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Screening of tomato (*Solanum lycopersicum* L.) genotypes for hotset traits

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Abstract

Tomato is a vegetable in high demand all over the world. Studies on the relationship of temperature and relative humidity have revealed that the reproductive stage of tomato is sensitive to widely varying weather parameters which largely affect the pollen viability and fruit set per cent. Morpho-phenological development of tomato largely depends on prevailing weather parameters, flowering phase being the most sensitive. Temperature fluctuations above 38°C and relative humidity below 50% are reported to adversely affect the fruit setting of tomato, by altering pollen viability. Selection of suitable growing system can largely influence the microclimate around the crop. Kerala is in urgent need of an indeterminate hotset tomato genotype. Department of Vegetable Science, College of Horticulture, Kerala Agricultural University has undertaken screening of 35 tomato genotypes in two different growing systems in the summer months of 2018, to evaluate for hotset characters. Observations were taken on hotset traits and yield parameters of the crop. The comparison of the structures and the variability of genotypes were assessed. The genotypic correlation of characters observed with yield was worked out. Based on the selection indices, hotset genotypes were suggested for further hybridization programme.

Key words: Fruit set per cent, Hotset, Pollen viability, Temperature tolerance, Tomato screening.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important solanaceous vegetable crop grown worldwide.It is considered as a commercial crop as far as the area, production, industrial value and contribution to human nutrition are concerned. In the world, it ranks second in importance and production after potato,but tops the list of processed vegetables. The world tomato requirement is increasing day by day. Even though tomato can be grown over a wide range of climatic conditions, the inability of the crop to set fruits and give expected yield under widely varying conditions of temperature and relative humidity is a limiting factor of tomato production in the tropics. Floral and fruit traits are severely affected due to drastic changes in the weather parameters which indicates the sensitivity of specific physiological processes of flower development to weather fluctuations. In tomato, proper morpho-phenological development and their functions largely depend on the prevailing weather conditions. Flowering phase is most sensitive to extremities of weather. A temperature above 38°C for at least 3-4 hours can cause detrimental effect on meiosis. Under the prevailing weather conditions of Kerala, the temperature in the summer months can reach up to 38°C or more. Unavailability of high temperature tolerant genotypes presents a major limitation for growing

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an economic crop in the summer months in the tropics. Wide genotypic variation is observed in the cultivars for hotset traits. In many cases, tomato is planted under protected structures in regions where summer is hot and arid. Prolonged hours of solar radiation in the tropics results in the increase of temperature in these structures. Insufficient ventilation leads to abnormal changes in the weather parameters including temperature and relative humidity and results in heat build-up inside the structure. This condition will impair the fertilization process and reduce the yield. One possible way to cope up with this problem is to use cost effective shelters during the hot season. Breeding inbred lines with desirable stress tolerance can increase the possibility of cultivating the crop in Kerala in summer months.Because of the difference in yield potential and performance in different ecological zones, testing of new genotypes is a must, and is an established practice in plant breeding. Hence, recently attempts were made to identify hotset genotypes in tomato in two different growing systems at Kerala Agricultural University. The objective was to evaluate 35 tomato genotypes for their response in pollen viability, fruit set per cent, number of fruits per plant, average fruit weight and yield per plant in two growing systems, polyhouse and rainshelter,during summer months in order to select heat tolerant hotset lines as genetic sources for incorporation in a breeding programme.The study also aimed at a comparison of performance of genotypes in both the structures for their utilization of summer tomato cultivation

Material and methods

The present investigation was carried out at the Department of Vegetable Science, College of Agriculture, Vellanikkara, Thrissur from January 2018 to June 2018. The site is located at an altitude of 22.25m above mean sea level, between 10°31' N latitude, and 76°13'E longitude. This area enjoys a tropical warm humid climate and receives an average rainfall of 2663 mm per year. The soil of the experimental plot is sandy loam in texture of the order Ultisol, with acidic reaction (pH 5.7).

The experiment was conducted in both rainshelter and polyhouse. A rainshelter with floor area 384m^2 (24 × 16m) and height 3.048m was used. The frames of the rainshelter were constructed using GI pipes and it was cladded with UV stabilized polythene sheet of 200-micron thickness and the sides were made with 64 meshes per square foot.

The polyhouse was of the saw-toothed type and was naturally ventilated,with gutter height of 4.5m,gutter slope of 2 per cent, eve height of 1.5m and floor area of 384m^2 (24 × 16m), oriented in the N-S direction. The frame was made up of GI pipes of

