combinations	
1	P_1 x P_3	LE 2 x LE 17
2	P_1 x P_4	LE 2x LE 20
3	P_1 x P_5	LE 2 x LE 39
4	P_1 x P_6	LE 2 x LE 38
5	P_1 x P_7	LE 2 x LE 1
6	P_2x P_4	LE 16 x LE 20
7	P_4 x P_5	LE 20 x LE 39
8	P_4 x P_7	LE 20 x LE 1
9	P_5 x P_6	LE 39 x LE 38
10	P_6 x P_7	LE 38 x LE 1
11	Check (Commercial)	Naveen
12	Check (Commercial)	Akshaya

The crossing technique included hand emasculation and artificial pollination. The emasculation was done during evening hours on the developed flower-buds likely to open next morning and bagged. On the next day morning (between 6.30 to 10.30 a.m.) the emasculated buds were pollinated by the pollen collected from the male parents. The pollinated buds were again bagged with paper bags and labeled. The ripe crossed fruits were harvested and the seeds were extracted separately. For the maintenance of parental lines, flower buds were selfed by bagging the individual buds and properly tagged and seeds were extracted from ripe fruits.

3.3 PART II: EVALUATION OF F_1 HYBRIDS

3.3.1 Materials

The 10 F_1 hybrids, seven parents and the two checks Naveen and Akshaya were evaluated for two seasons (July 2015- January 2016 and November 2015- March 2016). The details of the 10 F_1 hybrids are given in Table 2.

3.3.2 Methods

3.3.2.1 Design and Layout

The experiment was laid out in the naturally ventilated polyhouse as follows (Plate 10).

Design : RBD

Replications : 3

Treatments : 18 (10 F_1 hybrids + 7 parents + Check- Naveen, One of the parent Akshaya is also a check)

Spacing : 60 cm x 60 cm

Plants/ plot : 20

Plot size : 7.2 m^2

Seasons : 2 (July 2015- January 2016 and November 2015- March 2016).

3.3.2.2 Raising Seedlings

Tomato seedlings were raised in portrays filled with potting mixture comprising of coir pith and vermicompost in 1:1 ratio. Thirty days old seedlings with 4-5 true leaves and 10 cm height were transplanted to the main field (Plate 4 and 5).

3.3.2.3 Main Field Preparation

The experimental area inside the polyhouse was ploughed thoroughly using Mini Hoe and the weeds and stubbles were removed and brought to a fine tilth. Raised beds of 1m width were prepared and it was incorporated with 100 kg cowdung, 100 kg vermicompost and 2 ½ kg Rock Phosphate. Then beds were levelled and covered with black and white double shaded polythene mulch of 30 micron thickness. Holes were punched on the mulch as per the spacing (Plate 2 and 3).

3.3.2.4 Crop Management

The crop received timely management practices as per ad-hoc package of practices recommendations for precision farming for tomato (KAU, 2013). Fertilizer schedule is given in Appendix I.

Fertilizers were applied once in three days from planting till the end of the crop through fertigation. Drip system of irrigation was followed in the polyhouse. Misting was carried out regularly at specific intervals to reduce the excess temperature buildup in the polyhouse (Plate 7).

3.3.2.5 Training and Pruning

Since the polyhouse tomato is indeterminate in growth habit, they need regular training and pruning. A single stem was retained at early stages by removing all side shoots that develop on the main stem. The plants were trained by plastic twine loosely anchored at the base of the plants with the help of plastic clips and to overhead support wires running all along the length of rows of the bed (Plate 6).

Plate 1. Naturally ventilated saw tooth type polyhouse used for the study

Plate 2. Preparation of raised beds

Plate 3. Beds covered with mulch sheet

Plate 4. Protray seedlings ready for transplanting

Plate 5. Seedlings transplanted in planting holes

Plate 6. Training of tomato plants to single stem

Plate 7. Misting inside the polyhouse

Plate 8. Crossing block

Plate 9. A fruit set after hybridisation

Plate 10. Field view of the experiment

3.3.2.6 Plant Protection

Plant protection chemicals were applied when the incidence of bacterial wilt was observed.

3.3.3 Biometric Observations

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

3.3.3.1 Vegetative Characters

3.3.3.1.1 Plant Height (cm)

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

3.3.3.1.2 Height at Flowering (cm)

Height of the observational plants from the ground level to the first flower bud at the time of first flowering was recorded.

3.3.3.1.3 Node to First Inflorescence

Number of nodes from ground level to the first inflorescence at the time of first flowering was recorded.

3.3.3.1.4 Internodal Length (cm)

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

3.3.3.1.5 Leaf Length (cm)

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

3.3.3.1.6 Leaf Width (cm)

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

3.3.3.2 Flowering Characters

3.3.3.2.1 Days to First Flowering

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

3.3.3.2.2 Days to Fruit Set

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

3.3.3.2.3 Fruit Set (%)

Number of fruits present per inflorescence after two weeks of flowering was recorded. Percentage fruitset was calculated.

3.3.3.2.4 Pollen Viability (%)

Pollen viability of tomato flowers was analysed using acetocarmine dye method and expressed in percentage.

3.3.3.3 Fruit Characters and Yield

3.3.3.3.1 Fruits Plant $^{-1}$

Total number of fruits harvested per plant till last harvest was recorded and the average was calculated.

3.3.3.3.2 Fruits Truss $^{-1}$

Number of fruits per truss was recorded from observational plants and the average was worked out.

3.3.3.3.3 Fruit Length (cm)

Length of fruits was measured as the distance from pedicel attachment of the fruit to the apex using twine and scale. Average was taken and expressed in centimeters.

3.3.3.3.4 Fruit Girth (cm)

Fruit girth was taken from the same fruits used for recording the fruit length. Diameter was measured at the maximum width of the fruit. The average was worked out and expressed in centimeters.

3.3.3.3.5 Fruit Weight (g)

Weight of the fruits was found out using an electronic balance and expressed in grams.

3.3.3.3.6 Yield Plant $^{-1}$ (g)

Weight of all fruits harvested from selected plants was recorded and the total worked out and expressed in grams.

3.3.3.3.7 Yield Plot $^{-1}$ (kg)

The weight of the fruits from each plot per harvest was recorded and expressed as kilogram per plot.

3.3.3.4 Quality Characters

3.3.3.4.1 Total Soluble Solids (%)

Total soluble solids of tomato fruits was recorded using a hand refractometer (0-32^0 Brix). A drop of tomato juice was used to determine TSS and the value was expressed in per cent at room temperature.

3.3.3.4.2 Lycopene (mg/100g)

Lycopene content of the fruits was estimated at the full ripe stage by the following method of Srivastava and Kumar (1994)

Reagents

Acetone, petroleum ether (40-60 degree Celsius), anhydrous sodium sulphate and five per cent sodium sulphate.

Procedure

Tomato fruits were crushed with the help of pestle and mortar and pulped it well to a smooth consistency in a blender. Five to ten grams of this pulp was weighed and the pulp was extracted repeatedly with acetone using pestle and mortar until the residue become colourless. The acetone extracts were pooled and transferred to a separating funnel containing about 20 ml petroleum ether and gently mixed. 20 ml of 5% sodium sulphate solution were added and shaken the separating funnel gently. Volume of petroleum ether might be reduced during the process because of its evaporation and so 20 ml more of 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 coloureless. The petroleum ether extracts was pooled and washed once with little distilled water. The washed petroleum extracts containing carotenoids was poured into a brown bottle containing about ten gram anhydrous sodium sulphate and kept it aside for 30 minutes. The petroleum ether extracts was decanted into a 100ml 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 absorbance was measured in a spectrophotometer at 503nm using petroleum ether as blank.

$$\text{Lycopene (mg/100g)} = \frac{31.206 \times \text{Absorbance}}{\text{Weight of sample}}$$

3.3.3.4.3 Ascorbic Acid (mg/100g)

Ascorbic acid content of fruit was estimated by 2, 6-dichlorophenol indophenol dye method (Sadasivam and Manickam, 1996).

Reagents

1. Oxalic acid (4%)

2. Ascorbic acid (standard)

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

3. 2, 6-dichlorophenol indophenol dye

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

4. Working standard

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

Procedure

Five ml of working standard solution was pippeted out into a 100 ml conical flask and 10 ml four per cent oxalic acid was added. This was titrated against the dye (V_1). End point was the appearance of pink colour which persisted for atleast five seconds.

Five grams of fresh fruits 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 four per cent oxalic acid was added and titrated as above against the dye and the end point (V_2) was determined.

Ascorbic acid content of the sample was calculated using the formula

$$\text{Amount of ascorbic acid (mg/100g)} = \frac{0.5 \times V_2 \times 100}{V_1 \times 5 \times \text{weight of sample}} \times 100$$

3.3.3.5 Incidence of Pest and Diseases

The crop was monitored for the incidence of pests and diseases. There was no incidence of pests inside the polyhouse and only the incidence of bacterial wilt disease was noticed.

3.3.3.5.1 Bacterial Wilt (%)

The disease is caused by *Ralstonia solanacearum*. The warm humid climate coupled with acidic nature of soil intensify the incidence of the bacterial wilt. The per cent incidence of bacterial wilt among the observational plants was worked out.

3.3.3.6 Physiological Disorders

The following physiological disorders were observed during the crop period.

3.3.3.6.1 Fruit Cracking

Tomato fruits were monitored for both radial and concentric cracking. The number of fruits cracked were counted and expressed in percentage.

3.3.3.6.2 Blossom End Rot

The major cause of blossom end rot is the deficiency of calcium and imbalance of magnesium and potassium. Tomato fruits were closely observed for blossom end rot incidence and expressed in percentage.

3.3.3.6.3 Stigma Exertion

Flowers were observed for extrovert stigma condition which reduces fruit set under protected conditions. The flowers with exerted stigma were counted per inflorescence and expressed in percentage.

3.3.4 Statistical Analysis

3.3.4.1 Analysis of Variance

Analysis of variance (ANOVA) for individual character was carried out on the basis of mean value per entry per replication as suggested by Panse and Sukhatme (1967) for Randomized Block Design (RBD). The model of analysis of variance is as given below.

Table. 3. Analysis of Variance (ANOVA) for RBD

Source	d.f.	Mean squares	Expectation of mean squares
Replications	(r-1)	M_r	$\sigma^2e + g\,\sigma^2r$
Genotypes	(g-1)	M_g	$\sigma^2e + r\,\sigma^2g$
Parents	(p-1)	M_p	
Hybrids	(h-1)	M_h	
Parents Vs. hybrids	1	M_pVs. M_h	
Error	(r-1) (g-1)	M_e	σ^2e

Where,

r = number of replications

g = number of genotypes

p = number of parents

h = number of hybrids

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

3.3.4.2 Test of Significance

Test of significance for various components was carried out by 'F' test. The 'F' values were calculated as under.

Genotypes = $\frac{M_g}{M_e}$

Parents = $\frac{M_p}{M_e}$

Hybrids = $\frac{M_h}{M_e}$

Parents vs. hybrids = $\frac{M_{p\,vs}\,M_h}{M_e}$

M_g= mean squares of genotypes

M_p= mean squares of parents

M_h=mean squares of hybrids

M_e = mean squares of error

3.3.4.3 Critical Difference of the Estimates

To test the significance of differences of the estimates, critical difference is calculated as.

$$S.\ E.\ D = \sqrt{\frac{2M_e}{r}} \quad \text{and S.E.M} = \sqrt{\frac{M_e}{r}}$$

$$C.\ D. = S.\ E.\ D \times t$$

Where,

t = Table't' value for error degree of freedom at 0.01 and 0.05 levels of probability.

3.3.4.4 Co-efficient of Variation

The co-efficient of variation for each character was calculated as under,

$$C.V.\% = \frac{\sqrt{M_e}}{\bar{X}} x100$$

Where,

M_e = error mean square

$\bar{X}$ = general mean for the character

3.3.4.5 Pooled Analysis

Pooled analysis was done using the data of evaluation of the 18 treatments for two seasons.

Table.4. Anova for pooled analysis

Source	d.f.	Mean squars	Expectation of mean squars
Replication	(r-1)	Mr	σ2ea +g σ2r
Genotypes	(g-1)	Mg	σ2ea +r σ2g
Error a	(r-1)(g-1)	Mea	
Seasons	(s-1)	Ms	
Genotype Vs season	(s-1)(g-1)	MsVS.Mg	
Error b		Meb	σ2e

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

3.3.4.6 Heterosis

The magnitude of heterosis was estimated in relation to mid parent (MP), better parent (BP), and standard checks (hybrid Naveen and the variety Akshaya) as percentage increase or decrease of F_1s over the respective check.

Estimation of heterosis was carried out following the methods suggested by Turner (1953) and Hayes *et al.* (1955).

$$\text{Mid parent value (MP)} = \frac{P_1 + P_2}{2}$$

$$\text{a) Heterosis over mid parent (MP)} = \frac{F_1 - \overline{MP}}{\overline{MP}} \times 100 \quad \text{(Relative heterosis)}$$

Where,

$\overline{MP}$ = Mean performance of parent P_1 and P_2

$\overline{F_1}$ = Mean performance of hybrid

b) Heterosis over better parent (BP) $= \frac{F_1 - \overline{BP}}{\overline{BP}} \times 100$ (Heterobeltiosis)

Where,

$\overline{BP}$ = Mean performance of better parent

$\overline{F_1}$ = Mean performance of F_1 hybrid

c) Heterosis over standard check (SC) $= \frac{F_1 - \overline{SC}}{\overline{SC}} \times 100$ (Standard heterosis)

Where,

$\overline{SC}$ = Mean performance of standard check

3.3.4.6.1 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 following formula.

Mean deviation for heterosis over MP $= \sqrt{\frac{3 \times mse}{2r}} \times$ ‘ t’ value

Mean deviation for heterosis over BP & SC $= \sqrt{\frac{2 \times mse}{r}} \times$ ‘t’ value

Where,

r = Number of replications

t = Table value of ‘t’ at error degree of freedom at 0.01 and 0.05 levels of probability

m.s.e = Error mean sum of squares

.

3.3.4.7 Correlation

Simple correlation can be calculated with the help of the following formula.

$R_{xy} = MSP_t / [MSt_x . MS_{ty}]^{1/2}$

Where, MSPt = Mean sum of products of genotypes.

MS_{tx} = Mean square of treatments for the variable x.

MS_{ty} = Mean square of tretments for the variable y.

RESULTS

4. RESULTS

The experiment entitled "Evaluation of hybrids of indeterminate tomato (*Solanum lycopersicum* L.) under protected cultivation" was carried out at the Department of Olericulture, College of Agriculture, Vellayani, during 2015 -2016. The evaluation was done for two seasons (July 2015 to January 2016 and November 2015 to March 2016). The data collected were analysed statistically. The results are presented under the following heads.

4.1 ANALYSIS OF VARIANCE

Analysis of variance was conducted to test the significant difference among the treatments for the characters studied and this revealed that all the 18 treatments (10 hybrids + 7 parents + 2 checks-hybrid Naveen and variety Akshaya) (Plate 11 and 12) were significantly different for all the characters studied in the two seasons and in pooled data (Table 5 to 7).

4.2 MEAN PERFORMANCE OF TOMATO HYBRIDS AND PARENTS

The mean values of the treatments for all the character studied during the experimental period and their pooled means are given in Tables 8-15. During second season, one of the checks Naveen was completely affected by bacterial wilt and hence not included in pooled analysis. The results of each character are described in the ensuing paragraphs.

4.2.1 Biometric Characters

4.2.1.1 Vegetative Characters

4.2.1.1.1 Plant Height (m)

During the first season, among the hybrids, the plant height was highest for LE 20 x LE 1 (4.69 m) and lowest for LE 2 x LE 20 (2.29 m). Among the parents, LE 17 (4.85 m) was the tallest and LE 2 (1.34 m) was the shortest. The checks Naveen and Akshaya had a height of 3.23 m and 2.84 m respectively (Table 8).

Table. 5. ANOVA table for different biometric characters of tomato in first season (July 2015 – January 2016)

Source of variation	Plant height (m)	Height at flowering (cm)	Node to first inflorescence	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Days to first flowering	Days to fruit set	Fruit set (%)	Pollen viability (%)
Replication	0.16	4.76	0.40	0.03	10.54	8.30	0.02	0.18	21.90	10.83
Treatments	2.16 **	150.21 **	2.72 **	0.21 **	64.69 **	26.91 *	4.16 **	3.46 **	126.64 **	505.28 **
Parents	3.47 **	222.58 **	4.21 **	0.28 **	103.13 **	19.58	2.88 **	3.06 **	108.87 **	368.30 **
Hybrids	1.67 **	109.64 **	1.37 **	0.16 **	26.40 **	31.08 *	2.61 **	3.83 **	125.61 **	568.74 **
Parents Vs. Hybrid	0.86 *	53.83	7.22 **	0.04	237.48 **	59.52 *	29.31 **	0.19	129.92 **	576.72 **
Error	0.07	12.70	0.43	0.03	5.84	11.06	0.10	0.16	15.68	56.41
Total	0.75	56.51	1.17	0.09	24.89	16.04	1.40	1.22	51.51	198.67

Source of variation	Fruits plant $^{-1}$	Fruits truss $^{-1}$	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Yield plant $^{-1}$ (g)	Yield plot $^{-1}$ (kg)	TSS (%)	Lycopene (mg/100g)	Ascorbic acid (mg/100g)
Replication	93.17	0.07	0.01	0.01	0.82	39986.23	23.44	0.01	0.03	1.48
Treatments	1561.27 **	2.65 **	1.78 **	6.47 **	1425.80 **	1202576.25 **	487.25 **	0.13 **	1.91 **	74.83 **
Parents	181.88	2.71 **	1.97 **	5.63 **	1920.76 **	318377.21 **	117.67 *	0.20 **	0.29 **	31.25 **
Hybrids	1536.65 **	2.65 **	1.53 **	8.06 **	1315.12 **	1162117.12 **	435.20 **	0.05 **	2.49 **	35.23 **
Parents Vs. Hybrid	6445.60 **	4.06 **	1.56 **	2.63 **	44.80	6080098.00 **	2282.26 **	0.08 **	7.97 **	756.07 **
Error	97.04	0.09	0.02	0.07	7.31	92716.10	35.21	0.01	0.08	2.59
Total	566.56	0.91	0.59	2.12	462.05	446719.16	179.76	0.05	0.67	25.72

Table. 6. ANOVA table for different biometric characters of tomato in second season (November 2015- March 2016)

Source of variation	Plant height (m)	Height at flowering (cm)	Node to first inflorescence	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Days to first flowering	Days to fruit set	Fruit set (%)	Pollen viability (%)
Replication	0.00	0.34	0.04	0.11	0.31	0.00	0.10	0.35	11.31	12.38
Treatments	0.98 **	147.49 **	1.14 **	0.46 **	62.57 **	82.94 **	5.20 **	1.51 **	198.72 **	125.72 **
Parents	0.66 **	200.35 **	0.62 **	0.70 **	10.30 **	24.13 **	1.07 **	1.50 **	294.23 **	55.09 **
Hybrids	1.28 **	135.03 **	1.35 **	0.34 **	105.14 **	129.35 **	4.15 **	1.62 **	155.66 *	176.64 **
Parents Vs. Hybrid	1.09 **	33.14 **	2.97 **	0.48 **	13.76 **	96.39 **	41.46 **	0.49 **	13.18 **	145.65 **
Error	0.00	0.31	0.09	0.03	0.10	0.04	0.06	0.17	57.47	5.98
Total	0.31	47.52	0.43	0.17	20.14	26.63	1.71	0.60	100.83	44.63

Source of variation	Fruits plant $^{-1}$	Fruits truss $^{-1}$	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Yield plant $^{-1}$ (g)	Yield plot $^{-1}$ (kg)	TSS (%)	Lycopene (mg/100g)	Ascorbic acid (mg/100g)
Replication	0.71	0.06	0.01	0.00	1.71	99.89	3.46	0.00	0.09	0.02
Treatments	708.97 **	2.79 **	1.69 **	6.05 **	1146.46 **	226015.27 **	75.96 **	0.05 **	0.87 **	83.55 **
Parents	280.12 **	2.68 **	2.47 **	5.92 **	1375.73 **	127296.41 **	47.91 **	0.09 **	0.71 **	25.85 **
Hybrids	704.21 **	2.98 **	0.98 **	6.46 **	1100.94 **	94851.54 **	29.95 **	0.02 **	1.04 *	48.99 **
Parents Vs. Hybrid	3324.99 **	1.75 **	3.35 **	3.19 **	180.61 **	1998802.00 **	658.33 **	0.05 **	0.28	740.74 **
Error	0.76	0.04	0.02	0.01	2.58	426.86	2.14	0.00	0.26	1.46
Total	227.39	0.92	0.55	1.94	368.59	72602.07	25.82	0.02	0.45	27.67