Table 1. List of tomato genotypes used for study

Sl. No.	Accession number / name	Source
1	EC-145057	NBPGR, New Delhi
2	EC-151568	NBPGR, New Delhi
3	EC-157568	NBPGR, New Delhi
4	EC-160885	NBPGR, New Delhi
5	EC-163605	NBPGR, New Delhi
6	EC-164263	NBPGR, New Delhi
7	EC-164563	NBPGR, New Delhi
8	EC-164670	NBPGR, New Delhi
9	EC-165395	NBPGR, New Delhi
10	EC-165690	NBPGR, New Delhi
11	EC-165700	NBPGR, New Delhi
12	EC-249514	NBPGR, New Delhi
13	EC-521067 B	NBPGR, New Delhi
14	EC-528368	NBPGR, New Delhi
15	EC-538153	NBPGR, New Delhi
16	EC-620376	NBPGR, New Delhi
17	EC-620378	NBPGR, New Delhi
18	EC-620382	NBPGR, New Delhi
19	EC-620387	NBPGR, New Delhi
20	EC-620389	NBPGR, New Delhi
21	EC-620395	NBPGR, New Delhi
22	EC-620401	NBPGR, New Delhi
23	EC-620406	NBPGR, New Delhi
24	EC-620410	NBPGR, New Delhi
25	EC-620417	NBPGR, New Delhi
26	EC-620427	NBPGR, New Delhi
27	EC-620429	NBPGR, New Delhi
28	EC-631369	NBPGR, New Delhi
29	EC-631379	NBPGR, New Delhi
30	Pusa Ruby	NBPGR, New Delhi
31	Arka Abha	ICAR-IIHR, Bengaluru
32	Arka Saurabh	ICAR-IIHR, Bengaluru
33	Arka Alok	ICAR-IIHR, Bengaluru
34	Akshay	KAU, Thrissur
35	Anagha	KAU, Thrissur

76mm ID and 3mm thickness. The roof was made up of 200- micron UV stabilized polythene sheet and the sides were made up of 25 per cent shade net.

The experimental material consisted of 35 indeterminate tomato genotypes (Table 1), 29 NBPGR accessions, Pusa Ruby, three IIHR varieties (Arkha Abha, Arka Saurabh and Arka Alok) and two KAU released varieties (Akshaya and Anagha). The seedlings were prepared in pro-trays containing potting mixture of red earth, sand and cow dung in the ratio 2:1:1. Twenty-one days old seedlings were transplanted to the main field. Transplanting was done at a spacing of 1.0 m × 0.5m on raised beds. Raised beds of 23m length and 1m width were prepared. The beds were covered with black and white double shaded polythene mulch of 30-micron thickness.

Irrigation water was supplied through drip system. Misting was adopted during the hotter parts of the day inside the polyhouse to prevent temperature build-up inside. Polyhouse plants were supported by floricultural nets. Inside the rainshelter tall poles were used. The plants were pruned to single stem during the initial stages of growth. Since the plants were indeterminate in growth habit, regular pruning was practiced. Plant protection was undertaken as per the recommendations of the Kerala Agricultural University (KAU, 2016).

The air temperature and relative humidity were recorded daily in the morning (9.00 am) and in the afternoon (2.00 pm). The air temperature was recorded from two dry bulb thermometers fixed in the field at the height of foliage, and data averaged. The relative humidity was calculated from the reading of a whirling psychrometer and the mean value worked out. Observations were recorded on pollen viability, fruit set per cent, number of fruits per plant, average fruit weight and yield. Pollen viability was observed in the flowers that bloomed on the very day using acetocarmine stain (Abdul-Baki, 1992). Data were analyzed as per randomized block design (RBD) and analysis of variance (ANOVA) for each genotype and significance was defined as ($p = 0.05$) for each character separately (Panse and Sukhatme, 1985). The significance of correlation coefficients was evaluated using Pearson's correlation coefficient at $P = 0.05$(Miller et al.,1958).Selection indices were constructed considering four characters *viz.* pollen viability, fruit set per cent, number of fruits per plant and average fruit weight, using the method developed by Smith (1937) based on discriminative function of Fisher (1936).

Index value, I, for polyhouse plants = (pollen viability ×17.65342) + (fruit set per cent × 12.67458)+ (number of fruits × 15.62156) + (average fruit weight× 10.87764).

Index value, I, for rainshelter plants = (pollen viability × 7.668003) +(fruit set per cent × 3.333322)+ (number of fruits × 12.35267)+(average fruit weight× 9.881481)

Results and discussion

Among the weather parameters, temperature and relative humidity are key elements in determining the temperature tolerance of a genotype. The morning (9.00am) and afternoon (2.00pm) temperature and relative humidity recordings are depicted in Table 2.

Pollen viability (%)

The pollen viability of tomato differs greatly at elevated temperatures and fluctuating relative humidity, hence it is a principle element in selecting a hotset genotype. The pollen viability of both the structures is depicted in Figure1. The rainshelter plants invariably recorded higher pollen viability. Under polyhouse the pollen viability ranged between 41.9% and 56.2%, with EC-538153 exhibiting highest pollen viability. Rainshelter plants exhibited fairly wide range for pollen viability stretched between 45.5% and 66.7%, with EC-165395 in the top position. Under polyhouse only

Table 2. Temperature and relative humidity recorded during the experiment

Standard . week no	Month	Temperature (ºC)				Relative humidity (%)			
		Polyhouse		Rainshelter		Polyhouse		Rainshelter	
		9.00 am	2.00 pm	9.00 am	2.00 pm	9.00 am	2.00 pm	9.00 am	2.00 pm
5	January-February	27.8	34.5	28.2	37.5	71.2	43.1	67.2	59.2
6	February	28.1	35.4	28.7	38.2	72.5	45.5	66.5	58.6
7	February	29.6	36.2	30.2	38.7	79.7	43.4	67.4	57.5
8	February	29.8	37.2	31.3	39.9	73.3	44.7	68.1	56.3
9	February – March	31.6	37.5	33.2	39.8	68.5	49.2	63.5	61.2
10	March	32.2	37.6	34.7	40.7	74.2	47.5	65.7	59.8
11	March	32.5	36.4	34.3	39.7	74.5	49.5	68.5	57.5
12	March	30.8	34.5	31.3	37.8	78.8	45.2	76.2	59.3
13	March - April	31.3	37.5	33.2	39.6	73.6	46.4	68.4	58.2
14	April	31.2	36.1	32.8	40.5	79.2	48.5	68.7	56.7
15	April	31.8	37.0	33.6	41.2	73.5	47.3	68.5	59.5
16	April	32.3	37.1	34.3	40.2	74.5	47.5	69.2	60.3
17	April	32.8	37.6	35.2	41.3	74.3	46.3	68.5	57.4
18	April - May	33.2	37.5	36.4	40.7	75.7	45.2	70.3	58.5
19	May	33.7	36.9	36.2	39.5	75.2	48.7	64.6	57.5
20	May	33.4	36.5	35.8	38.9	75.5	46.3	67.5	59.2
21	May	33.7	36.4	36.1	39.2	80.2	59.2	74.2	66.7
22	May - June	31.5	35.2	32.3	38.1	86.7	64.5	75.5	68.2

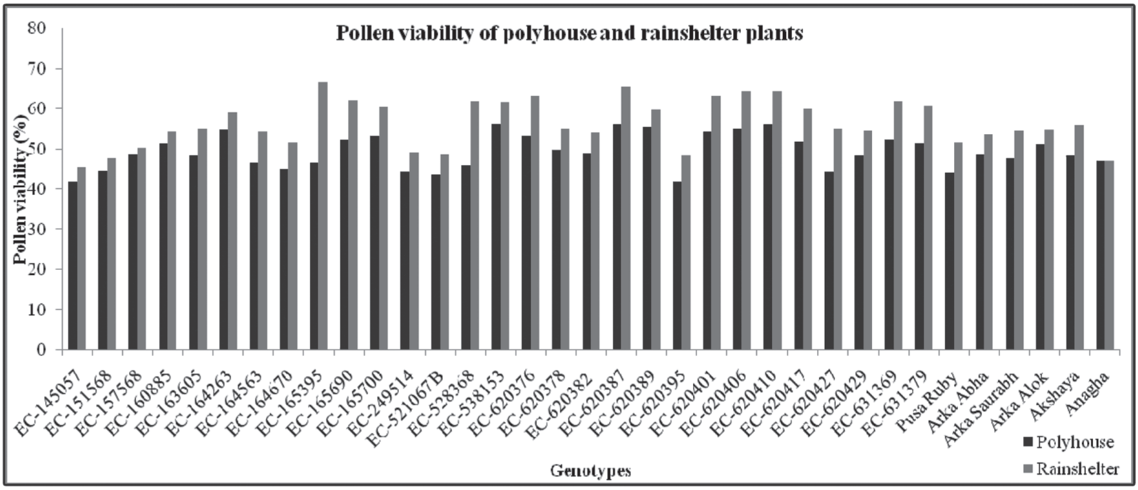

Figure 1. Pollen viability of polyhouse and rainshelter plants

five genotypes exhibited pollen viability above 55.0% *viz*.EC-538153 (56.2%), EC-620387 (56.1%), EC-620389 (55.5%), EC-620406 (55.1%) and EC-620410 (56.1%). Concomitantly inside rainshelter, 13 genotypes exhibited pollen viability exceeding 60% *viz*.EC-165395 (66.7%), EC-165690 (62.2%), EC-165700 (60.6%), EC-528368 (62.0%), EC-538153 (61.8%), EC-620376 (63.2%), EC-620387 (65.6%), EC-620401 (63.2%), EC-620406 (64.3%), EC-620410 (64.4%), EC-620417 (60.1%), EC-631369 (62.0%) and EC-631379 (60.8%).The increased temperature of rainshelter associated with increased RH with good light conditions ensuring proper photosynthesis could help in the proper development of male reproductive organs (Kittas et al., 2005).It is observed that just before anthesis the developing pollen grains and anthers started accumulating starch, which was finally converted to hexose in developing pollen grains (Harel et al., 2014). The availability of irradiance was 40% less under polyhouse condition, whereas there was only 10% reduction inside