Table. 7. Anova table for biometric characters of tomato in pooled analysis for two seasons (July 2015- January 2016 & November 2015 –March 2016)

Source of variation	Plant height (m)	Height at flowering (cm)	Node to first inflorescence	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)	Days to first flowering	Days to fruit set	Fruit set (%)	Pollen viability (%)
Replication	0.09	1.93	0.36	0.06	8.94	5.64	0.03	0.27	20.40	4.19
Treatments	2.96 **	277.86 **	3.29 **	0.58 **	88.53 **	58.52 **	9.38 **	4.26 **	249.25 **	425.97 **
Season	11.13 **	526.28 **	275.52 **	2.56 **	1234.56 **	286.91 **	39.36 **	8.23 **	971.81 **	8581.47 **
Treatments Vs. season	0.37 **	23.80 **	0.69 **	0.11 **	43.70 **	57.86 **	0.32 **	0.56 **	69.07 *	197.23 **
Error	0.04	5.40	0.26	0.03	2.82	5.41	0.08	0.16	36.20	31.64
Total	0.67	56.56	3.54	0.15	35.19	24.93	1.98	0.96	84.11	204.45

Source of variation	Fruits plant $^{-1}$	Fruits truss $^{-1}$	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Yield plant $^{-1}$ (g)	Yield plot $^{-1}$ (kg)	Total Soluble Solids (%)	Lycopene (mg/100g)	Ascorbic acid (mg/100g)
Replication	52.26	0.00	0.01	0.01	0.69	9464.93	10.61	0.01	0.07	0.76
Treatments	1905.82 **	5.44 **	3.31 *	12.80	2591.65 **	1148343.88 **	413.40 **	0.14 **	1.92 **	158.58 **
Season	6087.22 **	0.68 **	0.11	0.05 **	62.68 **	20028838.00 **	9345.75 **	0.04 **	71.42 **	92.59 **
Treatments Vs. season	138.57 **	0.11	0.07	0.06	17.65 **	230760.31 **	94.13 **	0.01	0.96 **	3.75 *
Error	51.59	0.07	0.02	0.04	5.00	46200.58	19.07	0.01	0.17	2.06
Total	418.88	0.93	0.55	2.06	417.26	447155.16	185.60	0.03	1.28	28.00

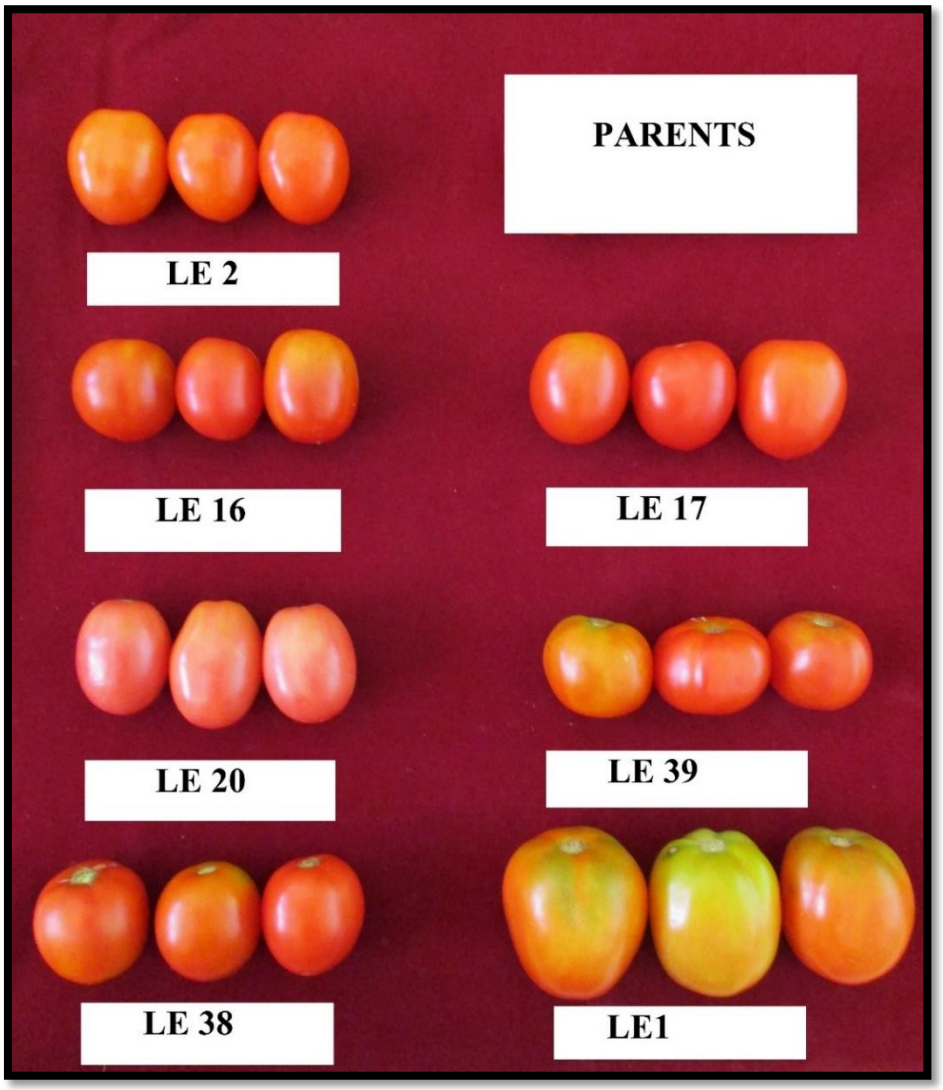


Plate 11. Seven parents used for hybridization

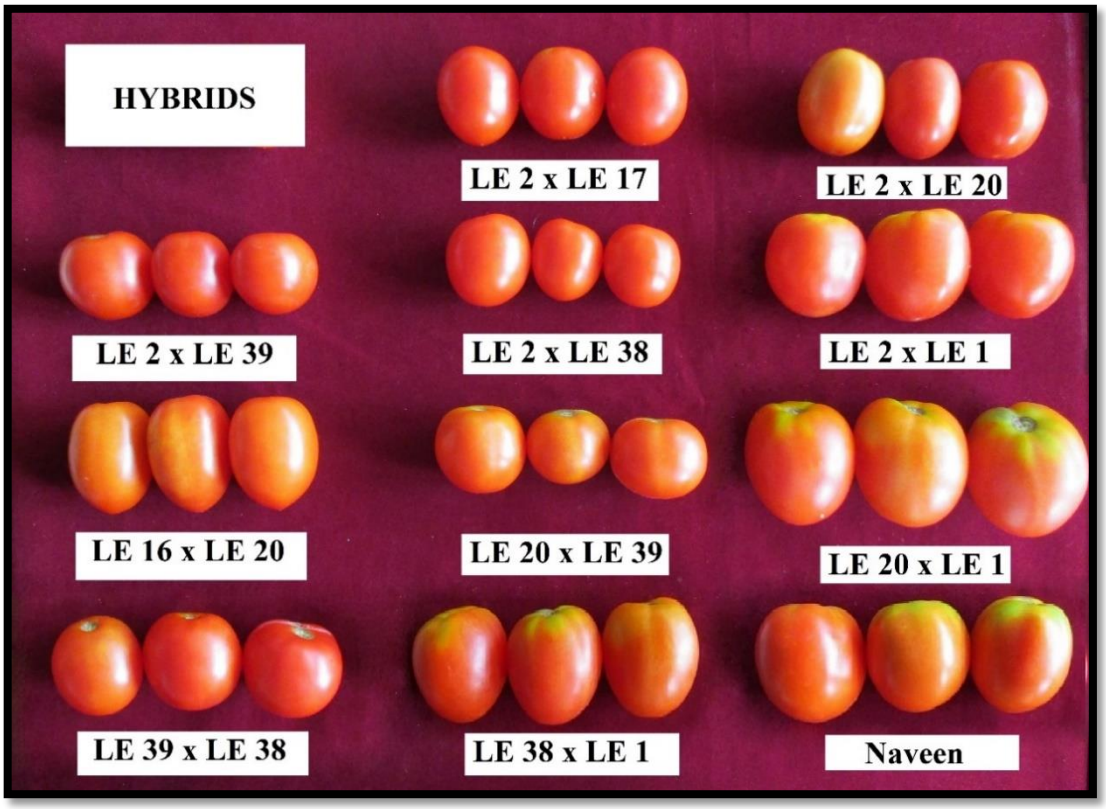


Plate 12. Fruits of ten F_1 hybrids and check Naveen

During second season, the same trend was noticed, but the plant height for all treatments was lower compared to the first season. Among the hybrids, LE 20 x LE 1 (3.69 m) was tallest and LE 2 x LE 20 (1.94 m) was the shortest. Among the parents, LE 17 (2.94 m) was the tallest which was on par with LE 1 (2.93 m) and shortest was LE 2 (1.63 m).

The pooled analysis revealed that, LE 20 x LE 1 (4.19 m) was the tallest hybrid and it was on par with LE 38 x LE 1 (3.96 m) and shortest was LE 2 x LE 20 (2.12 m). Among the parents, LE 17 (3.89 m) was the tallest and LE 2 (1.48 m) was the shortest.

4.2.1.1.2 Height at Flowering (cm)

Lower height at flowering is the desired character for earliness. Among the hybrids, LE 2 x LE 17 had lowest height at flowering during both the seasons. *ie*. 37.22 cm, 34.00 cm and 35.61 cm during the first season, second season and pooled data respectively. Among the parents, LE 2 recorded lowest height at flowering. *ie*. 31.00 cm during first season, 34.04 cm during second season and 32.52 cm in pooled (Table 8).

4.2.1.1.3 Node to First Inflorescence

Node to first inflorescence also is an indication of earliness. During first season, among the hybrids, LE 20 x LE 1 had lowest number of node to first inflorescence (14.11) and it was on par with LE 2 x LE 17 (14.33), LE 2 x LE 20 (14.22), LE 2 x LE 1 (14.56), LE 16 x LE 20 (14.77), LE 39 x LE 38 (14.33) and LE 38 x LE 1 (14.56). Among the parents, LE 17 recorded the lowest value (12.67) and it was on par with LE 1 (12.33) (Table 8).

During second season, lowest value was recorded in LE 38 x LE 1 (10.66) and was on par with LE 2 x LE 1 (10.67) and LE 20 x LE 1 (10.67). Among the parents, lowest number of nodes to first inflorescence was for LE 1 (10.33) and it was on par with LE 38 (10.56) and LE 20 (10.78).

Table. 8. Mean performance of hybrids, parents and checks for plant height, height at flowering and node to first inflorescence for two seasons and pooled mean

Treatments	Plant height (m)			Height at flowering (cm)			Node to first inflorescence		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	2.58	2.38	2.48	37.22	34	35.61	14.33	11.22	12.77
LE 2 x LE 20	2.29	1.94	2.12	43.36	36.7	40.03	14.22	11.67	12.94
LE 2 x LE 39	3.24	2.19	2.72	54.71	50.98	52.85	15.55	11.56	13.55
LE 2 x LE 38	2.84	2.27	2.55	49.38	42.62	46	15.99	12.22	14.11
LE 2 x LE 1	3.76	3.39	3.58	43.6	37.34	40.47	14.56	10.67	12.61
LE 16 x LE 20	3.56	2.4	2.98	53.92	47.64	50.78	14.77	11.56	13.17
LE 20 x LE 39	3.49	2.71	3.1	54.38	49.36	51.87	15.67	12.66	14.16
LE 20 x LE 1	4.69	3.69	4.19	49.61	45.07	47.34	14.11	10.67	12.39
LE 39 x LE 38	3.63	3.4	3.52	54.75	53.93	54.34	14.33	11.22	12.78
LE 38 x LE 1	4.35	3.58	3.96	52.29	48.31	50.3	14.56	10.66	12.61
LE 2	1.34	1.63	1.48	31	34.04	32.52	15	11.67	13.34
LE 16	3.23	2.33	2.78	54.04	56.82	55.43	15.55	11.33	13.44
LE 17	4.85	2.94	3.89	49.48	41.29	45.38	12.67	10.89	11.78
LE 20	3.43	2.73	3.08	53.99	48.44	51.22	14.67	10.78	12.72
LE 39 (Akshaya)	2.84	2.68	2.76	48.26	46.22	47.24	14.11	10.89	12.5
LE 38	2.75	2.24	2.49	53.39	39.49	46.44	14	10.56	12.28
LE 1	3.81	2.93	3.37	40.48	34.39	37.44	12.33	10.33	11.33
Naveen	3.23	-	-	56.38	-	-	13.78	-	-
Mean	3.33	2.67	3	48.9	43.92	46.19	14.46	11.21	12.85
CD (P=0.05)	0.465	0.073	0.235	5.422	0.928	2.678	1.096	0.514	0.592

Pooled mean revealed that, the number of nodes to first inflorescence was lowest in LE 20 x LE 1(12.39) and was on par with LE 2 x LE 17 (12.77), LE 2 x LE 1 (12.61), LE 39 x LE38 (12.78) and LE 38 x LE 1 (12.61). Among the parents, LE 1 (11.33) had lowest value which was on par with LE 17 (11.78).

4.2.1.1.4 Internodal Length (cm)

The hybrid, LE 2 x LE 20 recorded lowest internodal length for both the seasons and the values were 3.85 cm, 4.25 cm and 4.05 cm in first season, second season and pooled mean respectively, and it was on par with LE 2 x LE 17. Among the parents, LE 16 (3.96 cm) had shortest internodal length which was on par with LE 2 (4.02 cm) in first season where as LE 2 recorded minimum internodal length in second season (3.59 cm) and in pooled mean (3.81 cm) (Table 9).

4.2.1.1.5 Leaf Length (cm)

In the first trial, among the hybrids, LE 2 x LE 38 (43.67 cm) showed maximum leaf length which was on par with LE 16 x LE 20 (43.47 cm) and LE 39 x LE 38 (41.92 cm) and minimum leaf length was exhibited by LE 2 x LE 17 (34.04 cm). Among the parents, maximum leaf length was observed in LE 1 (45.60 cm) (Table 9).

LE 20 x LE 1 (39.28 cm) had maximum leaf length and LE 2 x LE 20 (20.24 cm) had minimum leaf length during the second trial and among parents highest value was for LE 1 (35.47 cm) and lowest for LE 2 (30.17 cm).

In pooled analysis, LE 20 x LE 1 recorded maximum leaf length (40.32 cm) and minimum leaf length was recorded in LE 2 x LE 17 (27.83 cm). Among parents, LE 1 exhibited highest value for leaf length (40.54 cm) and lowest value was observed in LE 39 (30.63 cm).

4.2.1.1.6 Leaf Width (cm)

During first season, leaf width was maximum in LE 16 x LE 20 (34.88 cm) which was on par with LE 2 x LE 20 (29.67 cm), LE 2 x LE 39 (29.51 cm), LE 2 x LE 38 (32.19 cm) and LE 39 x LE 38 (30.73 cm). Lowest leaf width was recorded

Table. 9. Mean performance of hybrids, parents and checks for internodal length, leaf length and leaf width for two seasons and pooled mean

Treatments	Internodal length (cm)			Leaf length (cm)			Leaf width (cm)		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	4	4.42	4.21	34.04	21.62	27.83	24.44	14.27	19.35
LE 2 x LE 20	3.85	4.25	4.05	37.81	20.24	29.02	29.67	14.3	21.99
LE 2 x LE 39	4.41	4.67	4.54	38.69	29.1	33.9	29.51	17.5	23.5
LE 2 x LE 38	4.43	4.75	4.59	43.67	28.2	35.94	32.19	25.77	28.98
LE 2 x LE 1	4.03	4.5	4.27	38.49	32.87	35.68	27.97	23.95	25.96
LE 16 x LE 20	4.21	4.58	4.4	43.47	33.4	38.44	34.88	24.9	29.89
LE 20 x LE 39	4.48	5.5	4.99	37.9	32	34.95	24.91	28.49	26.7
LE 20 x LE 1	4.43	4.75	4.59	41.36	39.28	40.32	26.59	32.59	29.59
LE 39 x LE 38	4.45	4.67	4.56	41.92	34.75	38.34	30.73	31.54	31.14
LE 38 x LE 1	4.47	4.89	4.68	40.11	34.04	37.08	28.29	21.8	25.05
LE 2	4.02	3.59	3.81	32.39	30.17	31.28	25.81	21.6	23.71
LE 16	3.96	4.25	4.1	38.31	31.44	34.87	28.31	30	29.15
LE 17	4.44	4.67	4.56	30.44	32.22	31.33	25.69	24.29	24.99
LE 20	4.46	4.59	4.52	39.37	30.74	35.05	27.4	28.18	27.79
LE39 (Akshaya)	4.23	4.67	4.45	31.13	30.14	30.63	22.62	26.74	24.68
LE 38	4.33	4.58	4.45	30.29	31.07	30.68	26.35	28.15	27.25
LE 1	4.88	5.16	5.02	45.6	35.47	40.54	30.88	25.17	28.03
Naveen	4.66	-	-	36.49	-	-	28.52	-	-
Mean	4.32	4.62	4.46	37.86	30.98	34.46	28.04	24.66	26.34
CD (P= 0.05)	0.285	0.277	0.198	3.864	0.528	1.937	5.464	0.347	2.682

in LE 2 x LE 17 (24.44 cm). Among the parents, LE 1 (30.88 cm) had highest leaf width (Table 9).

LE 20 x LE 1 (32.59 cm) exhibited maximum leaf width and LE 2 x LE 17 (14.27 cm) LE 2 x LE 20 (14.30 cm) minimum leaf width. Among parents, LE 16 recorded highest leaf width (30.00 cm) whereas, lowest value was for LE 2 (21.60 cm).

Pooled analysis revealed that, LE 39 x LE 38 (31.13 cm) had maximum leaf width and it was on par with LE 2 x LE 38 (28.98 cm), LE 16 x LE 20 (29.89 cm) and LE 20 x LE 1 (29.59 cm) and minimum was reported by LE 2 x LE 17 (19.35 cm) which was on par with LE 2 x LE 20 (21.99 cm). Among parents, highest value was recorded by LE 16 (29.15 cm) and lowest by LE 2 (23.70 cm).

4.2.1.2 Flowering Characters

4.2.1.2.1 Days to First Flowering

Among the 18 treatments, LE 2 x LE 20 was earliest to flower and this was on par with LE 2 x LE 38 during the first trial and second trial. The days to first flowering in LE 2 x LE 20 and LE 2 x LE 38 were 21.44 and 21.55 ; 22.44 and 22.55 in first trial and second trial respectively. During the first season, LE 39 x LE 38 (24.00) was latest to flower and it was on par with LE 38 x LE 1 (24.00) and LE 16 x LE 20 (23.89) and during second season also, LE 39 x LE 38 (25.67) was latest in flowering and this was on par with LE 38 x LE 1 (25.66) (Table 10).

Among the parents, LE 2 (23.33) was the earliest to flower during first season which was on par with LE 38 (23.44) and LE 20 (25.78) was the latest and it was on par with LE 1 (25.44). The checks Naveen and Akshaya recorded the same value for days to first flowering (24.11).In the second trial, earliest was LE 17 (25.22) which was on par with LE 2 (25.44) and LE 38 (25.56). LE 1(26.78) took maximum days for flowering and it was on par with LE 20 (26.56).

According to the pooled data, The hybrid, LE 2 x LE 20 (21.94) was the earliest to flower which was on par with LE 2 x LE 38 (22.05) and LE 39 x LE 38

Table.10. Mean performance of hybrids, parents and checks for days to first flowering, days to fruit set and fruit set per cent for two seasons and pooled mean

Treatments	Days to first flowering			Days to fruit Set			Fruit set (%)		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	23.22	24.67	23.94	9.00	8.00	8.50	63.47	54.00	58.74
LE 2 x LE 20	21.44	22.44	21.94	6.11	6.55	6.33	74.20	66.65	70.42
LE 2 x LE 39	22.33	22.89	22.61	9.11	8.22	8.66	62.15	58.33	60.24
LE 2 x LE 38	21.55	22.55	22.05	7.78	7.78	7.78	63.58	61.11	62.34
LE 2 x LE 1	23.11	23.78	23.44	9.44	8.67	9.05	71.08	58.07	64.57
LE 16 x LE 20	23.89	24.78	24.33	9.33	8.78	9.06	59.30	55.55	57.42
LE 20 x LE 39	23.00	24.33	23.66	9.44	9.00	9.22	55.25	41.67	48.46
LE 20 x LE 1	23.11	24.11	23.61	7.44	7.22	7.33	73.51	63.49	68.50
LE 39 x LE 38	24.00	25.67	24.84	9.33	8.11	8.72	67.72	61.11	64.41
LE 38 x LE 1	24.00	25.66	24.83	9.22	7.89	8.55	59.05	50.00	54.52
LE 2	23.33	25.44	24.39	8.44	7.22	7.83	73.09	61.47	67.28
LE 16	25.22	26.22	25.72	9.11	9.22	9.16	59.63	40.96	50.29
LE 17	24.22	25.22	24.72	9.67	8.45	9.06	58.33	61.11	59.72
LE 20	25.78	26.56	26.17	9.44	8.67	9.05	53.55	48.89	51.22
LE 39 (Akshaya)	24.11	25.67	24.89	8.67	8.00	8.33	63.64	62.96	63.30
LE 38	23.44	25.56	24.50	6.67	7.45	7.06	60.74	70.83	65.79
LE 1	25.44	26.78	26.11	9.22	8.55	8.89	62.83	60.00	61.41
Naveen	24.11	-	-	10.11	-	-	54.41	-	-
Mean	23.60	24.84	24.22	8.75	8.10	8.39	63.09	57.42	60.51
CD (P=0.05)	0.552	0.375	0.326	0.652	0.677	0.465	6.773	12.609	6.935

(24.84) was the latest to flower and it was on par with LE 38 x LE 1(24.83). Among the 18 treatments, LE 20 (26.17) took maximum days to flower and it was on par with LE 1(26.11). Among the parents LE 2 (24.39) was the earliest to flower and it was on par with LE 38 (24.50).