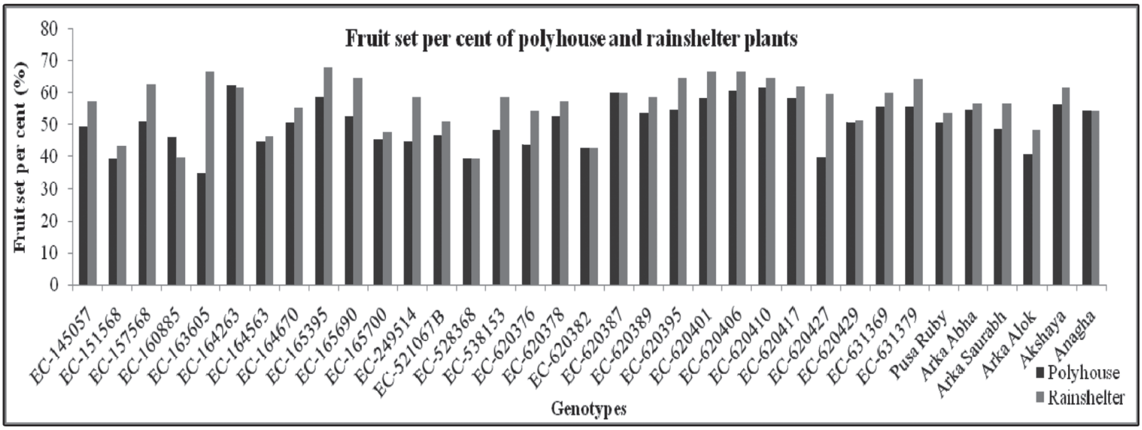

Figure 2. Fruit set per cent of polyhouse and rainshelter plants

rainshelter (Tilahun et al., 2017). The reduced levels of light under a polyhouse could lower the rate of photosynthesis, and could considerably reduce the photoassimilates available to developing sinks like pollen and anthers. Any stress in the phenological development stage in tomato could impair pollen fertility (Alsamir et al., 2017). The higher levels of pollen viability inside the rainshelter for summertime tomato was also supported by Xu et al.(2007), Rajasekhar et al.(2013), Cheema et al.(2014) and Pooja and Hakkin (2017).

Fruit set per cent

Data on fruit set per cent of polyhouse and rainshelter plants are depicted in Figure 2. Under polyhouse the genotype EC-164263 exhibited highest fruit set per cent (62.4%). Inside rainshelter the highest fruit set per cent was recorded for EC-165395 (67.9%). Fruit set per cent of rainshelter plants surpassed that of polyhouse plants in 29 genotypes. Four genotypes *viz*.,EC-528368 (39.3%), EC-620382 (42.7%), EC-620387 (59.9%) and Anagha (54.4%) exhibited staticity in the fruit set per cent between the structures. The genotypes EC-160885 (46.3% for polyhouse and 39.7% for rainshelter) and EC-164263 (62.4% for polyhouse and 61.5%for rainshelter) exhibited higher fruit set per cent under polyhouse. The reason for no change in the fruit set per cent in genotypes was attributed to their genetic value (Peet et al., 2002; Sato et al., 2006). In certain genotypes microclimate greatly influenced the attributes in a way favouring the full phenotypic expression of genotype (Rajasekhar et al., 2013). Anthers were more vulnerable to weather fluctuations and the reduction in the viability in turn reduced the fruit set per cent. The major factor for the reduction in the fruit set per cent was the high responsiveness in flower development, including both male and female organs, to temperature changes (Alsamir et al., 2017). The disparity in the fruit set per cent between protected structures was also noticed in the works of Chapagain et al.(2011), Rajasekhar et al.(2013) and Cheema et al.(2014).

Number of fruits per plant

The number of fruits per plant is function of the number of flowers per plant, pollen viability and fruit set per cent. Data on the number of fruits per plant are depicted in Figure 3. More number of fruits was noted for 34 genotypes inside rainshelter. In the polyhouse the number of fruits per plant varied between 10.0 and 23.2, while in the rainshelter, plants had the range between 11.3 and 67.0. Inside rainshelter four genotypes viz.EC-165395 (65.6), EC-165690 (67.0), EC-528368 (44.2) and EC-620376 (46.9) exhibited more than 40 fruits per plant, while on the contrary, under polyhouse the sole genotype with more than 20 fruits per plant was EC-165700 (23.2). Pandey et al. (2006) noted more number of flower clusters for smaller sized fruits and hence opined that fruit size could be a key element in selection. Modifications in the

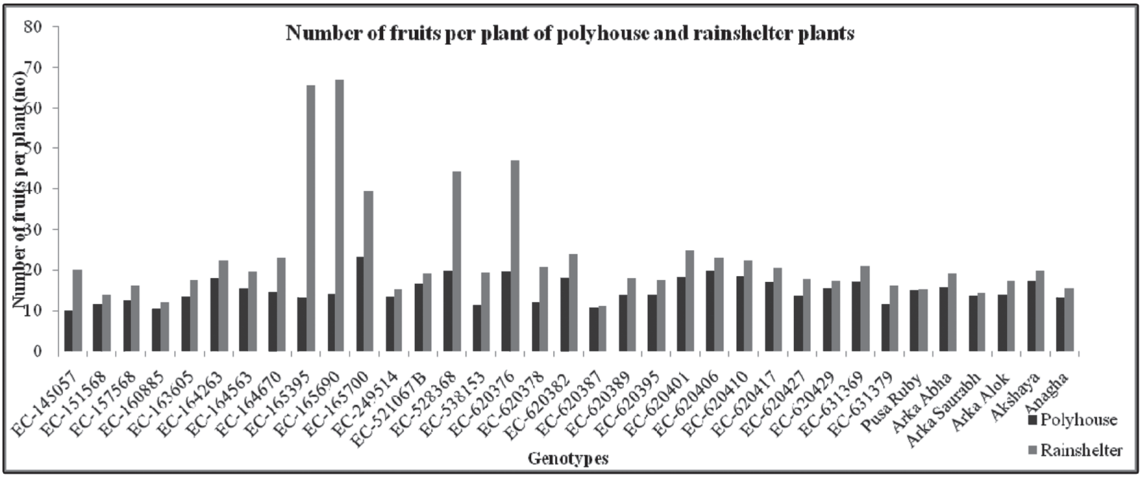

Figure 3. Number of fruits per plant for polyhouse and rainshelter plants

microclimate as an outcome of growing structure could result in developmental abnormalities in the male and female reproductive tissues by reduced supply of photosynthates and poor production of growth regulators (Hazra et al*.,* 2007).Phenological development of tomato was more favoured by the microclimate of rainshleter during summertime according to Parvej et al.(2010), which was further confirmed in this study. The performance of individual genotypes under two different growing systems was different. This indicated that the selection of genotype is important depending on the number of fruits per pant and growing system (Chapagain et al*.,* 2011; Fentik, 2017). Varied response of the genotypes under dissimilar growing systems for number of fruits per plant was also noted in the works of Parvej et al. (2010), Kanwar (2011), and Cheema et al. (2014)

Average fruit weight (g)

The average fruit weight ultimately determines the yield. The present study observed fairly high individual fruit weight for rainshelter plants (Table 3) for 27 genotypes. Pusa Ruby exhibited staticity in the average fruit weight between the structures (38.2 g). Six genotypes exhibited statistically non-significant variation in the average fruit weight between the structures viz.EC-145057 (34.4 g and 35.5 g for polyhouse and rainshelter respectively), EC-151568 (37.5 g and 38.5 g for polyhouse and rainshelter respectively), EC-165395 (23.4 g and 25.1 g for polyhouse and rainshelter respectively), EC-165690 (26.8 g and 28.4 g for polyhouse and rainshelter respectively), EC-620376 (8.4 g and 10.9 g for polyhouse and rainshelter respectively) and EC-620382 (65.2 g and 65.4 g for polyhouse and rainshelter respectively). The genotype EC-620417 exhibited higher average fruit weight under polyhouse (75.2 g and 72.4 g for polyhouse and rainshelter respectively). The average fruit weight of a genotype is gathered from the entire lifespan of the crop. The microclimate modified the photosynthate assimilation, further increasing or decreasing the availability to sinks (Tilahun et al*.,* 2017). The better photosynthesis under ensured light intensity resulted in better accumulation of photosynthates available for growing sinks inside rainshelter. The heat stress resulted in improper pollination and puffiness of the fruit,leading to less average fruit weight under polyhouse (Solankey et al*.,* 2017).The differential response of the genotypes in average fruit weight, and higher average fruit weight for rainshelter plants were also observed in the works of Chapagain et al. (2011) and Pooja and Hakkim (2017).

Yield per plant (g)

The mean yield from all pickings showed significant difference among the genotypes and between the structures (Table 3). Rainshelter plants recorded

Table 3. Average fruit weight and yield per plant of polyhouse and rainshelter plants