4.2.1.2.2 Days to Fruit Set

The data in Table 10 revealed that, the hybrid LE 2 x LE 20 was earliest for fruit set in the first season (6.11) and second season (6.55). Among the parents, LE 38 (6.67) was earliest for fruit set in first season whereas LE 2 (7.22) was earliest for fruit set in second season.

Among the hybrids, LE 2 x LE 1 (9.44) was the latest to fruit set during the first season and LE 20 x LE 39 (9.00) during second season. Among the parents, delayed fruit set was shown by LE 17 (9.67) during first season and LE 16 (9.22) during second season.

The pooled analysis revealed that, LE 2 x LE 20 (6.33) was the earliest to fruit set among the hybrids and LE 2 (7.22) among the parents.

4.2.1.2.3 Fruit Set (%)

Fruit set per cent decides the number of fruits and finally the yield. In the first trial, among the hybrids, the fruit set was highest for LE 2 x LE 20 (74.20 %) which was on par with LE 2 x LE 1 (71.08 %), LE 20 x LE 1 (73.51 %), LE 39 x LE 38 (67.72 %) and minimum fruit set was recorded in LE 20 x LE 39 (55.25 %) and it was on par with LE 16 x LE 20 (59.30 %) and LE 38 x LE 1(59.05 %). Among the parents, LE 2 (73.09 %) recorded maximum fruit set per cent and LE 20 (53.55 %) reported minimum fruit set. The checks Naveen and Akshaya recorded a fruit set per cent of 54.41 % and 63.64 % respectively (Table 10 and Figure 1).

Results of second trial revealed that, in general the fruit set was lesser than the first trial. Among the hybrids, LE 2 x LE 20 (66.65 %) recorded highest fruit set per cent which was on par with LE 2 x LE 39 (58.33 %), LE 2 x LE 38 (61.11%),

LE 20 x LE 1(63.49 %) and LE 39 x LE 38 (61.11 %). Minimum fruit set was

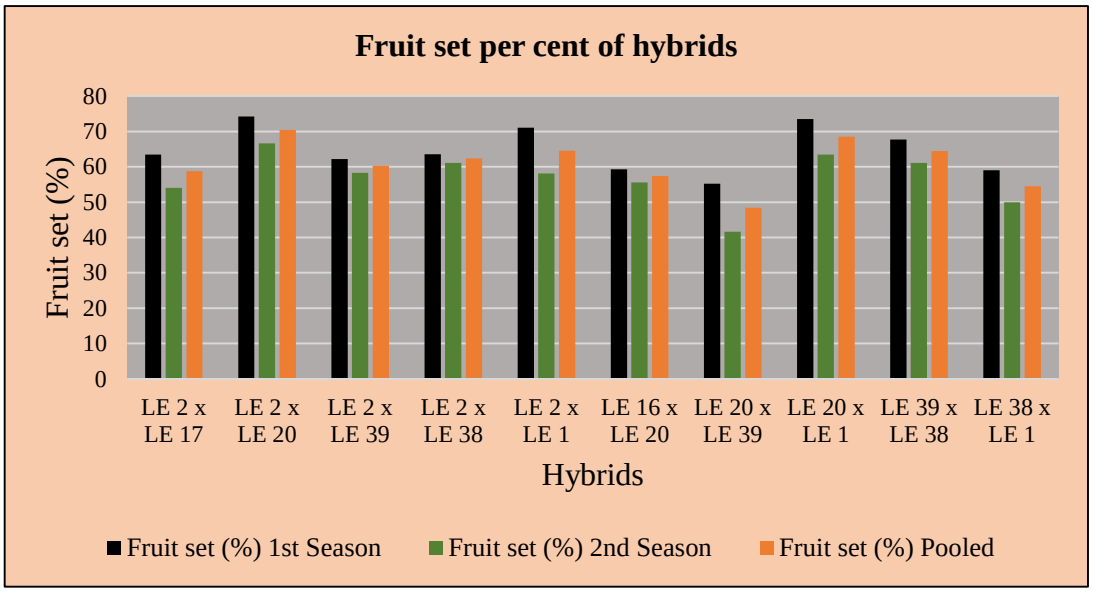


Figure 1. Mean performance of tomato hybrids for fruit set per cent

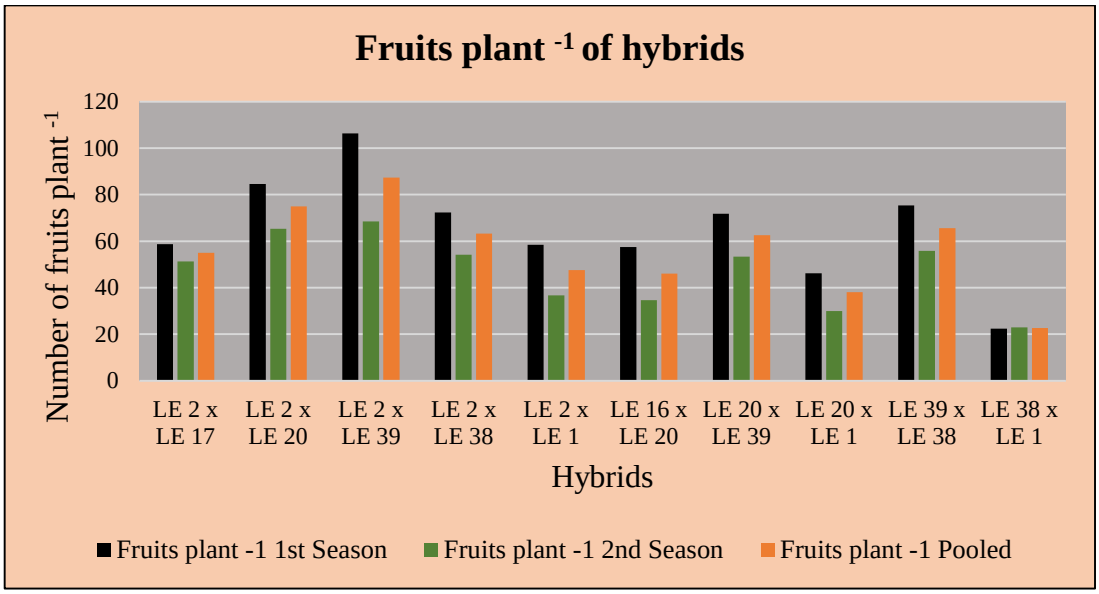


Figure 2. Mean performance of tomato hybrids for fruit plant $^{-1}$

shown by LE 20 x LE 39 (41.67 %) which was on par with LE 38 x LE 1 (50.00 %). Among the parents, LE 38 (70.83 %) showed highest fruit set and it was on par with all the other parents except LE 16 (40.96 %) and LE 20 (48.89 %) which showed minimum fruit set.

In the pooled analysis also, LE 2 x LE 20 (70.42 %) had maximum fruit set and it was on par with LE 2 x LE 1 (64.57 %), LE 20 x LE 1 (68.50 %), LE 39 x LE 38 (64.41 %) and minimum fruit set was in LE 20 x LE 39 (48.46 %) which was on par with LE 38 x LE 1 (54.52 %). Among parents, highest fruit set was given by LE 2 (67.28 %) and it was on par with LE 38 (65.79 %) and LE 16 (50.29 %) had lowest fruit set and which was on par with LE 20 (51.22 %).

4.2.1.2.4 Pollen Viability (%)

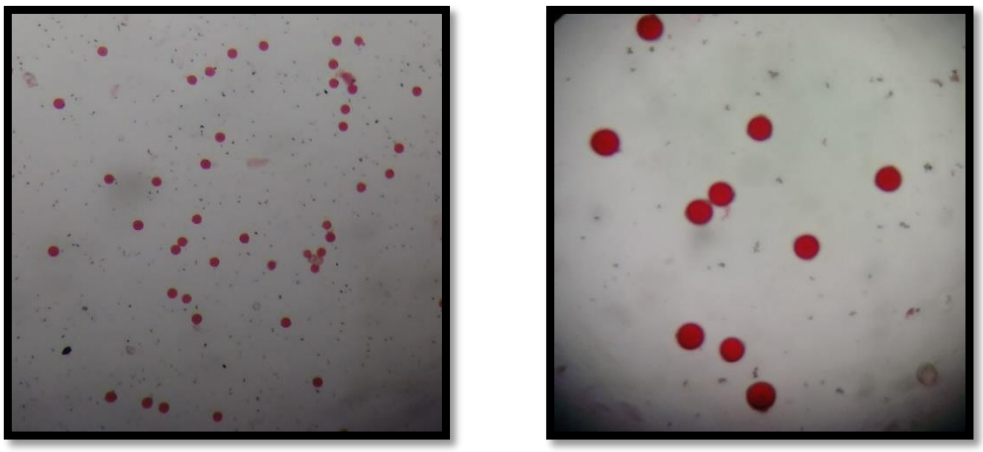
During first season, among the hybrids, LE 2 x LE 20 (89.34 %) had highest pollen viability which was on par with LE 2 x LE 17 (87.42 %) and LE 20 x LE 1 (81.01 %). Pollen viability was lowest in LE 2 x LE 39 (50.13 %) which was on par with LE 2 x LE 38 (55.55 %), LE 2 x LE 1 (57.15 %), LE 20 x LE 39 (60.48 %) and LE 38 x LE 1 (61.95 %). Among the parents, LE 1 (92.36 %) recorded maximum pollen viability and it was on par with LE 2 (83.61 %) and LE 39 (79.74 %) and lowest value for LE 17 (58.58 %) (Table 11 and Plate 13).

During second season, highest pollen viability was exhibited by LE 2 x LE 20 (66.79 %) and this was on par with LE 20 x LE 1(64.95 %) and lowest pollen viability was given by LE 38 x LE 1(44.11 %) and this was on par with LE 2 x LE 38 (47.56 %), LE 2 x LE 1(47.51 %). Among the parents the pollen viability ranged from 45.29 % (LE 17) to 56.10 % (LE 20) (Table 11).

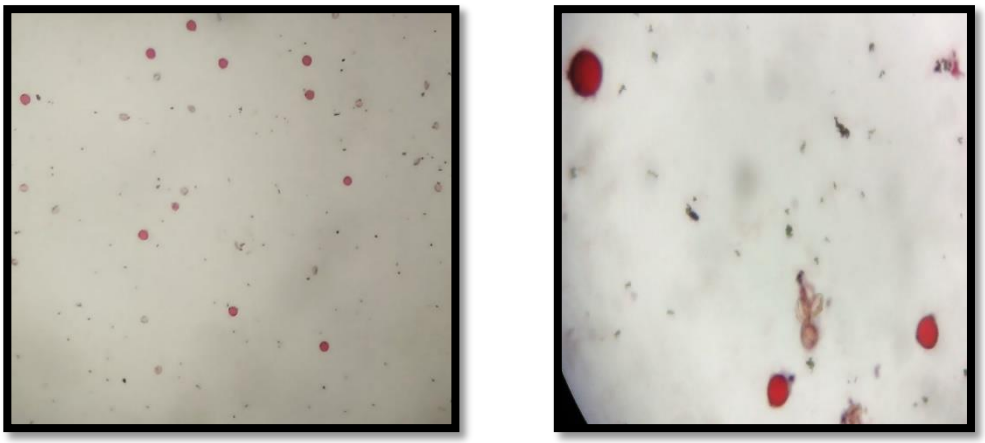
Pooled analysis revealed that maximum pollen viability was exhibited by LE 2 x LE 20 (78.07 %) and this was on par with LE 20 x LE 1(72.98 %) and the minimum pollen viability was given by LE 2 x LE 1(52.33 %) which was on par with the hybrids LE 2 x LE 38 (51.56 %) , LE 2 x LE 39 (51.75 %), LE 20 x LE 39 (56.64 %) , LE 38 x LE 1(53.03 %) and with the parent LE 17 (51.94 %). Among

Table. 11. Mean performance of hybrids, parents and checks for pollen viability, fruits plant $^{-1}$and fruits truss $^{-1}$ for two seasons and pooled mean

Treatments	Pollen viability (%)			Fruits plant $^{-1}$			Fruits truss $^{-1}$		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	87.42	55.24	71.33	58.66	51.33	55.00	4.11	3.78	3.94
LE 2 x LE 20	89.34	66.79	78.07	84.56	65.33	74.94	5.56	5.78	5.67
LE 2 x LE 39	50.13	53.37	51.75	106.33	68.44	87.39	2.78	2.56	2.67
LE 2 x LE 38	55.55	47.56	51.56	72.33	54.22	63.28	4.45	4.22	4.33
LE 2 x LE 1	57.15	47.51	52.33	58.44	36.67	47.56	4.33	3.56	3.94
LE 16 x LE 20	70.85	50.82	60.83	57.55	34.66	46.11	3.33	3.22	3.28
LE 20 x LE 39	60.48	52.81	56.64	71.78	53.34	62.56	2.89	2.67	2.78
LE 20 x LE 1	81.01	64.95	72.98	46.22	29.99	38.11	4.56	3.89	4.22
LE 39 x LE 38	71.77	61.32	66.55	75.44	55.78	65.61	3.44	3.67	3.56
LE 38 x LE 1	61.95	44.11	53.03	22.33	22.89	22.61	2.67	2.33	2.50
LE 2	83.61	53.05	68.33	50.89	36.01	43.45	5.22	5.11	5.17
LE 16	70.29	54.10	62.19	49.33	28.89	39.11	2.44	2.22	2.33
LE 17	58.58	45.29	51.94	41.22	21.78	31.50	2.67	2.78	2.72
LE 20	75.15	56.10	65.62	43.56	27.78	35.67	2.78	2.78	2.78
LE 39 (Akshaya)	79.74	45.83	62.78	43.00	43.11	43.05	3.55	3.56	3.55
LE 38	68.07	53.68	60.87	42.78	41.11	41.94	2.78	2.67	2.72
LE 1	92.36	49.05	70.70	26.89	17.34	22.11	3.22	3.22	3.22
Naveen	55.84	-	-	25.33	-	-	3.00	-	-
Mean	70.52	53.03	62.21	54.26	40.51	48.23	3.54	3.41	3.49
CD (P=0.05)	12.636	4.065	6.484	16.851	1.451	8.279	0.519	0.333	0.304



High pollen viability in LE 2 x LE 20 at 10 X and 40 X resolutions



Low pollen viability in LE 2 x LE 39 at 10 X and 40 X resolutions

Plate 13. Variability of pollen viability among the treatments

the parents highest pollen viability was obtained for LE 1 (70.70 %) which was on par with LE 2 (68.33 %).

4.2.1.3 Fruit Characters and Yield

4.2.1.3.1 Fruits Plant $^{-1}$

During both the seasons, the hybrid LE 2 x LE 39 and LE 38 x LE 1 recorded highest and lowest fruits plant $^{-1}$ respectively. But the number of fruits was lower in second season compared to first season. The number of fruits in the first season ranged from 22.33 (LE 38 x LE 1) to 106.33 (LE 2 x LE 39) and second season ranged from 22.89 (LE 38 x LE 1) to 68.44 (LE 2 x LE 39). Among the parents the values ranged from 26.89 (LE 1) to 50.89 (LE 2) and 17.34 (LE 1) to LE 39 (43.11) in first and second trials respectively (Table 11 and Figure 2).

Pooled analysis revealed that, LE 2 x LE 39 had maximum (87.39) and LE 38 x LE 1had minimum (22.61) number of fruits plant $^{-1}$. Among the parents, the highest fruits plant $^{-1}$ was obtained for LE 2 (43.45) and it was on par with LE 39 (43.05) and LE 38(41.94) while LE 1(22.11) got minimum fruits plant $^{-1}$ (Plate 16 and 19).

4.2.1.3.2 Fruits Truss $^{-1}$

According to the first season data, LE 2 x LE 20 (5.56) recorded maximum number of fruit truss $^{-1}$ whereas the minimum was recorded by LE 38 x LE 1 (2.67) which was on par with LE 2 x LE 39 (2.78), LE 20 x LE 39 (2.89). Among the parents, LE 2 (5.22) exhibited highest fruits truss^{-1} and LE 16 (2.44) had lowest value which was on par with LE 17 (2.67), LE 20 (2.78) and LE 38 (2.78) (Table 11).

In second season also the maximum fruits truss $^{-1}$ was recorded by LE 2 x LE 20 (5.78) and minimum by LE 38 x LE 1(2.33). Among the parents, maximum fruits truss $^{-1}$ was given by LE 2 (5.11) and minimum by LE 16 (2.22).

Pooled analysis showed that fruits truss $^{-1}$ was highest for the hybrid LE 2 x LE 20 (5.67) and lowest for LE 38 x LE 1 (2.50). Among the parents LE 2 (5.17) had maximum number of fruits truss $^{-1}$ (Plate 15 and 18).

4.2.1.3.3 Fruit Length (cm)

In the first crop, the fruit length was maximum in LE 20 x LE 1 (8.52 cm) and minimum in LE 20 x LE 39 (6.36 cm) among the hybrids and maximum fruit length was recorded in LE 1 (8.58 cm) and minimum in LE 39 (6.14 cm) which was on par with LE 2 (6.28 cm) among the parents (Table 12).

In the second crop, among the hybrids, the fruit length ranged from 8.42 cm (LE 20 x LE 1) to 6.57 cm (LE 20 x LE 39). Among the parents maximum fruit length was recorded in LE 1 (8.65 cm) and minimum in LE 39 (6.07 cm) and it was on par with LE 2 (6.29 cm) and LE 16 (6.08 cm).

The pooled data of first and second crops revealed that, among the hybrids, LE 20 x LE 1 (8.47 cm) had longest fruits and LE 20 x LE 39 (6.46 cm) had shortest fruits. Among the parents, LE 1 (8.62 cm) had longest fruits and LE 39 (6.11 cm) had shortest fruits.

4.2.1.3.4 Fruit Girth (cm)

The first season data on fruit girth showed that among the hybrids the values ranged from 12.82 cm (LE 20 x LE 39) to 17.48 cm (LE 20 x LE 1) and the hybrid LE 20 x LE 39 was on par with LE 2 x LE 17 (13.00 cm), LE 2 x LE 20 (13.17 cm), LE 2 x LE 39 (12.97 cm), LE 2 x LE 38 (12.91 cm) and LE 16 x LE 20 (13.11 cm). Among the parents, the fruit girth ranged from 12.01 cm (LE 2) to16.40 cm (LE 1) (Table 12).

During the second season also the same trend was observed. The fruit girth among the hybrids ranged from 12.86 cm (LE 20 x LE 39) to 17.29 cm (LE 20 x LE 1) and the parents showed a range of 12.12 cm (LE 2) to 16.52 cm (LE 1).

In the pooled mean, LE 20 x LE 1 (17.38 cm) had maximum fruit girth and minimum in LE 20 x LE 39 (12.84 cm) and it was on par with LE 2 x LE 17

Table.12. Mean performance of hybrids, parents and checks for fruit length, fruit girth and fruit weight for two seasons and pooled mean

Treatments	Fruit length (cm)			Fruit girth (cm)			Fruit weight (g)		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	6.8	6.71	6.75	13	12.94	12.97	41.33	41.33	41.33
LE 2 x LE 20	6.98	7.22	7.1	13.17	13.58	13.37	41.33	44	42.66
LE 2 x LE 39	6.48	6.72	6.6	12.97	13.28	13.12	36	38	37
LE 2 x LE 38	6.67	6.88	6.77	12.91	13.22	13.07	41.78	42.44	42.11
LE 2 x LE 1	7.7	7.55	7.62	14.04	14.15	14.1	80.78	78.22	79.5
LE 16 x LE 20	7.48	7.32	7.4	13.11	13.22	13.17	51.56	45.78	48.67
LE 20 x LE 39	6.36	6.57	6.46	12.82	12.86	12.84	43	42.66	42.83
LE 20 x LE 1	8.52	8.42	8.47	17.48	17.29	17.38	100.11	94.45	97.28
LE 39 x LE 38	6.96	6.92	6.94	14.02	13.99	14	54	54.22	54.11
LE 38 x LE 1	8.06	7.71	7.88	16.44	16.06	16.25	68.67	69.67	69.17
LE 2	6.28	6.29	6.28	12.01	12.12	12.07	36.89	37.11	37
LE 16	6.65	6.08	6.37	12.83	12.79	12.81	43.44	42	42.72
LE 17	6.59	6.35	6.47	13.53	13.36	13.45	44.44	43.33	43.89
LE 20	6.75	6.51	6.63	13.2	13.08	13.14	46.22	43.33	44.78
LE 39 (Akshaya)	6.14	6.07	6.11	13.14	13.27	13.2	46.67	46	46.33
LE 38	6.91	6.82	6.87	13.62	13.71	13.67	49.33	47.78	48.55
LE 1	8.58	8.65	8.62	16.4	16.52	16.46	110.66	99.22	104.94
Naveen	8.09	-	-	14.43	-	-	72.22	-	-
Mean	7.05	6.99	7.02	13.81	13.85	13.83	56.02	53.5	54.29
CD (P=0.05)	0.265	0.232	0.171	0.437	0.15	0.225	4.597	2.67	2.577

(12.97 cm). Among parents LE 1(16.46 cm) and LE 2 (12.07 cm) had maximum and minimum fruit girth respectively.

4.2.1.3.5 Fruit Weight (g)

During both the seasons, LE 20 x LE 1 and LE 2 x LE 39 had highest and lowest fruit weight respectively and the values ranged from 36.00 g to 100.11 g in the first season and 38.00 g to 94.45 g in the second season. The parents recorded a range of 36.89 g (LE 2) to 110.66 g (LE 1) in the first season and 37.11 g (LE 2) to 99.22 (LE 1) in the second season. The checks Naveen and Akshaya recorded 72.22g and 46.67g respectively (Table 12 and Figure 3).

The pooled analysis revealed that the LE 20 x LE 1 (97.28 g) had maximum fruit weight and LE 2 x LE 39 (37.00 g) had minimum fruit weight among the hybrids and LE 1 (104.94 g) had highest fruit weight and LE 2 (37.00 g) lowest fruit weight among the parents (Plate 14 and 17).

4.2.1.3.6 Yield Plant $^{-1}$ (g)

During the first crop, LE 20 x LE 1 (3505.20 g) gave highest yield and it was on par with LE 2 x LE 20 (3256.43 g) and LE 2 x LE 1 (3060.11 g). The lowest yield was given by LE 38 x LE 1 (1550.22 g). Among the parents, LE 1 (2458.22 g) was the highest yielder and LE 2 (1444.11 g) was the lowest yielder and it was on par with all other parents. The checks Naveen recorded a yield of 1361.11 g and Akshaya 1840.89 g (Table 13 and Figure 4).

During the second crop, among the hybrids the magnitude of yield varied from 1259.22 g (LE 38 x LE 1) to 1843.89 g (LE 20 x LE 1) and among the parents, the yield varied from 878.78 g (LE 2) to 1355.64 g (LE 1).

According to the pooled analysis results, LE 20 x LE 1 (2674.54 g) had highest yield plant $^{-1}$ and it was on par with LE 2 x LE 20 (2476.68 g) and LE 38 x LE 1 (1404.71 g) had lowest yield plant^{-1}. Among the parents, highest yield was observed in LE 1(1906.93 g) and lowest in LE 2 (1161.44 g) which was on par with LE 16, LE 17 and LE 20 (Plate 14 and 17).

Table.13. Mean performance of hybrids, parents and checks for yield plant $^{-1}$ and yield plot $^{-1}$ for two seasons and pooled mean

Treatments	Yield plant $^{-1}$ (g)			Yield plot $^{-1}$ (kg)		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	1852	1278.93	1565.46	35.62	23.28	29.45
LE 2 x LE 20	3256.43	1696.92	2476.68	62.88	30.43	46.65
LE 2 x LE 39	2602.2	1474.89	2038.54	50.33	27.14	38.74
LE 2 x LE 38	2373.22	1460.97	1917.09	45.94	26.78	36.36
LE 2 x LE 1	3060.11	1531.55	2295.83	59.14	26.84	42.99
LE 16 x LE 20	2186.78	1424.56	1805.67	42.3	25.26	33.78
LE 20 x LE 39	2148.33	1395.63	1771.98	41.59	24.46	33.03
LE 20 x LE 1	3505.2	1843.89	2674.54	67.68	32.32	50
LE 39 x LE 38	2355.31	1428.22	1891.76	45.36	25.03	35.19
LE 38 x LE 1	1550.22	1259.22	1404.72	29.85	21.81	25.83
LE 2	1444.11	878.78	1161.44	27.9	15.93	21.92
LE 16	1672.78	938.22	1305.5	32.28	16.51	24.4
LE 17	1561.55	892.25	1226.9	30.1	15.35	22.73
LE 20	1743.89	954.15	1349.02	33.64	15.71	24.68
LE 39 (Akshaya)	1840.89	1289.38	1565.13	35.51	23.38	29.45
LE 38	1790.44	1232.15	1511.29	34.51	22.14	28.33
LE 1	2458.22	1355.64	1906.93	47.38	24.2	35.79
Naveen	1361.11	-	-	20.42	-	-
Mean	2153.49	1313.84	1756.97	41.25	23.33	32.9
CD (P=0.05)	510.705	34.371	247.768	9.998	2.435	5.033

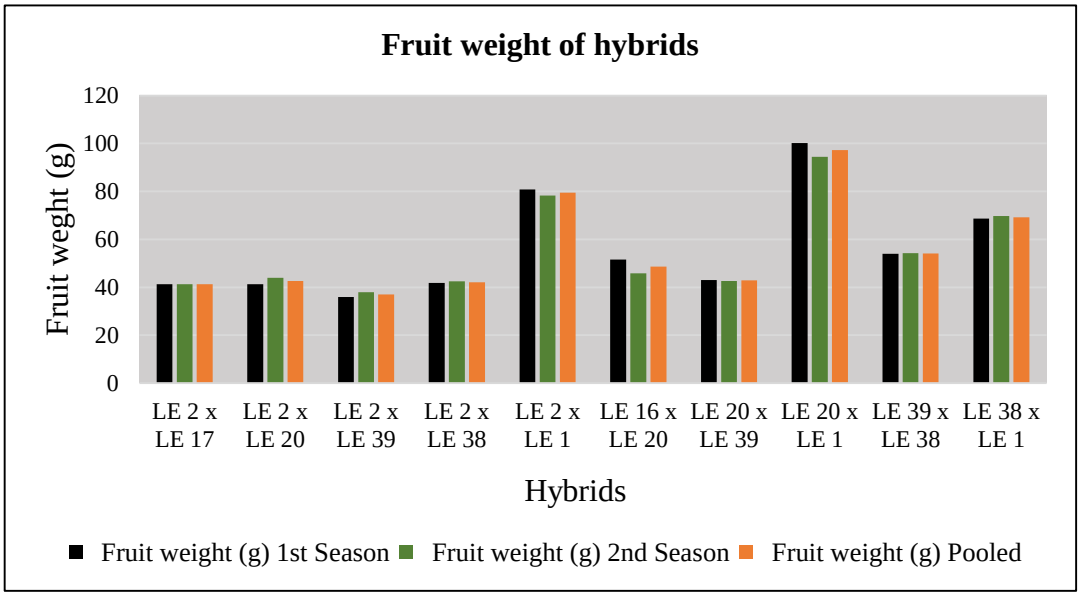


Figure 3. Mean performance of tomato hybrids for fruit weight

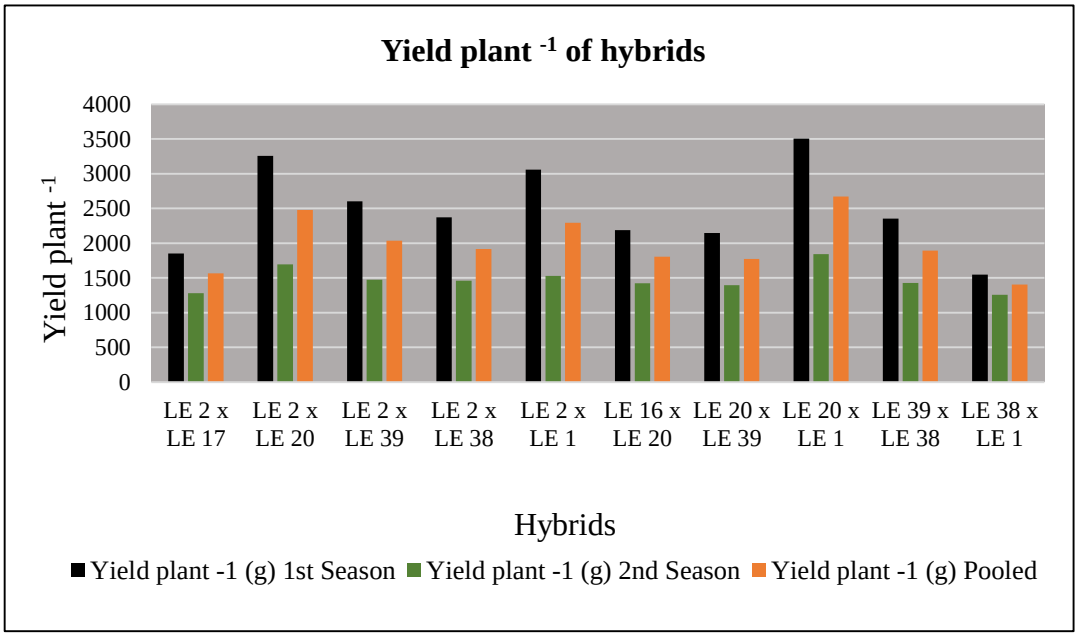


Figure 4. Mean performance of tomato hybrids for yield plant $^{-1}$

LE 20 x LE 1

Plate 14. Superior hybrid with highest fruit weight and yield

LE 2 x LE 20

Plate 15. Superior hybrid with highest fruits truss $^{-1}$

LE 2 x LE 39

Plate 16. Superior hybrid with highest fruits plant $^{-1}$

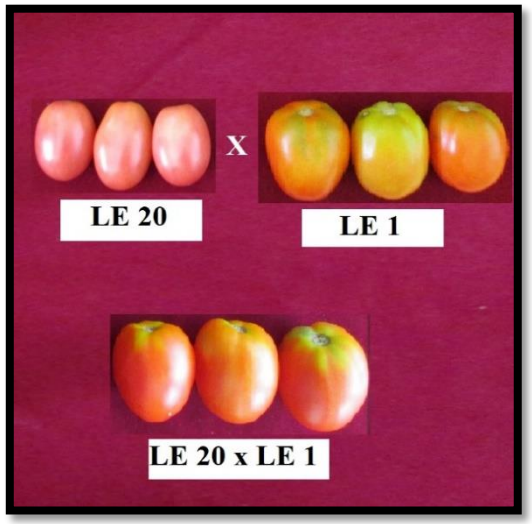


Plate 17. LE 20 x LE 1 with their parents LE 20 and LE 1

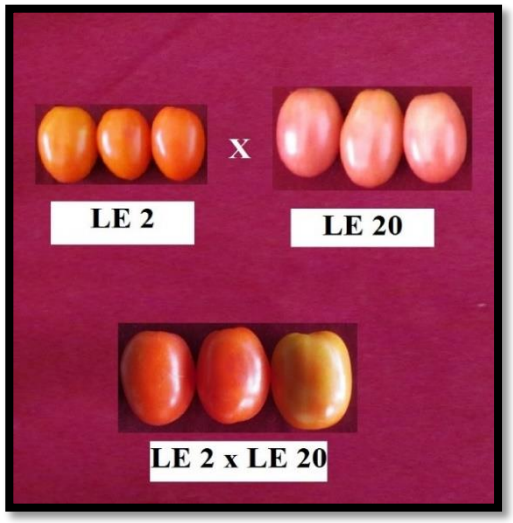


Plate 18. LE 2 x LE 20 with their parents LE 2 and LE 20

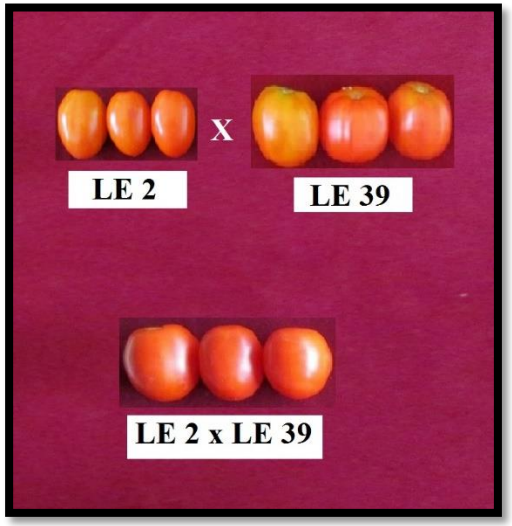


Plate 19. LE 2 x LE 39 with their parents LE 2 and LE 39

4.2.1.3.7 Yield Plot $^{-1}$ (kg)

The highest yield plot $^{-1}$ in first trial was recorded by LE 20 x LE 1(67.68 kg) and it was on par with LE 2 x LE 20 (62.88 kg) and LE 2 x LE 1 (59.14 kg) (Table 13). The lowest yield plot $^{-1}$ was given by LE 38 x LE 1 (29.85 kg) and it was on par with LE 2 x LE 17(35.62 kg). The parents showed a range of 27.90 kg (LE 2) to 47.38 kg (LE 1) in yield plot $^{-1}$.

During the second trial also, the hybrid LE 20 x LE 1(32.32 kg) recorded the highest yield plot^{-1} and it was on par with LE 2 x LE 20 (30.43 kg) and the lowest yield plot $^{-1}$ was given by LE 38 x LE 1(21.81 kg). Among the parents, LE 1 (24.20 kg) recorded maximum yield plot $^{-1}$ and it was on par with LE 39 (23.38 kg) and minimum yield plot $^{-1}$ was given by LE 17 (15.35 kg).

According to the pooled data, LE 20 x LE 1 (50.00 kg) had produced maximum yield plot^{-1} and it was on par with LE 2 x LE 20 (46.65 kg) while LE 38 x LE 1 (25.83 kg) had minimum yield plot $^{-1}$. Among the parents, the highest yield plot $^{-1}$ was recorded by LE 1 (35.79 kg) and lowest by LE 2 (21.92 kg) and it was on par with LE 16 (24.40 kg), LE 17 (22.73 kg) and LE 20 (24.68 kg).

4.2.2 Quality Characters

4.2.2.1 Total Soluble Solids (%)

In the first trial, among the parents the TSS ranged from 5.00 % (LE 20) to 5.80 % (LE 38) and among the hybrids, it ranged from 5.00 % (LE 20 x LE 1) to 5.40 % (LE 2 x LE 38). The check Naveen had a TSS content of 5.67 % (Table 14).

In the second trial, the TSS ranged from 5.13 % (LE 38 x LE 1) to 5.37 % (LE 2 x LE 17 and (LE 39 x LE 38) among the hybrids and 5.17 % (LE 1 and LE 20) to 5.67 % (LE 38) among the parents.

Pooled analysis showed that, among the hybrids maximum TSS was obtained for LE 2 x LE 38 (5.37 %) and it was on par with LE 2 x LE 17 (5.33 %)

Table. 14. Mean performance of hybrids, parents and checks for total soluble solids (TSS), lycopene and ascorbic acid for two seasons and pooled mean

Treatments	Total Soluble Solids (TSS %)			Lycopene (mg/100g)			Ascorbic acid (mg/100g)		
	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled	1st Season	2nd Season	Pooled
LE 2 x LE 17	5.3	5.37	5.33	12.79	11.44	12.11	28.28	27.96	28.12
LE 2 x LE 20	5.2	5.23	5.22	11.65	11.31	11.48	31.31	30.1	30.7
LE 2 x LE 39	5.2	5.27	5.23	13.83	12.38	13.1	25.25	23.65	24.45
LE 2 x LE 38	5.4	5.33	5.37	12.1	11.06	11.58	22.22	19.35	20.78
LE 2 x LE 1	5.23	5.23	5.23	11.66	10.59	11.12	33.33	31.07	32.2
LE 16 x LE 20	5.27	5.27	5.27	12.86	12	12.43	32.32	30.1	31.21
LE 20 x LE 39	5.2	5.27	5.23	13.16	10.78	11.97	27.27	25.8	26.53
LE 20 x LE 1	5	5.17	5.08	11.09	10.57	10.83	30.3	30.1	30.2
LE 39 x LE 38	5.33	5.37	5.35	13.4	11.55	12.48	28.28	21.51	24.9
LE 38 x LE 1	5.03	5.13	5.08	13.36	11.4	12.38	26.26	25.8	26.03
LE 2	5.23	5.23	5.23	12.97	11.34	12.15	26.47	23.65	25.06
LE 16	5.27	5.33	5.3	13.7	11.36	12.53	23.52	21.51	22.51
LE 17	5.47	5.37	5.42	13.32	10.55	11.93	18.62	17.2	17.91
LE 20	5	5.17	5.08	13.79	10.38	12.08	19.6	17.2	18.4
LE 39 (Akshaya)	5.2	5.33	5.27	13.48	11.62	12.54	20.58	19.35	19.96
LE 38	5.8	5.67	5.73	13.48	11.35	12.42	17.64	17.64	17.64
LE 1	5.13	5.17	5.15	13.02	11.52	12.27	18.18	15.05	16.61
Naveen	5.67	-	-	13.29	-	-	27.27	-	-
Mean	5.27	5.29	5.27	12.94	11.25	12.08	25.37	23.35	24.31
CD (P=0.05)	0.163	0.113	0.097	0.5	0.855	0.48	2.757	2.006	1.656

and LE 39 x LE 38 (5.35 %). LE 20 x LE 1 (5.08 %) had minimum TSS. Among the parents, LE 38 (5.73 %) had highest TSS and LE 1 (5.15 %) recorded lowest TSS which was on par with LE 20 (5.08 %).

4.2.2.2 Lycopene (mg/100g)

Lycopene content had a range of 11.09 mg/100g (LE 20 x LE 1) to 13.83 mg/100g (LE 2 x LE 39) among the hybrids and 12.97 mg/100g (LE 2) to 13.79 mg/100g (LE 20) among the parents in the first trial. Naveen recorded 13.29 mg/100g lycopene (Table 14).

In the second trial, among the hybrids, the lycopene content varied from 10.57 mg/100g (LE 20 x LE 1) to 13.10 mg/100g (LE 2 x LE 39) and among the parents it varied from 10.55 mg/ 100g (LE 17) to 11.62 mg/100g (LE 39).

In the pooled mean, highest lycopene content was recorded by LE 2 x LE 39 (13.10 mg/ 100g) and the lowest by LE 20 x LE 1 (10.83 mg/100g) which was on par with LE 2 x LE 1(11.12 mg/100g). Among the parents, LE 39 (12.54 mg/100g) got maximum lycopene and it was on par with all the parents except LE 17 (11.93 mg/100g).

4.2.2.3 Ascorbic Acid (mg /100g)

Among the hybrids the ascorbic acid content had a range of 22.22 mg/100g (LE 2 x LE 38) to 33.33 mg /100g (LE 2 x LE 1) in the first crop and 19.35 mg /100g (LE 2 x LE 38) to 31.07 mg /100g (LE 2 x LE 1) in the second crop (Table 14).

Among the parents, the ascorbic acid content varied from 17.64 mg/100g (LE 38) to 26.47 mg/100g (LE 2) in the first crop and 15.05 mg /100g (LE 1) to 21.51 mg /100g (LE 2) in the second crop. The hybrid Naveen recorded 2.27 mg/100g and variety Akshaya recorded 20.58 mg/100g ascorbic acid during first crop.

According to the pooled mean, highest ascorbic acid was obtained for LE 2 x LE 1(32.20 mg /100g) which was on par with LE 2 x LE 20 (30.71 mg /100g)

and LE 16 x LE 20 (31.21 mg /100g) while LE 2 x LE 3 8(20.78 mg /100g) had the lowest ascorbic acid content. Among the parents, LE 2 (25.06 mg /100g) had maximum ascorbic acid and LE 1 (16.61 mg /100g) had minimum and it was on par with LE 38 (17.64 mg /100g) and LE 16 (17.91 mg /100g).

4.2.3 Incidence of Pest and Diseases

The crop was monitored for the incidence of pest and diseases in both the seasons and there was no incidence of pests inside the polyhouse. The incidence of bacterial wilt was very less during the first season and there was incidence of bacterial wilt in the second season (Table 15 and Plate 20).

4.2.3.1 Bacterial Wilt (%)

During the first season, among the 18 treatments, only the check Naveen had the incidence of bacterial wilt (50%) and all other treatments were free from the disease.