Genotypes	Average fruit weight (g)		Yield per plant (g)	
	Polyhouse	Rainshelter	Polyhouse	Rainshelter
EC-145057	34.4	35.5	325.5	623.3
EC-151568	37.5	38.5	412.2	426.8
EC-157568	32.1	37.6	389.9	578.6
EC-160885	41.6	44.4	347.8	470.6
EC-163605	39.9	45.9	526.6	624.3
EC-164263	67.7	73.5	1067.1	1436.6
EC-164563	52.4	58.0	694.1	947.6
EC-164670	39.8	46.5	451.7	963.6
EC-165395	23.4	25.1	319.5	1505.8
EC-165690	26.8	28.4	376.5	1688.3
EC-165700	8.1	12.2	535.2	448.8
EC-249514	45.2	55.3	586.7	776.1
EC-521067 B	40.0	48.7	552.5	840.0
EC-528368	8.0	11.2	132.3	472.3
EC-538153	70.6	83.3	746.5	1164.5
EC-620376	8.4	10.9	136.0	409.5
EC-620378	54.2	58.5	679.1	751.7
EC-620382	65.2	65.4	1007.3	1208.1
EC-620387	70.8	89.3	617.5	930.7
EC-620389	64.3	70.2	864.9	1135.9
EC-620395	61.2	90.2	739.9	1387.7
EC-620401	75.5	93.6	1156.1	1764.3
EC-620406	85.8	94.2	1373.9	1685.6
EC-620410	86.3	92.4	1323.1	1875.0
EC-620417	75.2	72.4	1135.1	1256.5
EC-620427	64.1	73.2	843.9	1091.6
EC-620429	68.6	71.9	986.1	1138.8
EC-631369	65.1	70.8	1012.4	1357.2
EC-631379	69.4	71.9	723.1	1074.2
Pusa Ruby	38.2	38.2	462.2	425.1
Arka Abha	62.1	72.0	941.5	1029.9
Arka Saurabh	58.7	69.1	742.5	943.7
Arka Alok	56.0	69.0	723.5	1036.4
Akshaya	57.3	64.4	953.6	1147.1
Anagha	67.2	71.3	786.9	1057.7
CD (0.05)	5.7	7.1	201.4	379.1
CV	5.1	6.3	13.3	18.7

more yield in 33 genotypes. Under polyhouse the genotype EC-620406 exhibited highest yield per plant (1373.9 g) and inside rainshelter EC-620410 (1875.0 g) produced highest yield per plant. Under polyhouse condition seven genotypes recorded yield per plant exceeding 1000g *viz.*EC-164263 (1067.1 g), EC-620382 (1007.3 g), EC-620401 (1156.1 g), EC-620406 (1373.9 g), EC-620410 (1323.1 g), EC-620417 (1135.1 g) and EC-631369 (1012.4 g). Inside rainshelter, five genotypes exhibited yield per plant exceeding 1500g *viz.*EC-165395 (1505.8 g), EC-165690 (1688.3 g), EC-620401 (1764.3 g), EC-620406 (1685.6 g) and EC-620410 (1875.0 g). Two genotypes,EC-165700 (535.2 g and 448.8 g for polyhouse and rainshelter respectively) and Pusa Ruby (462.2 g and 425.1 g for polyhouse and rainshelter respectively), recorded more yield under polyhouse condition. Alam et al. (2010) proposed the suitability of genotypes with yield between 1.0 and 2.0 kg for selection. The light intensity and temperature at which photosynthesis and respiration were exactly balanced, i.e., the compensation point, is important to make a better use of both these climatic parameters under protected conditions. A genotype exhibiting a compensation point at low light intensity and temperature might have a high photosynthetic efficiency and such genotypes perform better under shade (Lekshmi and Celin, 2015; Singh and Kumar, 2017). The variability in the yield per plant for dissimilar genotypes under dissimilar growing systems was also proposed byChapagain et al. (2011), Cheema et al. (2014), and Nangare et al. (2015). Pooja and Hakkim (2017) had also reported more yield per plant inside rainshelter.

Correlation

In the genotypic correlation analysis under polyhouse (Table 4),the yield exhibited very strong significant correlation with fruit set per cent (r=0.839**), number of fruits per plant (r=0.953**) and average fruit weight (r=0.934**). Average fruit weight exhibited very strong significant correlation with fruit set per cent (r=0.939**) and number of fruits per plant (r=0.882**). Number of fruits per plant exhibited strong correlation with fruit set per cent (r=0.777**). In the genotypic correlation analysis inside rainshelter (Table 5), the yield exhibited very strong significant correlation with number of fruits per plant (r=0.893**) and average fruit weight (r=0.921**), whereas strong correlation existed with fruit set per cent (r=0.730), and moderately strong correlation with pollen viability (r=0.546**). Very strong correlation was observed between average fruit weight and fruit set per cent

Table 4. Genotypic correlation of polyhouse plants

	Pollen viability	Fruit set per cent	No. of fruits per plant	Average fruit weight	Yield per plant
Pollen viability	1.00	-0.027	0.004	-0.025	0.017
Fruit set per cent		1.00	0.777**	0.939**	0.839**
Number of fruits per plant			1.00	0.882**	0.953**
Average fruit weight				1.00	0.934**
Yield per plant					1.00

Table 5. Genotypic correlation of rainshelter plants

	Pollen viability	Fruit set per cent	No. of fruits per plant	Average fruit weight	Yield per plant
Pollen viability	1.00	0.350**	0.584**	0.524**	0.546**
Fruit set per cent		1.00	0.510**	0.909**	0.730**
Number of fruits per plant			1.00	0.794**	0.893**
Average fruit weight				1.00	0.921**
Yield per plant					1.00

(r=0.909**). Even though the genotypic peculiarities were the basis of dissimilarity among the genotypes, the full phenotypic expression depended on the prevailing microclimate of the growing structure, and the weather parameters could improve or worsen the phenotypic expression (Jindal and Khan, 2015). The genotypic correlation of pollen viability, fruit set per cent, number of fruits per plant and average fruit weight with yield in tomato were also documented by previous workers namely Kumar et al. (2014), Wali and Kabura (2014), Jaffin (2016), Ashish et al. (2017), Paupiere et al. (2017), and Tolessa and Heuvelink (2018).

Selection index

The correlation analysis of the investigation hinted the significance of pollen viability, fruit set per cent, number of fruits per plant and average fruit weight on yield for the selection of hotset genotypes for better fruit setting in the tropical climate during summer months. Selection index was constructed to identify suitable genotypes for further breeding experiments, following simultaneous selection model considering four characters viz.pollen viability, fruit set per cent, number of fruits per plant and average fruit weight (Table 6 and Table 7). Among the polyhouse plants the genotype EC-620410 with index 2993.5 was in the first position, followed by EC-620406 with index 2983.7, and followed by EC-620401 with index 2805.1. Among the rainshelter plants genotype EC-620401 with index 1937.5was in the first rank, followed by EC-620406 with index 1930.6, and followed by EC-620410 with index 1898.2. Under polyhouse the genotypes EC-620410 (2993.5), EC-620406 (2983.7), EC-620401 (2805.1), EC-164263 (2775.9), EC-620417 (2743.1), EC-620387 (2685.3), EC-631369 (2601.5), EC-620389 (2576.0), EC-538153 (2552.9) and EC-631379 (2547.4) secured top ten ranks according to the index. Inside rainshelter the genotypes EC-620401 (1937.5), EC-620406 (1930.6), EC-620410 (1898.2), EC-165690 (1799.9), EC-165395 (1796.2), EC-538153 (1730.8), EC-620387 (1724.7), EC-620395 (1693.3), EC-164263 (1661.2) and EC-620417 (1636.1) secured top ten ranks according to the index. The seven genotypes EC-164263, EC-538153, EC-620387, EC-620401, EC-620406, EC-620410 and EC-620417 secured ranks in the top ten in both the growing systems indicating the heat tolerance with satisfactory levels yield irrespective of the growing system. Thus they could be considered as hotset high yielding genotypes among the thirty five screened genotypes with potential to be used in further breeding experiments. The selection of genotypes based on the construction of selection index was also proposed by Sherpa et al. (2014), Gosh et al. (2018), and Ruggieri et al. (2019).

High day and night temperature are known to cause drastic reduction in the flowering and fruit setting

Table 6. Selection index for polyhouse plants

Genotypes	Means				Index I	Rank according to index
	Pollen viability (%)	Fruit set per cent (%)	Number of fruits per plant (number)	Average fruit weight (g)		
EC-620410	56.1	61.3	18.4	86.3	2993.5	1
EC-620406	55.1	60.5	19.9	85.8	2983.7	2
EC-620401	54.4	58.2	18.3	75.5	2805.1	3
EC-164263	54.8	62.4	18	67.7	2775.9	4
EC-620417	51.9	58.4	17.2	75.2	2743.1	5
EC-620387	56.1	59.9	10.6	70.8	2685.3	6
EC-631369	52.2	55.6	17.1	65.1	2601.5	7
EC-620389	55.5	53.5	14.0	64.3	2576.0	8
EC-538153	56.2	48.5	11.4	70.6	2552.9	9
EC-631379	51.5	55.4	11.6	69.4	2547.4	10
EC-620429	48.3	50.6	15.5	68.6	2482.3	11
Arka Abha	48.7	54.6	15.6	62.1	2471.0	12
Akshaya	48.4	56.2	17.4	57.3	2461.8	13
Anagha	47.0	54.4	13.2	67.2	2456.4	14
EC-620382	49.1	42.7	18.0	65.2	2398.4	15
EC-620378	49.8	52.6	12.1	54.2	2324.4	16
EC-620395	42.0	54.7	13.9	61.2	2317.6	17
Arka Saurabh	47.7	48.7	13.5	58.7	2308.7	18
Arka Alok	51.1	40.5	13.8	56.0	2240.1	19
EC-164563	46.6	44.7	15.5	52.4	2201.3	20
EC-620427	44.2	39.6	13.5	64.1	2190.3	21
EC-160885	51.3	46.3	10.3	41.6	2105.9	22
EC-165690	52.2	52.6	14.1	26.8	2100.0	23
EC-164670	44.9	50.5	14.5	39.8	2092.2	24
Pusa Ruby	44.0	50.5	15.1	38.2	2068.2	25
EC-521067 B	43.6	46.8	16.7	40.0	2058.9	26
EC-249514	44.4	44.7	13.4	45.2	2051.4	27
EC-157568	48.6	50.8	12.5	32.1	2046.3	28
EC-165395	46.6	58.6	13.2	23.4	2026.1	29
EC-165700	53.3	45.4	23.2	8.1	1966.9	30
EC-163605	48.3	34.7	13.4	39.9	1935.8	31
EC-145057	41.9	49.2	10	34.4	1893.7	32
EC-620376	53.3	43.6	19.6	8.4	1891.1	33
EC-151568	44.6	39.5	11.7	37.5	1878.7	34
EC-528368	46.0	39.3	19.8	8.0	1706.5	35