During the second season, the hybrids LE 2 x LE 39 and LE 2 x LE 38 were free from bacterial wilt whereas 100 % bacterial wilt incidence was observed in the check Naveen. Among the hybrids, LE 16 x LE 20 and LE 38 x LE 1 (16.67 %) had highest incidence of bacterial wilt and among parents, the highest incidence was observed in LE 20 (30 %).

4.2.4 Physiological Disorders

The crop was monitored for the incidence of physiological disorders in two seasons and fruit cracking, blossom end rot and stigma exertion were observed (Table 15 and Plate 20).

4.2.4.1 Fruit Cracking (%)

The fruit cracking is characterized by breaking of the fruit walls. In both the trials, among the 18 treatments, the incidence of fruit cracking was observed only in four treatments and all the other treatments were free from this disorder. The incidence of fruit cracking was more in second season when compared to first season.

Table. 15. Incidence of bacterial wilt and physiological disorders for tomato hybrids, parents and checks for two seasons

Treatments	Incidence of bacterial wilt (%)		Incidence of fruit cracking (%)		Incidence of blossom end rot (%)		Incidence of stigma exertion (%)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
LE 2 x LE 17	0	6.67	0	0	0	0	0	14.28
LE 2 x LE 20	0	10.00	0	0	0	0	0	31.54
LE 2 x LE 39	0	0	0	0	0	0	0	19.05
LE 2 x LE 38	0	0	13.33	16.67	0	0	0	22.22
LE 2 x LE 1	0	13.33	0	0	0	0	0	9.52
LE 16 x LE 20	0	16.67	0	0	0	0	0	11.11
LE 20 x LE 39	0	13.33	0	0	13.33	16.67	0	22.22
LE 20 x LE 1	0	13.33	0	0	0	0	0	9.52
LE 39 x LE 38	0	13.33	23.33	26.67	10.00	26.67	0	20.63
LE 38 x LE 1	0	16.67	0	0	0	0	0	11.11
LE 2	0	6.67	0	0	0	0	0	23.61
LE 16	0	13.33	53.33	56.67	0	0	0	25.39
LE 17	0	23.33	0	0	16.67	23.33	0	35.35
LE 20	0	30.00	0	0	0	0	0	11.11
LE 39 (Akshaya)	0	10.00	0	0	0	0	0	35.55
LE 38	0	13.33	20.00	26.67	0	0	0	9.52
LE 1	0	16.67	0	0	0	0	0	9.52
Naveen	50	100.00	0	-	0	-	0	-

Bacterial wilt

Fruit cracking

Blossom end rot **Stigma exertion**

Plate 20. Incidence of bacterial wilt and physiological disorders in tomato

The incidence of fruit cracking in LE 2 x LE 38, LE 38, LE 39 x LE 38 and LE 16 were 13.33% ; 16.67 %, 20.00% ; 26.67 %, 23.33% ; 26.67% and 53.33% ; 56.67 in first and second seasons respectively.

4.2.4.2 Blossom End Rot (%)

It is characterized by the formation of water soaked lesion in the blossom end. During both the seasons, all other treatments except LE 17, LE 20 x LE 39 and LE 39 x LE 38 were free from blossom end rot. The incidence of blossom end rot in LE 39 x LE 38, LE 20 x LE 39 and LE 17 were 10.00%; 26.67%, 13.33% ; 16.67% and 16.67% ;23.33% in first and second season respectively.

4.2.4.3 Stigma Exertion (%)

High temperature leads to exerted stigma condition which adversely affect the fruit set. In the first crop, there was no incidence of stigma exertion since the temperature was favourable to the crop. In the second trial, the incidence of stigma exertion varied from 9.52 % to 35.55%. Among the hybrids the incidence of stigma exertion was least in LE 2 x LE 1 and LE 20 x LE 1(9.52 %) and among the parents, LE 38 and LE 1(9.52 %) recorded the least incidence of stigma exertion.

4.3 CORRELATION ANALYSIS

Using the first season data, simple correlation was carried out for fourteen characters and the results are presented in Table 16.

Days to first flowering exhibited a significant positive correlation with days to fruit set (0.5290) and lycopene (0.5257) and showed a significant negative correlation with fruit set per cent (-0.4354), fruits plant $^{-1}$ (-0.5747), fruits truss $^{-1}$ (-0.5780), ascorbic acid (-0.4041), yield plant $^{-1}$ (-0.4380) and yield plot $^{-1}$ (0.4313).

Days to fruit set had a significant positive correlation with lycopene (0.4531) and significant negative correlation with fruit set per cent (-0.4924), pollen viability (-0.2908), fruits plant $^{-1}$ (-0.2692), fruits truss $^{-1}$ (-0.5234), yield plant $^{-1}$ (-0.4245) and yield plot $^{-1}$ (-0.4409).

Fruit set percentage showed a significant correlation with pollen viability (0.3751), fruits plant $^{-1}$ (0.2730), fruits truss $^{-1}$(0.7077), ascorbic acid (0.3515), yield plant $^{-1}$ (0.5050) and yield plot $^{-1}$ (0.5106) and it was negatively correlated with total soluble solids (-0.1587) and lycopene (0.6083).

Pollen viability had a positive significant correlation with fruits truss $^{-1}$ (0.3731) and significant negative correlation with total soluble solids (-0.2937).

Fruits plant $^{-1}$ had a significant positive correlation with fruits truss $^{-1}$ (0.2780) and it was negatively correlated with fruit length (-0.4701 cm), fruit girth (-0.4501) and fruit weight (0.4827).

Fruit length was positively correlated with fruit girth (0.8635) and fruit weight (0.8965) and fruit girth was positively correlated with the fruit weight (0.8743).

Yield plant $^{-1}$ had a significant positive correlation with fruit set per cent (0.5050), fruits plant $^{-1}$ (0.4984), fruits truss $^{-1}$ (0.4744), fruit length (0.3048), fruit girth (0.3193), fruit weight (0.3555) and ascorbic acid (0.4521). It was negatively correlated with days to first flowering (-0.4380), days to fruit set (-0.4245), TSS (-0.3136) and lycopene (-0.6498).

Yield plot $^{-1}$ had a significant positive correlation with yield plant $^{-1}$ (0.9925), ascorbic acid (0.4233), fruits truss $^{-1}$(0.4748), fruits plant $^{-1}$ (0.5205) and fruit weight (0.3229).

Ascorbic acid was positively correlated with fruit set per cent (0.3515), fruits plant $^{-1}$ (0.2944), fruits truss $^{-1}$ (0.4605) and had significant negative correlation with days to first flowering (-0.4041) and lycopene (-0.5280).

4.4 ESTIMATION OF HETEROSIS

The magnitude of relative heterosis, heterobeltiosis and standard heterosis over the hybrid Naveen and variety akshaya were worked out based on the first season data. It showed an increase or decrease of F_1 value over the mid-parent (relative heterosis), better parent (heterobeltiosis) and standard check (standard

Table. 16. Correlation coefficient for the flowering and fruit characters of tomato

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.0000	**0.5290**	**-0.4354**	0.1462	**-0.5747**	**-0.5780**	0.1991	0.2139	***0.2839***	-0.1050	**0.5257**	**-0.4041**	**-0.4380**	**-0.4313**
X2		1.0000	**-0.4924**	***-0.2908***	***-0.2692***	**-0.5234**	0.0603	-0.0112	0.0965	-0.0984	**0.4531**	0.0151	**-0.4245**	**-0.4409**
X3			1.0000	**0.3751**	***0.2730***	**0.7077**	0.0687	0.1060	0.1486	-0.1587	**-0.6083**	**0.3515**	**0.5050**	**0.5106**
X4				1.0000	-0.1688	**0.3731**	0.0949	0.1079	0.1781	***-0.2937***	-0.1749	-0.0065	0.0948	0.1069
X5					1.0000	***0.2780***	**-0.4701**	**-0.4501**	**-0.4827**	-0.1264	-0.1222	***0.2944***	**0.4984**	**0.5205**
X6						1.0000	0.0189	-0.0675	0.0140	-0.1494	**-0.7297**	**0.4605**	**0.4744**	**0.4748**
X7							1.0000	**0.8635**	**0.8965**	-0.1375	**-0.3715**	0.2376	***0.3048***	0.2623
X8								1.0000	**0.8743**	-0.2640	***-0.3107***	0.0491	***0.3193***	***0.2944***
X9									1.0000	-0.2197	**-0.3854**	0.0790	**0.3555**	***0.3229***
X10										1.0000	0.2015	-0.2307	***-0.3136***	**-0.3478**
X11											1.0000	**-0.5280**	**-0.6498**	**-0.6373**
X12												1.0000	**0.4521**	**0.4233**
X13													1.0000	**0.9925**
X14														1.0000

(Bold - Significant at 1 % level Bold italics – Significant at 5 % level)

X1-Days to first flowering X2- Days to fruit set X3- Fruit set (%) X4- Pollen viability (%) X5- Fruits plant $^{-1}$
X6- Fruits truss $^{-1}$ X7- Fruit length (cm) X8- Fruit girth (cm) X9- Fruit weight (g) X10-TSS(%)
X 11-Lycopene (mg/100g) X12- Ascorbic acid (mg/100g) X13- Yield plant $^{-1}$ (g) X14- Yield plot $^{-1}$(kg)

heterosis) for various characters. The character wise results are summarized in the following paragraphs (Tables 17 to 26).

4.4.1 Biometric Characters

4.4.1.1 Vegetative Characters

4.4.1.1.1 Plant Height (m)

The heterosis over the mid parent ranged from -16.70 % (LE 2 x LE 17) to 55.31 % (LE 2 x LE 39). Heterobeltiosis ranged from -46.87 % (LE 2 x LE 17) to 27.93 % (LE 39 x LE 38). Among the ten hybrids LE 20 x LE 1 showed maximum standard heterosis over the two checks Naveen and Akshaya.*ie.* 45.15 % and 65.26 % respectively (Table 17).

4.4.1.1.2 Height at Flowering (cm)

The magnitude of heterosis varied from -7.49 % (LE 2 x LE 17) to 38.05 % (LE 2 x LE 39) over mid parent and -24.77 % (LE 2 x LE 17) to 13.36 % (LE 2 x LE 39) over better parent. Highest negative significant standard heterosis over the hybrid Naveen was given by LE 2 x LE 17 (-33.97 %). The standard heterosis over the variety Akshaya exhibited a range of -22.88 % (LE 2 x LE 17) to 13.44 % (LE 39 x LE 38) (Table 17).

4.4.1.1.3 Node to First Inflorescence

For node to first inflorescence, lowest value is the desired one and none of the hybrid showed significant negative heterosis. Only LE 2 x LE 20 recorded negative value for relative heterosis (-4.11 %) and heterobeltiosis (-5.18 %) (Table 18).

4.4.1.1.4 Internodal Length (cm)

The estimates of heterosis varied from -9.36 % (LE 2 x LE1) to 6.82 % (LE 2 x LE 39) over the mid parent,-17.29 % (LE 2 x LE 1) to 4.17 % (LE 2 x LE 39) over better parent, -17.37 % (LE 2 x LE 20) to -4.00 % (LE 20 x LE 39) over the

Table.17. Heterosis (%) for plant height and height at flowering

Hybrids	Plant height (m)				Height at flowering (cm)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	-16.70*	-46.87**	-20.31**	-9.27	-7.49	-24.77**	-33.97**	-22.88**
LE 2 x LE 20	-3.7	-33.11**	-28.97**	-19.13*	2.03	-19.70**	-23.09**	-10.17
LE 2 x LE 39	55.31**	14.2	0.31	14.2	38.05**	13.36*	-2.95	13.36*
LE 2 x LE 38	39.04**	3.27	-12.06	0.12	17.02**	-7.52	-12.42*	2.3
LE 2 x LE 1	46.11**	-1.31	16.29*	32.39**	21.99**	7.71	-22.66**	-9.67
LE 16 x LE 20	6.7	3.59	10	25.23**	-0.17	-0.22	-4.35	11.72
LE 20 x LE 39	11.16	1.55	7.84	22.77**	6.36	0.72	-3.54	12.67*
LE 20 x LE 1	29.59**	23.18**	45.15**	65.26**	5.03	-8.11	-12.00*	2.78
LE 39 x LE 38	29.92**	27.93**	12.37	27.93**	7.72	2.55	-2.88	13.44*
LE 38 x LE 1	32.55**	14.17*	34.54**	53.17**	11.41*	-2.06	-7.25	8.34

Table.18. Heterosis (%) for node to inflorescence and internodal length

Hybrids	Node to first inflorescence				Internodal length (cm)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	3.61	-4.44	4.04	1.58	-5.51	-9.98**	-14.22**	-5.51
LE 2 x LE 20	-4.11	-5.18	3.24	0.8	-9.12**	-13.54**	-17.37**	-8.98**
LE 2 x LE 39	6.86*	3.69	12.90**	10.23*	6.82*	4.17	-5.43	4.17
LE 2 x LE 38	10.32**	6.64	16.11**	13.37**	6.10*	2.31	-4.93	4.72
LE 2 x LE 1	6.53	-2.96	5.66	3.17	-9.36**	-17.29**	-13.51**	-4.72
LE 16 x LE 20	-2.21	-4.99	7.26	4.72	0.08	-5.53	-9.72**	-0.55
LE 20 x LE 39	8.88**	6.82	13.72**	11.03**	3.03	0.45	-4	5.75
LE 20 x LE 1	4.56	-3.77	2.44	0.02	-5	-9.09**	-4.93	4.72
LE 39 x LE 38	1.98	1.58	4.04	1.58	3.81	2.62	-4.65	5.04
LE 38 x LE 1	10.57**	3.98	5.66	3.17	-3	-8.41**	-4.22	5.51

(**-Significant at 1% level, *- Significant at 5% level)

RH- Relative heterosis, HB- heterobeltiosis, SH (H)- standard heterosis over the check Naveen and SH(V)- standard heterosis over the variety Akshaya

check Naveen and -8.98 % (LE 2 x LE 20) to 5.75 % (LE 20 x LE 39) over the check Akshaya (Table 18).

4.4.1.1.5 Leaf Length (cm)

LE 2 x LE 38 had highest significant positive relative heterosis, heterobeltiosis and standard heterosis over the two checks Naveen and Akshaya. The magnitude of heterosis ranged between -2.66 % (LE 20 x LE 1) to 39.33 % (LE 2 x LE 38) over mid parent,-15.58 % (LE 2 x LE 1) to 34.81% (LE 2 x LE 38) over better parent, -6.72% (LE 2 x LE 17) to 19.68 % (LE 2 x LE 38) over the hybrid Naveen and 9.35 % (LE 2 x LE 17) to 40.30 % (LE 2 x LE 38) over variety Akshaya (Table 19).

4.4.1.1.6 Leaf Width (cm)

The hybrid, LE 16 x LE 20 showed high significant positive relative heterosis (25.22 %), heterobeltiosis (23.22 %) and standard heterosis over the hybrid Naveen (22.30 %) and the variety Akshaya (54.20 %) (Table 19).

4.4.1.2 Flowering characters

4.4.1.2.1 Days to First Flowering

Out of the 10 hybrids, 8 hybrids exhibited significant negative relative heterosis over the mid parent.and this ranged from -2.34 % (LE 2 x LE 17) to -12.68 % (LE 2 x LE 20). LE 2 x LE 20 had high significant negative relative heterosis, heterobeltiosis and standard heterosis over the two checks Naveen and Akshaya. And the values of heterobeltiosis ranged from -4.13% (LE 2 x LE 17) to -16.82 % (LE 2 x LE 20). Heterosis over the check Naveen and Akshaya ranged from -3.69% (LE 2 x LE 17) to -11.06 % (LE 2 x LE 20) (Table 20).

4.4.1.2.2 Days to Fruit Set

Among the 10 hybrids LE 2 x LE 20 had high significant negative relative heterosis (31.64%), heterobeltiosis (-35.26 %) and standard heterosis over hybrid Naveen (-39.55%) and variety Akshaya (-29.46 %) (Table 20).

Table. 19. Heterosis (%) for leaf length and leaf width

Hybrids	Leaf length (cm)				Leaf width (cm)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	8.34	5.07	-6.72	9.35	-5.09	-5.31	-14.31	8.05
LE 2 x LE 20	5.37	-3.97	3.62	21.47**	11.53	8.28	4.04	31.18*
LE 2 x LE 39	21.83**	19.45**	6.04	24.31**	21.85*	14.32	3.46	30.45*
LE 2 x LE 38	39.33**	34.81**	19.68**	40.30**	23.42*	22.15*	12.86	42.29**
LE 2 x LE 1	-1.29	-15.58**	5.49	23.67**	-1.33	-9.43	-1.93	23.65
LE 16 x LE 20	11.92*	10.41*	19.14**	39.67**	25.22**	23.22*	22.30*	54.20**
LE 20 x LE 39	7.52	-3.74	3.86	21.76**	-0.39	-9.09	-12.65	10.14
LE 20 x LE 1	-2.66	-9.31*	13.34*	32.87**	-8.77	-13.91	-6.78	17.54
LE 39 x LE 38	36.51**	34.69**	14.89**	34.69**	25.52*	16.64	7.76	35.87**
LE 38 x LE 1	5.71	-12.03**	9.93	28.87**	-1.13	-8.39	-0.79	25.08*

Table. 20. Heterosis (%) for days to first flowering and days to fruit set

Hybrids	Days to first flowering				Days to fruit set			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	-2.34*	-4.13**	-3.69**	-3.69**	-0.61	-6.90*	-11.01**	3.85
LE 2 x LE 20	-12.68**	-16.82**	-11.06**	-11.06**	-31.64**	-35.26**	-39.55**	-29.46**
LE 2 x LE 39	-5.85**	-7.37**	-7.37**	-7.37**	6.49	5.12	-9.92**	5.12
LE 2 x LE 38	-7.85**	-8.06**	-10.60**	-10.60**	2.98	-7.86*	-23.07**	-10.23*
LE 2 x LE 1	-5.24**	-9.17**	-4.15**	-4.15**	6.93*	2.42	-6.62*	8.96*
LE 16 x LE 20	-6.31**	-7.33**	-0.91	-0.91	0.61	-1.16	-7.71*	7.69*
LE 20 x LE 39	-7.80**	-10.78**	-4.60**	-4.60**	4.29	0	-6.62*	8.96*
LE 20 x LE 1	-9.75**	-10.34**	-4.13**	-4.13**	-20.24**	-21.18**	-26.40**	-14.12**
LE 39 x LE 38	0.95	-0.44	-0.44	-0.44	21.70**	7.65*	-7.75*	7.65*
LE 38 x LE 1	-1.81	-5.67**	-0.46	-0.46	16.07**	0	-8.83**	6.38

(**-Significant at 1% level, *- Significant at 5% level)

RH- Relative heterosis, HB- heterobeltiosis, SH (H)- standard heterosis over the check Naveen and SH(V)- standard heterosis over the variety Akshaya

4.4.1.2.3 Fruit Set %

LE 20 x LE 1 expressed highest positive significant heterosis over the mid parent and the better parent and it was 26.32 % and 16.99 % heterosis respectively and LE 2 x LE 20 recorded positive significant standard heterosis over the check Naveen (36.38 %) and Akshaya (16.59 %) and this was followed by LE 20 x LE 1 which had 35.11 % heterosis over the check Naveen and 15.50% heterosis over the check Akshaya (Table 21).

4.4.1.2.4 Pollen Viability %

Among the 10 hybrids, only LE 2 x LE 17 (22.96 %) showed positive significant heterosis over the mid parent. And none of the hybrids showed significant positive heterosis over the better parent. LE 2 x LE 20 exhibited high positive significant heterosis over the check Naveen *ie*. 60.01% followed by LE 2 x 17 (56.56%). None of the hybrids showed positive significant heterosis over the check Akshaya (Table 21).

4.4.1.3. Fruit characters and yield

4.4.1.3.1 Fruits Plant $^{-1}$

Among the 10 hybrids evaluated, LE 2 x LE 39 showed highest positive significant heterosis over mid parent, better parent and the two checks Naveen and Akshaya.The magnitude of heterosis varied from -35.89 % (LE 38 x LE 1) to 126.52 % (LE 2 x LE 39) over the mid parent, -47.79 % (LE 38 x LE 1) to108.96 % (LE 2 x LE 39) over the better parent, -11.84 % (LE 38 x LE 1) to 319.77 % (LE 2 x LE 39) over the check Naveen and -48.06 % (LE 38 x LE 1) to 147.31 % (LE 2 x LE 39) over the check Akshaya (Table 22).