Index I =(Pollen viability × 17.65342)+(Fruit set per cent ×12.67458)+(No of fruits / plant ×15.62156)+(Avg fruit wt ×10.87764)

of tomato. The failure of fertilization after exposure to high temperature stress is mainly attributed to decrease in the pollen viability, and this problem is severe in tropics. High temperature is also associated with lower levels of soluble sugars in the developing pollen grains and anthers. Though it depends on the genotype, different genotypes respond differently to growing conditions. So it is essential to consider hotset traits, yield, growing conditions and weather parameters to select a hotset genotype. During the last decade, the use of rainshelters has steadily increased since they offer many environmental and economic benefits in the tropics. They have special importance during the rainy season. They are also important in warm sunny days where they can reduce the light intensity and effective heat during the day time. The microclimate of rainshelter has positively influenced the morpho-phenological development of hotset genotypes in summer. The study revealed the suitability of rainshelter for proper fruit setting and yield in tomato during the summer months. The correlation segment of the study elucidated how the change in each variable might affect the final yield

Table 7. Selection index for rainshelter plants

Genotypes	Means				Index I	Rank according to index
	Pollen viability (%)	Fruit set per cent (%)	Number of fruits per plant (No.s)	Average fruit weight (g)		
EC-620401	63.2	66.5	24.8	93.6	1937.5	1
EC-620406	64.3	66.4	23.1	94.2	1930.6	2
EC-620410	64.4	64.4	22.4	92.4	1898.2	3
EC-165690	62.2	64.4	67.0	28.4	1799.9	4
EC-165395	66.7	67.9	65.6	25.1	1796.2	5
EC-538153	61.8	58.6	19.3	83.3	1730.8	6
EC-620387	65.6	59.9	11.3	89.3	1724.7	7
EC-620395	48.4	64.4	17.5	90.2	1693.3	8
EC-164263	59.1	61.5	22.4	73.5	1661.2	9
EC-620417	60.1	61.6	20.6	72.4	1636.1	10
EC-631369	62.0	59.8	20.9	70.8	1632.5	11
EC-631379	60.8	64.3	16.1	71.9	1589.9	12
EC-620389	59.8	58.5	17.9	70.2	1568.3	13
EC-620427	55.1	59.4	17.7	73.2	1562.5	14
Arka Abha	53.8	56.3	19.1	72.0	1547.6	15
EC-620429	54.6	51.3	17.4	71.9	1515.1	16
Akshaya	55.9	61.4	19.8	64.4	1514.3	17
EC-620382	54.1	42.7	24.0	65.4	1499.9	18
Arka Alok	54.9	48.4	17.4	69.0	1479.1	19
Arka Saurabh	54.6	56.5	14.4	69.1	1467.7	20
EC-620378	55.1	57.5	20.8	58.5	1449.2	21
Anagha	47.1	54.4	15.5	71.3	1438.5	22
EC-164563	54.4	46.6	19.6	58.0	1387.7	23
EC-620376	63.2	54.4	46.9	10.9	1353.0	24
EC-164670	51.7	55.3	23.1	46.5	1325.6	25
EC-163605	55.0	66.4	17.6	45.9	1314.0	26
EC-249514	49.3	58.5	15.3	55.3	1308.5	27
EC-528368	62.0	39.3	44.2	11.2	1263.1	28
EC-521067 B	48.6	50.7	19.1	48.7	1258.8	29
EC-165700	60.6	47.6	39.6	12.2	1233.1	30
EC-157568	50.4	62.5	16.0	37.6	1164.0	31
Pusa Ruby	51.7	53.5	15.2	38.2	1140.0	32
EC-145057	45.5	57.5	20.0	35.5	1138.4	33
EC-160885	54.4	39.7	12.1	44.4	1137.7	34
EC-151568	47.8	43.3	14.0	38.5	1064.2	35

Index I =(Pollen viability × 7.668003)+(Fruit set per cent ×3.333322)+(No of fruits / plant ×12.35267)+(Avg fruit wt ×9.881481)

under the prevailing weather conditions of Kerala. The higher yield from rainshelter was a cumulative effect of high pollen viability, high fruit set per cent, high number of fruits per plant, high average fruit weight and increased retention of matured fruits on the plant which were all the practical outcomes associated with the favourable microclimate of the structure. The less cost associated with rainshelter could also give an additional advantage to the growers. The selection indices had identified seven hotset genotypes *viz*. EC-164263, EC-538153, EC-620387, EC-620401, EC-620406, EC-620410 and EC-620417, for further hybridization programme aimed at evolving hotset genotypes for the summer months of tropics. Evaluation of putative high temperature tolerant tomato genotypes for their response to high temperature field conditions would be helpful for the selection of high temperature-set lines. They might serve as a genetic source for incorporation in a breeding programme.

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