4.4.1.3.2 Fruits Truss $^{-1}$

Out of the 10 hybrids, three hybrids recorded positive significant heterosis over the mid parent with maximum value for LE 20 x LE 1 (51.89 %) followed by LE 2 x LE 20 (38.86 %) and LE 16 x LE 20 (27.63 %). Heterobeltiosis ranged from -46.84 % (LE 2 x LE 39) to 41.51 % (LE 20 x LE 1). Among the hybrids studied,

Table. 21. Heterosis (%) for fruit set and pollen viability

Hybrids	Fruit set (%)				Pollen viability (%)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	-3.41	-13.16**	16.66**	-0.26	22.96**	4.55	56.56**	9.63
LE 2 x LE 20	17.18**	1.52	36.38**	16.59**	12.55	6.85	60.01**	12.04
LE 2 x LE 39	-9.09*	-14.96**	14.24*	-2.34	-38.62**	-40.05**	-10.22	-37.13**
LE 2 x LE 38	-4.98	-13.01**	16.87**	-0.09	-26.75**	-33.56**	-0.51	-30.33**
LE 2 x LE 1	4.59	-2.75	30.64**	11.69*	-35.05**	-38.12**	2.35	-28.33**
LE 16 x LE 20	4.79	-0.55	8.99	-6.82	-2.57	-5.72	26.88*	-11.15
LE 20 x LE 39	-5.71	-13.19*	1.54	-13.19*	-21.90**	-24.15**	8.32	-24.15**
LE 20 x LE 1	26.32**	16.99**	35.11**	15.50**	-3.27	-12.28	45.09**	1.6
LE 39 x LE 38	8.89	6.42	24.48**	6.42	-2.88	-9.99	28.54*	-9.99
LE 38 x LE 1	-4.43	-6.02	8.53	-7.22	-22.76**	-32.92**	10.95	-22.31**

Table. 22. Heterosis (%) for fruits plant $^{-1}$ and fruits truss $^{-1}$

Hybrids	Fruits plant $^{-1}$				Fruits truss $^{-1}$			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	27.38	15.28	131.60**	36.44	4.14	-21.31**	37.00**	15.67*
LE 2 x LE 20	79.06**	66.17**	233.82**	96.66**	38.86**	6.38	85.22**	56.38**
LE 2 x LE 39	126.52**	108.96**	319.77**	147.31**	-36.73**	-46.84**	-7.44	-21.86**
LE 2 x LE 38	54.45**	42.15*	185.55**	68.23**	11.12	-14.87**	48.22**	25.14**
LE 2 x LE 1	50.29**	14.85	130.73**	35.93	2.65	-17.04**	44.44**	21.95**
LE 16 x LE 20	23.92	16.66	127.200**	33.86	27.63**	19.90*	11.11	-6.19
LE 20 x LE 39	65.86**	64.79**	183.34**	66.94**	-8.74	-18.67*	-3.67	-18.67*
LE 20 x LE 1	31.23	6.12	82.48**	7.5	51.89**	41.51**	51.89**	28.24**
LE 39 x LE 38	75.91**	75.46**	197.84**	75.46**	8.74	-3.1	14.78	-3.1
LE 38 x LE 1	-35.89	-47.79*	-11.84	-48.06*	-11	-17.08*	-11	-24.86**

(**-Significant at 1% level, *- Significant at 5% level)

RH- Relative heterosis, HB- heterobeltiosis, SH (H)- standard heterosis over the check Naveen and SH(V)- standard heterosis over the variety Akshaya

five hybrids recorded positive significant heterosis over the two checks and the maximum heterosis was shown by LE 2 x LE 20 (85.22 %) over the check Naveen and 56.38 % over the check Akshaya (Table 22).

4.4.1.3.3 Fruit Length (cm)

The magnitude of per cent heterosis varied from -1.37 % (LE 20 x LE 39) to 11.64 % (LE 16 x LE 20) over the mid parent, -10.30 % (LE 2 x LE 1) to 10.87 % (LE 16 x LE 20) over the better parent, -21.43 % (LE 20 x LE 39) to 5.36 % (LE 20 x LE 1) over the check Naveen and 3.47 % (LE 20 x LE 39) to 38.74 % (LE 20 x LE 1) over the check Akshaya (Table 23).

4.4.1.3.4 Fruit Girth (cm)

LE 20 x LE 1 had highest significant positive relative heterosis, heterobeltiosis and standard heterosis over the two check Naveen and Akshaya and the heterosis per cent was 18.10 % over the mid parent, 6.59 % over the better parent, 21.09 % over the check Naveen and 32.97 % over the check Akshaya (Table 23).

4.4.1.3.5 Fruit Weight (g)

Heterosis for fruit weight over the mid parent extended from -14.16 % (LE 38 x LE 1) to 27.63 % (LE 20 x LE1). Heterosis over the better parent ranged from -37.95 % (LE 38 x LE 1) to 11.54 % (LE 16 x LE 20) and LE 20 x LE 1 showed highest heterosis over the two checks, *ie*. 38.62 % over the check Naveen and 114.53% over the check Akshaya (Table 24).

4.4.1.3.6 Yield Plant $^{-1}$ (g)

Out of the 10 hybrids evaluated, seven hybrids exhibited significant positive heterosis over the mid parent with maximum heterosis by LE 2 x LE 20 (104.29 %). Heterobeltiosis ranged from -36.94 % (LE 38 x LE 1) to 86.73 % (LE 2 x LE 20). LE 20 x LE 1 showed highest heterosis over the two checks and its magnitude varied from 13.89 % (LE 38 x LE 1) to 157.52 % (LE 20 x LE 1) over the check

Table. 23. Heterosis (%) for fruit length and fruit girth

Hybrids	Fruit length (cm)				Fruit girth (cm)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	5.70**	3.24	-15.95**	10.69**	1.77	-3.94*	-9.93**	-1.09
LE 2 x LE 20	7.16**	3.46	-13.72**	13.62**	4.44**	-0.25	-8.78**	0.18
LE 2 x LE 39	4.27*	3.13	-19.94**	5.43*	3.09*	-1.34	-10.16**	-1.34
LE 2 x LE 38	1.06	-3.57	-17.59**	8.52**	0.74	-5.21**	-10.53**	-1.75
LE 2 x LE 1	3.59*	-10.30**	-4.86**	25.28**	-1.14	-14.35**	-2.7	6.85**
LE 16 x LE 20	11.64**	10.87**	-7.54**	21.76**	0.74	-0.66	-9.15**	-0.23
LE 20 x LE 39	-1.37	-5.78**	-21.43**	3.47	-2.64	-2.85	-11.15**	-2.43
LE 20 x LE 1	11.22**	-0.66	5.36**	38.74**	18.10**	6.59**	21.09**	32.97**
LE 39 x LE 38	6.56**	0.63	-14.01**	13.24**	4.76**	2.91	-2.86	6.67**
LE 38 x LE 1	4.00**	-6.10**	-0.41	31.14**	9.55**	0.28	13.93**	25.11**

Table. 24. Heterosis for fruit weight and yield plant $^{-1}$

Hybrids	Fruit weight (g)				Yield plant $^{-1}$ (g)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	1.64	-7	-42.77**	-11.43*	23.23	18.6	36.07	0.6
LE 2 x LE 20	-0.54	-10.58*	-42.77**	-11.43*	104.29**	86.73**	139.25**	76.89**
LE 2 x LE 39	-13.83**	-22.86**	-50.15**	-22.86**	58.43**	41.36**	91.18**	41.36**
LE 2 x LE 38	-3.1	-15.32**	-42.15**	-10.48*	46.74**	32.55*	74.36**	28.92*
LE 2 x LE 1	9.49**	-27.00**	11.85**	73.09**	56.84**	24.48*	124.82**	66.23**
LE 16 x LE 20	15.00**	11.54*	-28.61**	10.48*	28.01*	25.4	60.66**	18.79
LE 20 x LE 39	-7.42	-7.86	-40.46**	-7.86	19.86	16.7	57.84**	16.7
LE 20 x LE 1	27.63**	-9.53**	38.62**	114.53**	66.83**	42.59**	157.52**	90.41**
LE 39 x LE 38	12.50**	9.46*	-25.23**	15.71**	29.72*	27.94*	73.04**	27.94*
LE 38 x LE 1	-14.16**	-37.95**	-4.92	47.14**	-27.03*	-36.94**	13.89	-15.79

(**-Significant at 1% level, *- Significant at 5% level)

RH- Relative heterosis, HB- heterobeltiosis, SH (H)- standard heterosis over the check Naveen and SH(V)- standard heterosis over the variety Akshaya

Naveen and -15.79 % (LE 38 x LE 1) to 90.41 % (LE 20 x LE 1) over the check Akshaya (Table 24).

4.4.1.3.7 Yield Plot $^{-1}$ (kg)

The data on per cent heterosis revealed a range of -27.09 % to 104.33 % over the mid parent,-36.99 % to 86.88 % over the better parent, 46.21 % to 231.48 % over the check Naveen and -15.94 % to 90.58 % over the check Akshaya. LE 2 x LE 20 exhibited highest relative heterosis and heterobeltiosis and highest standard heterosis was given by LE 20 x LE 1 (Table 25).

4.4.2 Quality characters

4.4.2.1 Total Soluble Solids (%)

None of the hybrids had positive significant heterosis over the mid parent, better parent and the standard check Naveen. Only the hybrid LE 2 x LE 38 exhibited a positive significant heterosis over the check Akshaya (Table 25).

4.4.2.2 Lycopene (mg /100g)

The magnitude of heterosis varied from -17.26 % (LE 20 x LE 1) to 4.58 % (LE 2 x LE 39) over the mid parent,-16.57 % (LE 20 x LE 1) to 4.01 % (LE 2 x LE 39) over the check Naveen. None of the hybrids exhibited positive significant heterosis over the better parent and over the check Akshaya (Table 26).

4.4.2.3 Ascorbic Acid (mg/100g)

Out of the 10 hybrids, eight hybrids exhibited positive significant heterosis over the mid parent and it varied from 0.75 % (LE 2 x LE 38) to 60.40 % (LE 20 x LE1). Heterosis over the better parent ranged from -4.61 % (LE 2 x LE 39) to 54.59 % (LE 20 x LE1).The magnitude of per cent heterosis extended from -18.52 % (LE 2x LE 38) to 22.22 % (LE 2 x LE 1) over the check Naveen and 7.97 % (LE 2 x LE 38) to 61.95 % (LE 2 x LE 1) over the check Akshaya (Table 26).

Table. 25. Heterosis for yield plot $^{-1}$ and Total Soluble Solids

Hybrids	Yield plot $^{-1}$ (kg)				Total Soluble Solids (TSS %)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	22.81	18.31	74.44**	0.3	-0.93	-3.05*	-6.47**	1.92
LE 2 x LE 20	104.33**	86.88**	207.97**	77.07**	1.63	-0.64	-8.24**	0
LE 2 x LE 39	58.75**	41.74**	146.53**	41.74**	-0.32	-0.64	-8.24**	0
LE 2 x LE 38	47.20**	33.09*	124.99**	29.36*	-2.11	-6.90**	-4.71**	3.85*
LE 2 x LE 1	57.13**	24.84*	189.68**	66.55**	0.96	0	-7.65**	0.64
LE 16 x LE 20	28.32*	25.72	107.18**	19.12	2.6	0	-7.06**	1.28
LE 20 x LE 39	20.29	17.13	103.73**	17.13	1.96	0	-8.24**	0
LE 20 x LE 1	67.06**	42.85**	231.48**	90.58**	-1.32	-2.6	-11.76**	-3.85*
LE 39 x LE 38	29.54*	27.72	122.15**	27.72	-3.03*	-8.05**	-5.88**	2.56
LE 38 x LE 1	-27.09*	-36.99**	46.21	-15.94	-7.93**	-13.22**	-11.18**	-3.21*

Table. 26. Heterosis (%) for lycopene and ascorbic acid

Hybrids	Lycopene (mg/100g)				Ascorbic acid (mg/100g)			
	RH	HB	SH (H)	SH (V)	RH	HB	SH (H)	SH (V)
LE 2 x LE 17	-2.71	-4.00*	-3.81*	-5.12**	25.44**	6.84	3.7	37.41**
LE 2 x LE 20	-12.91**	-15.50**	-12.36**	-13.55**	35.92**	18.28**	14.81**	52.14**
LE 2 x LE 39	4.58**	2.6	4.01*	2.6	7.33	-4.61	-7.41	22.69**
LE 2 x LE 38	-8.53**	-10.28**	-9.00**	-10.24**	0.75	-16.06**	-18.52**	7.97
LE 2 x LE 1	-10.26**	-10.45**	-12.29**	-13.48**	49.29**	25.92**	22.22**	61.95**
LE 16 x LE 20	-6.42**	-6.72**	-3.26	-4.58*	49.91**	37.41**	18.52**	57.05**
LE 20 x LE 39	-3.44*	-4.52*	-0.98	-2.33	35.74**	32.51**	0	32.51**
LE 20 x LE 1	-17.26**	-19.56**	-16.57**	-17.71**	60.40**	54.59**	11.11*	47.23**
LE 39 x LE 38	-0.59	-0.62	0.8	-0.57	47.99**	37.41**	3.7	37.41**
LE 38 x LE 1	0.84	-0.89	0.53	-0.84	46.62**	44.44**	-3.7	27.60**

(**-Significant at 1% level, *- Significant at 5% level)

RH- Relative heterosis, HB- heterobeltiosis, SH (H)- standard heterosis over the check Naveen and SH(V)- standard heterosis over the variety Akshaya

DISCUSSION

5. DISCUSSION

Tomato is one of the major commercial vegetable crop in India and it has a constant demand throughout the year all over the world. The cultivation of tomato in open field condition is challenged by many production constraints which includes biotic and abiotic stresses which influence the yield and quality of tomato mostly during rainy season. Therefore, production under protected conditions is the best alternative for obtaining increased yield with superior quality tomato year round. Under protected cultivation the natural environment is modified to the suitable conditions for optimum plant growth and this altered growing conditions especially light and temperature are known to influence both composition and quality of tomato fruits which ultimately helps in the production of quality tomatoes suitable for exports and domestic consumption.

Tomato hybrids are now extensively used in commercial production since, hybrids are superior to open pollinated varieties in earliness, adaptability, yield and quality characters. Exploitation of hybrid vigour is one of the important means, by which, the crop yield can be increased tremendously.

The present investigation was carried out at the Department of Olericulture, College of Agriculture, Vellayani during 2015- 2016, to evaluate the yield and quality of F_1 hybrids of indeterminate tomato under protected cultivation. The experiment was conducted in the saw tooth type naturally ventilated polyhouse attached to the Department of Olericulture, College of Agriculture, Vellayani. Ten superior hybrids selected from the previous research conducted in department were evaluated along with their parents and two checks Naveen and Akshaya in Randomized Block Design with 18 treatments in three replications for two seasons (July 2015 to January 2016 and November 2015 to March 2016). The salient results of the present investigation are discussed in this chapter.

5.1 MEAN PERFORMANCE OF TOMATO HYBRIDS AND PARENTS

5.1.1 Vegetative Characters

In the present study, significant difference was observed for all the vegetative characters viz. plant height, height at flowering, node to first inflorescence, internodal length, leaf length and leaf width studied among the treatments for both the seasons.

Plant height is a good indicator of plant vigour which may contribute towards greater productivity. Variation in height is attributed to the inherent genetic difference. Among the hybrids, it ranged from 2.29 m to 4.70 m during first season and 1.94 m to 3.69 m during second season. In pooled it exhibited a range of 2.12 m to 4.19 m. Among parents, the plant height ranged from 1.48 m to 3.90 m in pooled data. The hybrid LE 20 x LE 1 was the tallest among the treatments. Singh *et al*. (2014) reported a range of 106.00-315.00 cm in plant height inside polyhouse. The plant height of tomato was higher inside the polyhouse than outside and this may be due to the favorable micro-climatic conditions and enhanced photosynthesis and respiration (Rajasekhar *et al*., 2013). These results were in line with the results of Ganesan (2001), Hazarika and Phookan (2005), Kumar and Arumugam (2010), Cheema *et al.* (2013), Sringarm (2013) and Rana *et al.* (2014).

Minimum height at flowering, lower number of nodes to first inflorescence and short internodes are the preferred traits for tomato. Among the hybrids, minimum height at flowering for both the seasons were exhibited by LE 2 x LE 17 and LE 20 x LE 1 had lowest number of nodes. Lowest internodal length was recorded by LE 2 x LE 20 (4.05 cm). Among the parents, LE 2 exhibited minimum height at flowering and lowest internodal length. Similar result was also reported by Ganesan (2002). Leaf length ranged from 34.04 cm to 43.67 cm among hybrids and 30.29 cm to 45.67 cm among the parents in the first season and 20.24 cm to 39.28 cm and 30.17 cm to 35.47 cm among hybrids and parents respectively during the second season. Leaf width had a range of 19.35 cm to 31.13 cm among the hybrids and 23.70cm to 29.15 cm among the parents in pooled data. Increased Co_2 in polyhouse causes greater leaf expansion and larger canopy as reported by Suseela

(2013). Similar results were also reported by Papadopoulos and Ormrod (1991), Rajshekar *et al*. (2013) and Nangare *et al*. (2015).

In the first season the leaf length and leaf width had a mean value of 37.86 cm and 28.04 cm whereas in second season the mean values of leaf length and leaf width were reduced to 30.98 cm and 24.66 cm respectively. The reduced leaf length and leaf width during second season may be due to the high temperature inside the polyhouse. Exposure of tomato plants to high temperature causes membrane disintegration which leads to reduction in photosynthesis rate, reduction in leaf area per plant and there by reduction in dry matter production (Camejoa *et al*., 2005). In a study conducted by Mamtha *et al*. (2015) in tomato hybrid Arka Ananya, at mild temperature increase there was a reduction in leaf area and LAI (21.6 and 21.8%) at peak fruiting stage and final harvest stage (25.7 and 25.6%).and they pointed that the mild temperature increase influenced the yield plant $^{-1}$ by causing reductions in photosynthetic capacity and the source of photosynthates.

5.1.2 Flowering Characters

Days to first flowering determines the earliness which is a highly desirable attribute to fetch the premium price in the market at right time. In this study the hybrid LE 2 x LE 20 was the earliest to flower. In pooled analysis, the days to first flower recorded a range of 21.94 to 24.84 among the hybrids and 24.38 to 24.50 among the parents. Singh *et al*. (2014) reported a range of 23.16 to 44.00 days to flower in tomato and similar results were also reported by Amarananjundeshwara *et al*. (2008) and Sharma and Singh (2015). Early flowering in the experiment in all treatments for both the seasons might be due to the congenial growing environment inside the polyhouse as compared to open field condition (Pandey *et al*., 2006). The two season study showed that the days to fruit set varied from 6.33 (LE 2 x LE 20) to 9.22 (LE 20 x LE 39) among the hybrids and 7.06 (LE 39) to 9.16 (LE 16) among the parents.

Fruit set per cent of tomato varieties is one of the important parameters for summer and rainy season tomato production, which implies the tolerance and resistance of a variety to a particular temperature and environment. The pooled

analysis showed that LE 2 x LE 20 (70.42%) and LE 2 (67.28%) had highest fruit set per cent among the hybrids and parents respectively. Pandey *et al*. (2006) reported a range of 83.1% to 93.9%, while a range of 50.65 to 84.09 % in fruit set was reported by Singh *et al*. (2014). A perusal of the data on fruit set per cent revealed that in general higher yielders had higher fruit set per cent.

In this study, during first season fruit set per cent was 63.09 per cent and during second season it was 57.42 per cent. This reduction in fruit set per cent during second season may be due to the high temperature which caused stigma exertion and flower drop which inturn reduced the fruit set (Ozores-Hampton *et al*., 2012). Moreover, high temperature leads to low levels of carbohydrates, reduced or abnormal pollen production, hormonal imbalances, abnormal development of the female reproductive tissues and lack of pollination (Peet *et al*., 1997). According to Sato *et al.* (2002), reduced fruit-set at elevated temperature is mainly due to reduced pollen germination and release and disturbed microsporogenesis and reproductive processes were much more sensitive to temperature stress than vegetative growth. According to the pooled data, among hybrids, the fruit set per cent varied from 48.46 % to 70.42 %. This variation in fruit set in different treatments might be because of the varietal character and growing environment as opined by Sharma *et al*. (2011).

The amount of viable pollen in a flower determines fruit set in plants to a greater extent (Animasaun, 2014). Pooled data showed that LE 2 x LE 20 (78.07 %) and LE 1 (70.70 %) had highest pollen viability among the hybrids and parents respectively. During first season, the mean value for pollen viability was 72.52 % and it was reduced to 53.03 % during second season. The decrease in pollen viability during second season may be due to the increased temperature at flowering and fruit set of tomato. Akhtar *et al*. (2012) pointed that the pollen viability was drastically reduced due to desiccation of stigma at high temperature. The negative impact of increased temperature on pollen viability was reported by Peet *et al*. (1998), Sato *et al.* (2006) and Khanal *et al*. (2013). Splitting of anther cone is a morphological abnormality of the flower exposed to high temperature and by

disrupting the channels for pollen transfer to the stigma, it leads to evasion of self fertilization and consequently leads to low fruit setting (Singh *et al*., 2010).

5.1.3 Fruit Characters and yield

The fruit characters like fruits plant $^{-1}$, fruits truss $^{-1}$, fruit length, fruit girth and fruit weight varied significantly in all the treatments.

In the present study, among the hybrids, LE 2 x LE 39 had highest fruits plant $^{-1}$ for both the seasons.ie, 106.33 and 68.44 during first and second season respectively. Chaudhry *et al*. (2003) studied 12 indeterminate tomato hybrids and reported significant difference in number of fruits plant.$^{-1}$ Farooq *et al.* (2006) also reported a significant variation for number of fruits per plant in the evaluation of five tomato hybrids under plastic tunnel.

Fruits truss^{-1} is one of the important criteria to select better variety for its preferable fruit size and higher yield. Generally, more the number of fruits truss^{-1}, higher the fruit yield. Gavrish *et al.* (1988) reported that tomato crop inside the net house produced higher number of fruits cluster^{-1} than in the open field and it may be due to the better environmental conditions inside the net house. Pooled analysis showed that the fruit truss $^{-1}$ was highest for LE 2 x LE 20 (5.67) and it ranged from 2.50 to 5.67 among the hybrids and 2.33 (LE 16) to 5.17 (LE 2) among the parents. These results are in corroboration with the findings of Pandey *et al*. (2006) who reported a range of 5.5 to 6.8 for fruits cluster^{-1} and Singh *et al*. (2006) who reported a range of 3.6 to 5.6 fruits truss^{-1}.

Apart from fruits plant $^{-1}$ and fruits truss $^{-1}$, fruit size also exerts significant influence on yield. In this study, the pooled data of first and second crop revealed that, among the hybrids, LE 20 x LE 1 had maximum fruit length (8.47 cm), fruit girth (17.38 cm), fruit weight (97.28 g), yield plant^{-1} (2674.54 g) and yield plot^{-1} (50.00 kg). Among the parents, LE 1 had maximum fruit length (8.62 cm), fruit girth (16.46 cm), fruit weight (104.94 g), yield plant^{-1} (1906.93 g) and yield plot^{-1} (35.79 kg). Among the hybrids, the fruit length varied from 6.46 cm to 8.47 cm, fruit girth varied from 12.84 cm to 17.38 cm, fruit weight varied from 37.00 g to

97.28g. The variation in fruit size in different tomato hybrids reported to be inter varietal associated with the genetic makeup of cultivars and governed by the cell size and intercellular space of the flesh (Singh *et al*., 2014). Chaudhry *et al*. (2006) reported significant differences in fruit size (length and width) in different tomato hybrids under study. Farooq *et al*. (2013) reported a range of 5.70 cm to 7.89 cm for fruit length among the hybrids studied. For fruit girth, Sharma and Singh (2015) reported a range of 14.96 cm to 17.26 cm which is in line with the present findings.

It was observed that total yield per plant was mainly dependent upon the fruit weight and number of fruits plant $^{-1}$. Here, the hybrid LE 2 x LE 39 had highest fruits plant $^{-1}$ (87.39) whereas, its fruit weight was 37.00 g. The number of fruits per plant was influenced by the size of fruits (equatorial and polar fruit diameters). The fruit weight increased or decreased depending upon the number of fruits per plant and fruit size. Early fruiting and smaller size of fruits tended to produce larger number of fruits per plant (Rao *et al.*, 2007).

Fruit yield is the major determinant variable for selecting a particular variety or hybrid for its commercialization and income generation capability. The plants grown in polyhouse recorded significantly higher yield as compared to open field (Kumari *et al*., 2014). Rana *et al*. (2014) reported that the fruit yield obtained from the polyhouse was higher (2.6 kg plant^{-1}) than the open field (1.5 kg plant^{-1}) and the tomato plants grown in polyhouse condition produced about 50 per cent higher fruit yield (90 t ha^{-1}) than in open field conditions (54 t ha^{-1}). He concluded that the significant higher yield in the plants under polyhouse condition than those in the open field was associated with the production of more number of fruits with greater length and diameter and fruit weight than those in open field. These results are in agreement with Bhattarai and Subedi (1996), Kang and Sidhu (2005), Pandey *et al.* (2006), Parvej *et al*. (2010) and Chapagain *et al.* (2011) who reported higher yield under polyhouse condition.

In the present study, same trend was observed for all the yield related attributes for both the seasons but there was variation in the results of second season as compared to first season. During first season LE 2 x LE 39 had 106.33 fruits plant $^{-1}$ whereas, in second season it had only 68.44 fruits plant $^{-1}$. In first season,

LE 20 x LE 1 had an yield of 3505.20 g plant $^{-1}$ over seven months and during second season it was only 1843.89g plant $^{-1}$ over five months. This wide variation may be due to the influence of high temperature on tomato during the second season which resulted in low pollen viability and fruit set per cent. Temperature inside the polyhouse in first and second seasons are given in Appendix II and figures 5 and 6.

The effect of high temperature on plant growth characters and yield was studied by many workers. High temperature condition strongly affects the vegetative and reproductive organs and tissues of tomato plants that ultimately reduces yield and fruit quality (Abdul-Baki, 1991; Abdelmageed *et al*., 2003). Under high temperature stress, there will be a reduction in the supply of photosynthates and the reduced carbohydrate supply resulted in lower fruit yield. (Kinet and Peet, 1997; Abdelmageed and Gruda , 2009; Islam 2011; Zhang *et al*., 2012). In a study Akhtar *et al*. (2012), reported that, mean fruit number plant $^{-1}$ was drastically reduced from 50.61 in autumn-winter to 14.32 in spring-summer and the mean yield decreased from 1.87 kg plant $^{-1}$ in autumn-winter to 0.32 kg plant $^{-1}$ in spring-summer. The marketable tomato yield was reduced by the high temperature probably as a result of an increase in the mean temperature. Therefore, the high day temperatures should be compensated by lower night temperatures in order to obtain an acceptable mean temperature (Huckstadt *et al*., 2013).

This warrants attunation in the decision of the polyhouse structures or any other suitable methods to reduce the temperature to the ideal for growth and development of tomato.

5.1.4 Quality Characters

The quality characters include total soluble solids, lycopene and ascorbic acid. The total soluble solids implies the amount of sugar present in fruit juice. Hence, a higher content of soluble solids is desirable for processed product like juice, ketchup, sauce and puree. The lycopene content is responsible for the red colour in tomato and the ascorbic acid content improves the nutritive quality of tomato. The data obtained on average total soluble solids, lycopene and ascorbic acid showed highly significant differences among the hybrids studied during both

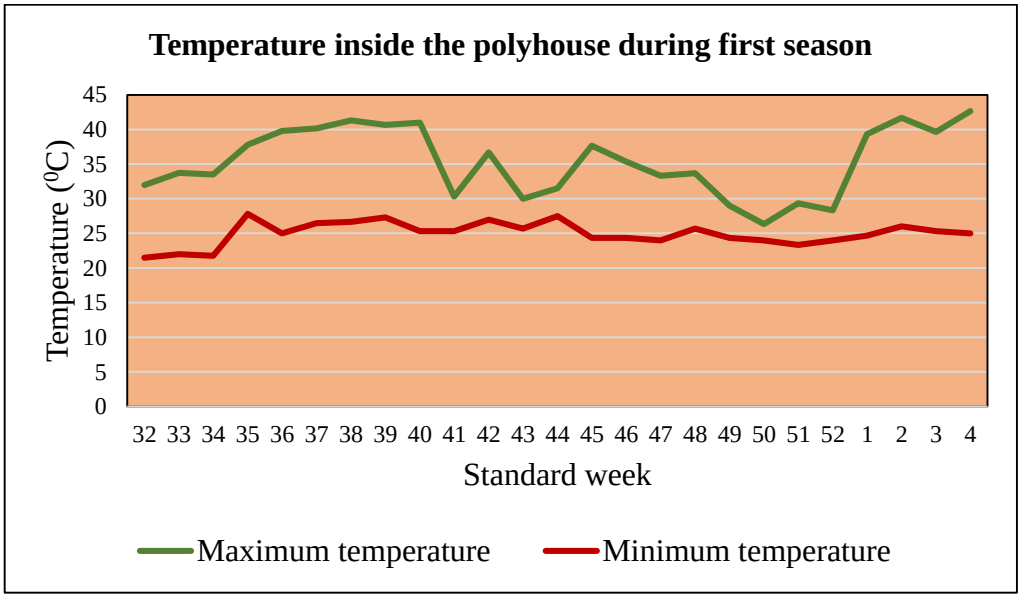


Figure 5. Temperature inside the polyhouse during first season

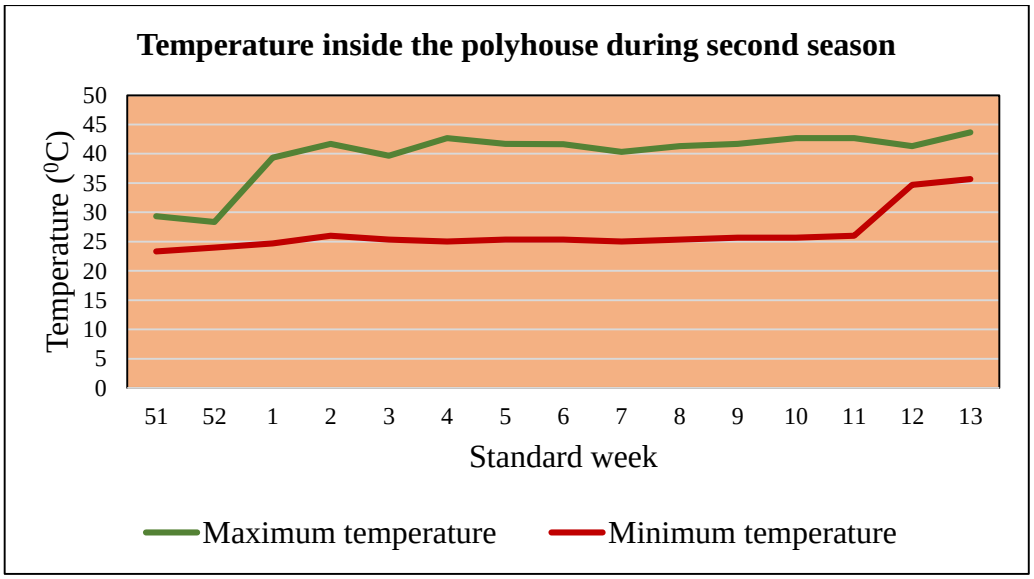


Figure 6. Temperature inside the polyhouse during second season

the years. Among the hybrids maximum TSS was obtained for LE 2 x LE 38 (5.37 %), highest lycopene content was given by LE 2 x LE 39 (13.10 mg/ 100g) and highest ascorbic acid was obtained for LE 2 x LE 1(32.20 mg /100g).

The results of the present investigation are in agreement with the reports by Hazarika and Phookan (2005) who reported a significant variation in TSS among the cultivars ranging from 4.24 to 6.54 per cent. The higher TSS in these cultivars may be due to enhanced deposition of solids and more conversion of organic acids to sugar. Helyes *et al*. (2003) reported that fruits from the indeterminate tomato cultivar Daniela grown in the greenhouse had a higher lycopene content than field grown fruit. Similar variability in quality characters was reported by Phookan *et al.* (1996), Purkayastha and Mahanta (2011), Sharma *et al*. (2011) and Singh *et al*. (2014). Greenhouse tomato fruits were superior to fruits of open field crop in view of fruit size, TSS content, ascorbic acid content and pH (Mahajan and Singh, 2006). Similar results were given by Zhu- *et al.* (2003), Singh *et al.* (2005) and Cheema *et al*. (2013). Also the tomatoes inside the polyhouse was glossy in appearance. The tomatoes grown under shade net structures were glossy in appearance with good colour development as compared to open field (Nangare *et al*., 2015).

5.1.5 Incidence of Pest and Diseases

In the present study there was no incidence of insect pests inside the polyhouse. Nangare *et al*. (2015) observed less incidence of pests and diseases in all crops inside the shade net houses as compared to open field. Low incidence of pests under polyhouse was reported by Singh *et al*. (2012) in tomato and capsicum. It can be attributed to completely covered polyhouse in which the entry of insects are avoided and the level of insect pest infestation was much lower inside the greenhouses than outside as insect screens effectively prevented most of the invasion (Sringarm *et al*., 2013).

Among the diseases, bacterial wilt caused by *Ralstonia solanacearum* was observed inside the polyhouse. During both the seasons, the hybrids LE 2 x LE 39 and LE 2 x LE 38 was free from bacterial wilt incidence whereas, the check Naveen

showed 50 per cent bacterial wilt incidence in first season and in second season it had 100 per cent bacterial wilt and all other treatments showed only less incidence of the disease. Sharma and Singh (2015) studied the performance of tomato hybrids in relation to disease incidence and reported a range of 0.00 per cent to 83.00 per cent incidence of bacterial wilt disease.

5.1.6 Physiological Disorders

The physiological disorders like fruit cracking, blossom end rot and stigma exertion was observed inside the polyhouse. Only four treatments LE 16, LE 38, LE 2 x LE 38 and LE 39 x LE 38 had fruit cracking and only three treatments LE 17, LE 20 x LE 39 and LE 39 x LE 38 had blossom end rot. Singh *et al*. (2003) and Singh *et al*. (2006) reported variation in blossom end rot incidence among tomato varieties grown under greenhouse condition. During first season there was no incidence of stigma exertion since the temperature was favourable for the crop but during second season, the treatments showed a range of 9.52 to 35.55 % stigma exertion. This was mainly due to the high temperature during the second season. Stigma exertion leads to evasion of self pollination, consequently resulting in low fruit setting percentage. Singh *et al*. (2010) reported 11.31% to 80.67% stigma exertion in his study.

These findings of the present investigation underlines the importance of optimum environmental condition and proper selection of varieties or hybrids for getting higher marketable yield of high quality.

5.2 CORRELATION

In a breeding programme, correlation coefficient helps the breeder to select an efficient trait and allocate appropriate weightage for optimal results. Correlation studies provide information that selecting one character will result in progress for all positively correlated characters **(**Wali and Kabura, 2014).

A critical appraisal of the correlation effects in this study revealed that the yield plant $^{-1}$ had a significant positive correlation with fruit set per cent (0.5050), fruits plant^{-1} (0.4984), fruits truss^{-1} (0.4744), fruit length (0.3048), fruit girth

(0.3193), fruit weight (0.3555) and ascorbic acid (0.4521). It was negatively correlated with days to first flowering (-0.4380), days to fruit set (-0.4245), TSS (-0.3136) and lycopene (-0.6498). Meena and Bahadur (2014) reported a significant and positive correlation of fruit yield plant^{-1} with number of fruits plant $^{-1}$, fruit set per cent, fruit weight and polar diameter of fruit. Similar results have also been reported by Kumar *et al.* (2003) for number of fruits plant^{-1}, Susic *et al*. (2002), Rani *et al.* (2010) for fruit weight, Singh *et al.* (2004) for number of fruits plant-^{1}, fruit weight and fruit diameter. The fruit yield plant^{-1} was positively and significantly correlated with number of fruits plant^{-1} and fruit width and negatively and significantly correlated with days to last fruit harvest and shelf life. (Reddy *et al*., 2013).

5.3 HETEROSIS

Heterosis is expressed as per cent increase or decrease of F_1 hybrid over its parents. In majority cases of practical plant breeding the superiority of F_1 over mid parent is of no use since, it does not offer the hybrid any advantage over the better parent. Therefore, heterosis is estimated over the better parent which is often called as heterobeltiosis. In many cases the superior parent of hybrid may be inferior to the best commercial variety or hybrid. In such cases it will be desirable to estimate heterosis in relation to the best commercial variety or F_1 hybrid of the crop. Such an estimate is known as standard heterosis or useful or economic heterosis. In this study heterosis over mid parent (relative heterosis), over better parent (heterobeltiosis) and over the check (standard heterosis) were studied.

5.3.1 Vegetative characters

In the present study the heterosis for plant height ranged from -16.70 % to 55.31% and -46.87 % to 27.93 % over mid parent and better parent respectively. LE 20 x LE 1 showed maximum standard heterosis over the two check Naveen and Akshaya. ie. 45.15 % and 65.26 % respectively. Positive heterosis for plant height was also reported by Rani and Veeraragavathatham (2008) and Sharma and Thakur

(2008). Singh and Asati (2011), Chattopadhyay and Paul (2012), and Yadav *et al*. (2013).

Lower height at flowering is the desirable character and its magnitude of heterosis varied from -7.49 % to 38.05 % over mid parent, -24.77 % to 13.36 % over better parent, -33.97 % to -2.55 % over the check Naveen and -22.88 % to 13.44 % over the check Akshaya. Minimum number of node to first inflorescence and lowest internodal length is the favourable character for tomato. None of the hybrid showed significant negative heterosis for node to first inflorescences. LE 2 x LE 1 showed highest significant negative heterosis over the mid parent (-9.36 %) and better parent (-17.29 %). LE 2 x LE 20 had highest significant negative heterosis over the check Naveen (-17.37 %) and Akshaya (-8.98 %) for internodal length. For leaf length, the magnitude of heterosis ranged between -2.66 % to 39.33 % over mid parent,-15.58 % to 34.81% over better parent, -6.72 % to 19.68 % over the check Naveen and 9.35 % to 40.30% over Akshaya. For leaf width, LE 16 x LE 20 showed high significant positive relative heterosis (25.22 %), heterobeltiosis (23.22 %) and standard heterosis over the two checks Naveen (22.30 %) and Akshaya (54.20 %). Kaushik *et al*., (2016) reported a high heterosis for leaf size in brinjal hybrids over its parents. The larger leaves of the hybrid are a consequence of increased cell size and number of the photosynthetic palisade mesophyll cells and other leaf cells (Saeki *et al*., 2016).

5.3.2 Flowering characters

Flowering characters include days to first flowering, days to fruit set, fruit set per cent and pollen viability. Out of the ten hybrids, significant negative heterosis were shown by eight hybrids over the mid parent, nine hybrids over the better parent and seven hybrids over the two standard checks Naveen and Akshaya for days to first flowering. LE 2 x LE 20 was the hybrid with highest significant negative heterosis for days to first flower and days to fruit set. Negative heterosis for days to first flowering was reported by Premalakshme *et al*. (2005), Chauhan *et*

al. (2014) Joshi and Thakur (2003), Ahmad *et al*. (2011), Kumari and Sharma (2011), Mali and Patel (2014), Shankar *et al*. (2014) and Kumar and Singh (2016).

For fruit set per cent, LE 20 x LE 1 had highest positive significant relative heterosis and heterobeltiosis and LE 2 x LE 20 had highest standard heterosis over the two checks and the highest positive significant heterosis over the check Naveen was given by LE 2 x LE 20 followed by LE 2 x LE 17. Similar positive significant heterosis was also given by Himanshu *et al*. (2008). In case of pollen viability, only LE 2 x LE 17 showed positive significant heterosis over mid parent. Five hybrids had significant positive heterosis over the check Naveen and none of the hybrids shown significant positive heterosis over better parent and the check Naveen. Among the 28 F_1 hybrids, P_3 x P_5 (20.65 %) exhibited the maximum positive heterosis for pollen viability (Patwary *et al*., 2013). Abdullateef *et al.* (2012) reported high heterosis of brinjal hybrid for pollen viability over its parents.

5.3.3 Fruit characters and yield

A critical appraisal of the results showed significant positive heterosis for fruits plant $^{-1}$ by six hybrids over mid parent and five hybrids over better parent and check Akshaya and nine hybrids over the check Naveen. LE 2 x LE 39 was the one which showed highest heterosis for all the estimates. Similar results were reported by Chauhan *et al*. (2014) who reported that for number of fruits plant $^{-1}$ heterosis varied from 13.13% to 30.07% over mid parent, and 169.61% to 320.36% over standard parent. Rai *et al*. (2003), Premalakshmi *et al* (2005), Singh *et al.* (2008) Singh *et al*. (2012) also reported more than 100 per cent heterosis for this trait which supports finding of the present study. Significant positive heterosis was also reported by Singh *et al.* (2012), Saleem *et al*. (2013), Mali and Patel (2014) and Kumar and Singh (2016) for this trait.

Significant positive heterosis for fruits truss $^{-1}$ were shown by only three hybrids over mid parent, two hybrids over better parent and five hybrids over the two checks. LE 20 x LE 1 had highest standard heterosis over the two checks for fruit length, fruit girth, fruit weight, yield plant $^{-1}$ and yield plot $^{-1}$. Chattopadhyay and Paul (2012) and Chauhan *et al*. (2014) also reported significant positive

heterosis for fruit length in tomato. High heterosis for yield plant $^{-1}$ was reported by Chaudhary and Malhotra (2001), Dudi and Sanwal (2004), Ahmad *et al*. (2011), Chauhan *et al*. (2014), Gul *et al*. (2011), Kumari and Sharma (2011) and Kurian *et al.* (2001). Positive heterosis for all these characters were also reported by Gul (2010) and Kumar *et al*. (2012). Positive and highly significant heterosis was found for yield over the better parent by Bhatt e*t al*. (2001) and over mid-parent and better parent along with better performance in term of yield plant $^{-1}$ by Sekhar *et al*. (2010). Thus, the observed high heterosis for yield plant $^{-1}$ might be due to increase in fruit size and fruit weight rather than increase in number of fruits plant $^{-1}$ as reported by Singh *et al*. (2012).

5.3.4 Quality characters

None of the hybrids showed positive significant heterosis over the mid parent, better parent and the standard check Naveen for TSS as Naveen had highest TSS than all the other treatments. Only the hybrid LE 2 x LE 38 exhibited a positive significant heterosis over the check Akshaya. Only LE 2 x LE 39 had positive significant heterosis over mid parent and the check Naveen. For ascorbic acid, positive significant heterosis were shown by eight hybrids over mid parent, seven hybrids over better parent, four hybrids over the check Naveen and nine hybrids over the check Akshaya. Similar study for heterosis for quality characters in tomato was conducted by Kurian and Peter (2001), Makesh *et al*. (2002) Bhatt *et al.* (2004), Kumar *et al*. (2006), Mali and Patel (2014) Shankar *et al*. (2014).

From the foregoing discussions based on the mean performance and heterosis, it can be concluded that LE 20 x LE 1 was the best hybrid superior for yield plant $^{-1}$, yield plot $^{-1}$, fruit length, fruit girth and fruit weight (Table 27). The hybrid LE 2 x LE 20 was superior for earliness to flowering and to fruit set, fruit set per cent, pollen viability and fruits truss $^{-1}$ and LE 2 x LE 39 was superior for fruits plant $^{-1}$.

Table. 27. Promising hybrids on the basis of mean performance and heterosis

Characters	Mean performance	Standard heterosis	Superior hybrids
Plant height (m)	LE 20 x LE 1 LE 38 x LE 1 LE 2 x LE 1	LE 20 x LE 1	LE 20 x LE 1
Height at flowering(cm)	LE 2 x LE 17 LE 2 x LE 20 LE 2 x LE 1	LE 2 x LE 17	LE 2 x LE 17
Node to first inflorescence	LE 20 x LE 1 LE 2 x LE 1 LE 2 x LE 17	LE 20x LE 1	LE 20 x LE 1
Internodal length (cm)	LE 2 x LE 20 LE 2 x LE 17 LE 2 x LE 1	LE 2 x LE 20	LE 2 x LE 20
Leaf length (cm)	LE 20 x LE 1 LE 16 x LE 20 LE 39 x LE 38	LE 2 x LE 38 LE 16 x LE 20	LE 16 x LE 20
Leaf width (cm)	LE 39 x LE 38 LE 16 x LE 20 LE 20 x LE 1	LE 16 x LE 20	LE 16 x LE 20
Days to first flowering	LE 2 x LE 20 LE 2 x LE 38 LE 2 x LE 39	LE 2 x LE 20	LE 2 x LE 20
Days to fruit set	LE 2 x LE 20 LE 20 x LE 1 LE 2 x LE 38	LE 2 x LE 20	LE 2 x LE 20
Fruit set (%)	LE 2 x LE 20 LE 20 x LE 1 LE 2 x LE 1	LE 2 x LE 20	LE 2 x LE 20
Pollen viability (%)	LE 2 x LE 20 LE 20 x LE 1 LE 2 x LE 17	LE 2 x LE 20	LE 2 x LE 20

Table.27. continued

Characters	Mean performance	Standard heterosis	Superior hybrids
Fruits plant $^{-1}$	LE 2 x LE 39 LE 2 x LE 20 LE 39 x LE 38	LE 2 x LE 39	LE 2 x LE 39
Fruits truss^{-1}	LE 2 x LE 20 LE 2 x LE 38 LE 20 x LE 1	LE 2 x LE 20	LE 2 x LE 20
Fruit length (cm)	LE 20 x LE 1 LE 38 x LE 1 LE 2 x LE 1	LE 20 x LE 1	LE 20 x LE 1
Fruit girth (cm)	LE 20 x LE 1 LE 38 x LE 1 LE 2 x LE 1	LE 20 x LE 1	LE 20 x LE 1
Fruit weight (g)	LE 20 x LE 1 LE 2 x LE 1 LE 38 x LE 1	LE 20 x LE 1	LE 20 x LE 1
Yield plant^{-1} (g)	LE 20 x LE 1 LE 2 x LE 20 LE 2 x LE 1	LE 20 x LE 1	LE 20 x LE 1
Yield plot $^{-1}$ (kg)	LE 20 x LE 1 LE 2 x LE 20 LE 2 x LE 1	LE 20 x LE 1	LE 20 x LE 1
TSS (%)	LE 2 x LE 38 LE 39 x LE 38 LE 2 x LE 17	LE 2 x LE 38	LE 2 x LE 38
Lycopene (mg/100g)	LE 2 x LE 39 LE 39 x LE 38 LE 16 x LE 20	LE 2 x LE 39	LE 2 x LE 39
Ascorbic acid (mg/100g)	LE 2 x LE 1 LE 16 x LE 20 LE 2 x LE 20	LE 2 x LE 1	LE 2 x LE 1

SUMMARY

6. SUMMARY

The present investigation entitled “Evaluation of hybrids of indeterminate tomato (*Solanum lycopersicum* L.) under protected cultivation” was done at the Department of Olericulture, College of Agriculture, Vellayani, during 2015 -2016. The main objective was to evaluate the yield and quality of F_1 hybrids of indeterminate tomato under protected cultivation.

The experiment was conducted in the saw tooth type naturally ventilated polyhouse of size 480 m^2 (30 m x 16 m) attached to the Department of Olericulture, College of Agriculture Vellayani. The roof of polyhouse was made up of 200 micron ultraviolet stabilized polythene sheet and its sides were made up of 40 mesh insect proof net. It was also provided with fogger unit to reduce the temperature inside the polyhouse and drip irrigation system for efficient use of water and fertilizers. This experiment was conducted in two parts. In part I, the seeds of ten superior F_1 hybrids selected based on the specific combining ability and *per se* performance in the previous research programme conducted in the Department of Olericulture were produced in a crossing block. In part II, these ten hybrids were evaluated along with their parents and two checks Naveen and Akshaya (one of the parent) in Randomized Block Design with 18 treatments in three replications for two seasons (July 2015 to January 2016 and November 2015 to March 2016).The salient findings of present study are summarized below.

Observations were recorded on the vegetative characters like plant height (m), height at flowering (cm), node to first inflorescence, internodal length (cm),leaf length (cm), leaf width (cm), flowering characters like days to first flowering, days to fruit set, fruit set (%), Pollen viability (%) and fruit, yield characters like fruits plant $^{-1}$, fruits truss $^{-1}$, fruit length (cm), fruit girth (cm), fruit weight (g), yield plant $^{-1}$ (g) and yield plot $^{-1}$(kg) and quality characters like TSS

(%), lycopene (mg/100g) and ascorbic acid (mg/100g). The incidence of pests and diseases and physiological disorders were also moniterd.

Analysis of variance showed significant difference between the treatments for all the characters for both the seasons. According to the pooled data, among the hybrids, LE 20 x LE 1 recorded highest plant height (4.19 m) with lowest number of node to first inflorescence (12.39) and maximum leaf length (40.32 cm).Whereas maximum leaf width was exhibited by LE 39 x LE 38 (31.14 cm) . Lowest height at flowering is an indication of earliness and it was observed in LE 2 x LE 17 (37.22 cm; 34 cm) for first and second season. Shortest internodal length was recorded in LE 2 x LE 20 (4.05 cm) and it also exhibited earliness to flower (21.94 days) and to set fruit (6.33 days) with highest fruit set per cent (70.42 %), pollen viability (78.07 %) and fruits truss $^{-1}$ (5.67). Whereas, the highest fruits plant $^{-1}$ was given by LE 2 x LE 39 during first season (106.33), second season (68.44) and in pooled (87.39). The hybrid LE 20 x LE 1 had highest fruit length (8.52 cm ; 8.42 cm ;8.47 cm), fruit girth (17.48 cm ; 17.29 cm ; 17.38 cm), fruit weight (100.11 g ; 94.45 g ; 97.28), yield plant $^{-1}$ (3505.20 g ; 1843.89 g ; 2674.54 g) and yield plot $^{-1}$ (67.68 kg ; 32.32 kg ; 50.00 kg) during first trial, second trial and pooled. For quality characters, LE 2 x LE 38, LE 2 x LE 39 and LE 2 x LE 1 had highest TSS (Total Soluble Solids) (5.37 %), lycopene (13.10 mg/100g) and ascorbic acid (32.20 mg/100g) respectively.

Among the parents LE 1exhibited maximum fruit length (8.58 cm ; 8.65 cm ;8.62 cm), fruit girth (16.40 cm ; 16.52 cm ; 16.46 cm), fruit weight (110.66 g ; 99.22 g ; 104.94), yield plant $^{-1}$ (2458.22 g ; 1355.64 g ; 1906.93 g) and yield plot $^{-1}$ (47.38 kg ; 24.20 kg ; 35.79 kg) during first trial, second trial and pooled mean respectively. According to pooled data, LE 2 was early to flowering (24.39) with highest fruit set per cent (67.28 %), fruits truss $^{-1}$ (5.17) and fruits plant $^{-1}$ (43.45). Parents showed a range of 5.08 % (LE 20) to 5.73 % (LE 38) for total soluble solids, 11.94 mg/100g (LE 17) to 12.55 mg/100g (LE 39) for lycopene and 16.62 mg/100g (LE 1) to 25.06 mg/100g (LE 2) for ascorbic acid.

No pest incidence was noticed inside the polyhouse for both the seasons. Regarding incidence of diseases, 50 per cent bacterial wilt incidence was observed in the check Naveen and all other treatments were free from this disease during first season. But during second season, Naveen exhibited 100 per cent bacterial wilt and there was no plants remained for taking observation whereas the hybrids LE 2 x LE 39 and LE 2 x LE 38 was free from the bacterial wilt and other treatments exhibited a range of 6.67 % to 30 %.

The important physiological disorders like fruit cracking, blossom end rot and stigma exertion was noticed inside the polyhouse for few hybrids and parents.

In both the seasons, all the treatments except LE 16, LE 38, LE 39 x LE 38 and LE 2 x LE 38 was free from fruit cracking. In the first trial, the highest incidence of fruit cracking was observed in LE 16 (53.33 %) followed by LE 39 x LE 38 (23.33 %), LE 38 (20.00 %) and LE 2 x LE 38 (13.33 %) and in second trial, LE 16 (56.67 %) followed by LE 38 (26.67 %), LE 2 x LE 38 (16.67 %) and LE 39 x LE 38 (26.67 %). Only three treatments LE 17 (16.67 % ; 23.33 %), LE 20 x LE 39 (13.33 % ; 16.67 %) and LE 39 x LE 38 (10.00 % ; 26.67 %) exhibited blossom end rot during first and second season respectively. All other treatments were free from this physiological disorder. In the first crop, there was no incidence of stigma exertion since the temperature was favourable for the crop. In the second trial, the incidence of stigma exertion varied from 9.52 % to 35.55 %. Among the hybrids the incidence of stigma exertion was least in LE 2 x LE 1 and LE 20 x LE 1 (9.52 %) and among the parents, LE 38 and LE 1(9.52 %) recorded least incidence of stigma exertion.

The correlation analysis revealed that the yield plant $^{-1}$ had a significant positive correlation with leaf length (0.4153), fruit set per cent (0.5050), fruits plant $^{-1}$ (0.4984), fruits truss^{-1} (0.4744), fruit length (0.3048), fruit girth (0.3193), fruit weight (0.3555) and ascorbic acid (0.4521).

The first season data was taken and the magnitude of heterosis was estimated as per cent increase or decrease of F_1 value over the mid-parent (relative

heterosis), better parent (heterobeltiosis) and standard check Naveen and Akshaya (standard heterosis) for various characters.

LE 2 x LE 20 showed highest standard heterosis over the two checks Naveen and Akshaya for days to first fowering (-11.06 %; -11.06 %) and to fruit set (-39.55 %; -29.46 %), fruit set per cent (36.38 %; 16.59 %), pollen viability (60.01 %; 12.04 %) and fruits truss $^{-1}$ (85.22 %; 56.38 %). Whereas LE 2 x LE 39 had highest standard heterosis for fruits plant $^{-1}$ (319.77 %; 147.31 %). LE 20 x LE 1 had highest standard heterosis for fruit length (5.36 %; 38.74 %), fruit girth (21.09 %; 32.79 %), fruit weight (38.62 %; 114.53 %), yield plant $^{-1}$ (157.52 %; 90.41 %) and yield plot $^{-1}$ (231.48 %; 90.58 %). LE 2 x LE 38 (-4.71 %; 3.85 %), LE 2 x LE 39 (4.01 %; 2.6 %), LE 2 x LE 1 (22.22 %; 61.95 %) had highest standard heterosis for quality characters like TSS, lycopene and ascorbic acid content respectively.

Based on mean performance and heterosis, LE 20 x LE 1 was superior for fruit length, fruit girth, fruit weight, yield plant $^{-1}$ and yield plot $^{-1}$. The hybrid LE 2 x LE 20 was superior for earliness to flowering and to fruit set, fruit set %, pollen viability % and fruits truss $^{-1}$ and for fruits plant $^{-1}$ LE 2 x LE 39 was superior. The hybrid LE 2 x LE 38 was superior for TSS and for lycopene content LE 2 x LE 39 and for ascorbic acid content LE 2 x LE 1 was superior. Thus the promising hybrids for yield and yield attributes were LE 20 x LE 1 followed by LE 2 x LE 20.

FUTURE LINE OF WORK

The superior hybrids LE 20 x LE 1 and LE 2 x LE 20 can be subjected to farm trials and multilocational trials and if found superior over the check variety can be recommended for cultivation in naturally ventilated polyhouse.

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EVALUATION OF HYBRIDS OF INDETERMINATE TOMATO (*Solanum lycopersicum* L.) UNDER PROTECTED CULTIVATION

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ABSTRACT

The present investigation entitled "Evaluation of hybrids of indeterminate tomato (*Solanum lycopersicum* L.) under protected cultivation" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during 2015-2016 with the objective of evaluating the yield and quality of F_1 hybrids of indeterminate tomato under protected cultivation.

The experiment was conducted in the saw tooth type naturally ventilated polyhouse of size 480 m^2 (30m x 16m) attached to the Department of Olericulture, Vellayani. It was conducted as two parts. In part I, the seeds of ten selected superior F_1 hybrids were produced in a crossing block. These ten F_1 hybrids were selected based on the specific combining ability and *per se* performance in the previous research programme conducted in the Department of Olericulture. In part II, these ten hybrids were evaluated along with their parents and two checks Naveen and Akshaya (one of the parent) in Randomized Block Design with 18 treatments in three replications for two seasons (July 2015 to January 2016 and November 2015 to March 2016).

Analysis of variance showed significant difference between the treatments for all the characters for both the seasons. Pooled analysis revealed that among the hybrids, LE 20 x LE 1 had highest fruit yield plant $^{-1}$ (2674.54 g) and it was on par with LE 2 x LE 20 (2476.68 g). The fruit characters like fruit length (8.47 cm), fruit girth (17.38 cm) and fruit weight (97.28 g) were also highest for LE 20 x LE 1 whereas the number of fruits plant^{-1} was highest for LE 2 x LE 39 (87.39). The hybrid LE 2 x LE 20 was the earliest to flower and to fruit set. It also recorded highest pollen viability (78.07 %), fruit set per cent (70.42 %) and fruits truss^{-1} (5.67). For quality characters, LE 2 x LE 38, LE 2 x LE 39 and LE 2 x LE 1 had highest TSS (Total Soluble Solids) (5.37 %), lycopene (13.10 mg/100g) and ascorbic acid (32.20 mg/100g) respectively. Among the parents, LE 1 had highest fruit length (8.62 cm), fruit girth (16.46 cm), fruit weight (104.94 g), yield plant $^{-1}$ (1906.93 g) and yield plot^{-1} (35.79 kg) whereas number of fruits plant $^{-1}$ was highest for LE 2 (43.45). No insect pest was noticed in the polyhouse for both the seasons.

LE 2 x LE 39 and LE 2 x LE 38 was free from the bacterial wilt incidence for both the seasons. In both the seasons, all the treatments except LE 16, LE 38, LE 39 x LE 38 and LE 2 x LE 38 was free from fruit cracking and all the treatments except LE 17, LE 20 x LE 39 and LE 39 x LE38 was free from blossom end rot. Among the hybrids the incidence of stigma exertion was least in LE 2 x LE 1 and LE 20 x LE 1 (9.52 %).

Correlation studies revealed that, yield plant $^{-1}$ had a significant positive correlation with fruit set per cent (0.5050), fruits plant $^{-1}$ (0.4984), fruits truss^{-1} (0.4744), fruit length (0.3048), fruit girth (0.3193), fruit weight (0.3555) and ascorbic acid (0.4521).

Relative heterosis, heterobeltiosis and standard heterosis over the hybrid and variety were worked out for all yield and quality characters. The highest standard heterosis over the hybrid (Naveen) and the variety (Akshaya) was shown by LE 20 x LE 1 for fruit length (5.36 % ; 38.74 %), fruit girth (21.09 % ; 32.79 %), fruit weight (38.62 % ; 114.53 %), yield plant^{-1} (157.52 % ; 90.41 %) and yield plot^{-1} (231.48 % ; 90.58 %) and LE 2 x LE 39 for number of fruits plant $^{-1}$ (319.77 % ; 147.31 %).

Based on mean performances and standard heterosis, LE 20 x LE 1 and LE 2 x LE 20 were the promising hybrids for yield and yield attributes. They can be recommended for cultivation in naturally ventilated polyhouse after further confirmatory trials.

APPENDIX - I

FERTIGATION SCHEDULE FOR PRECISION FARMING IN TOMATO

50 Split – 150Days

Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
		Basal Dose P (kg/ha)	65.00	1.300
1	3rd Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00
2	6th Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00
3	9th Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00
4	12th Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00
5	15th Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00

Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
6	18 th Day after planting	19:19:19	8.60	0.170
		13:0:45	4.50	0.010
		Urea	8.60	0.175
		12:61:0	0.00	0.00
7	21st Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
8	24th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
9	27th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
10	30st Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030

Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
11	33rd Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
12	36th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
13	39th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
14	42nd Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
15	45th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
16	48th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
17	51st Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
18	54th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	4.40	0.090
		12:61:0	1.30	0.030
19	57th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
20	60th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
21	63th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
22	66st Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
23	69th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
24	72th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
25	75th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
26	78th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
27	81st Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
28	84th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
29	87th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
30	90th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
31	93rd Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
32	96th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
33	99th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
34	102 rd Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
35	105th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
36	108rd Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
37	111th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
38	114th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
39	117th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020
40	120th Day after planting	19:19:19	4.30	0.090
		13:0:45	15.10	0.300
		Urea	10.30	0.210
		12:61:0	1.30	0.020

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
41	123rd Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
42	126th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
43	129th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
44	132th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
45	135th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00

Sl s Sl No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha) 200 sq m TOMATO	
46	138rd Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
47	141th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
48	144th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
49	147th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00
50	150th Day after planting	19:19:19	0.00	0.00
		13:0:45	16.90	0.340
		Urea	4.35	0.090
		12:61:0	0.00	0.00

APPENDIX –II

Temperature inside the polyhouse during the cropping period

6th August 2015 to 23rd January 2016 and 14th December 2015 to 27th March 2016

Temperature inside polyhouse (weekly average) during first season			Temperature inside polyhouse (weekly average) during second season		
Standard week	Maximum temperature	Minimum temperature	Standard week	Maximum temperature	Minimum temperature
32	32	21.5	51	29.33	23.33
33	33.75	22	52	28.33	24
34	33.5	21.75	1	39.33	24.67
35	37.8	27.8	2	41.67	26
36	39.8	25	3	39.67	25.33
37	40.17	26.5	4	42.67	25
38	41.33	26.66	5	41.67	25.33
39	40.66	27.33	6	41.66	25.33
40	41	25.33	7	40.33	25
41	30.33	25.33	8	41.33	25.33
42	36.67	27	9	41.67	25.67
43	30	25.67	10	42.67	25.67
44	31.5	27.5	11	42.67	26
45	37.67	24.33	12	41.33	34.67
46	35.33	24.33	13	43.67	35.67
47	33.33	24			
48	33.67	25.67			
49	29	24.33			
50	26.33	24			
51	29.33	23.33			
52	28.33	24			
1	39.33	24.67			
2	41.67	26			
3	39.67	25.33			
4	42.67	25			