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Performance of Some Tomato (*Solanum lycopersicum* L.) Genotypes in Summer and Winter Seasons

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Abstract

An experiment was conducted at the Vegetable Research Field of Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur during October 2006 to March 2007 and May to September 2007 to evaluate the performance of tomato (*Solanum lycopersicum*) genotypes in summer and winter seasons. Early flowering was observed in summer compared to winter. Pollen viability decreased greatly during summer ranging from 30.44 % in TMS 003 to 86.08 % in C 11 compared to that in winter (70.33 % in C 61 to 100.00 % in VRT 002). Fruit set (%) markedly decreased in summer, which ranged from 4.69 % in TMS 017 to 39.15 % in C 51 while it ranged from and 49.00 % in TMS 008 to 90.01 % in HT 017 during winter. During summer, fruit set (%) exhibited positive significant and correlation with viable pollen grains (%). Yield per plant ranged from 1224 g in C 61 to 2670 g in VRT 003 and 37 g in TMS 015 to 94 g in C 11 in winter. The genotypes HT 019, C 11, C 21, C 41, C 51, HT 016 and HT 017 exhibited a considerable heat tolerance in relation to fruit setting ability.

Keywords: Tomato, heat tolerance, pollen viability

1. Introduction

Production of tomato (*Solanum lycopersicum* L.) in Bangladesh is huge in winter mainly from December to February and less in early and late winter months, but not in summer. Thus, the production of tomato in Bangladesh is confined only in the winter season. There are many varieties, such as Ratan and Roma VF are exclusively grown in winter. All these varieties are heat sensitive and usually fail to set fruit under high temperature. Because of high price and demand of tomato in summer, the need for suitable variety summer has long been demanded. The optimum day/night temperatures for fruit set in tomato is in the range of 26-32^{o}C/15-20^{0} C (Kuo *et al.,* 1979). However, there is usually genotypic variation in their fruit setting ability at high temperature (Charles and Harris, 1972). Because of favourable growing conditions and high demand, we have many varieties for winter and introduced from abroad. But, limited efforts have been given so far to overcome the high temperature barrier preventing fruit set in summer and rainy seasons. Moreover, demand has been created among farmers for summer variety.

BARI has been developed some heat tolerant open pollinated (OP) and F_1 Hybrid tomato varieties such as BARI Tomato-4, BARI Tomato-5, BARI Tomato-10 (Anupama), BARI Tomato-13, BARI Hybrid Tomato-3 and BARI Hybrid Tomato-4 (BARI, 2011). But these varieties are not enough to meet up the existing demand. However, limited research was conducted to improve yield and quality of tomato during summer in Bangladesh. To develop cultivars for hot summer, selection of genotypes which are capable of setting fruits under heat stress is needed.

There are many factors responsible for fruit setting process which are needed to be explored under high temperature stress. Comparative performances of the genotypes under normal and high temperature conditions are also needed for better understanding of the reaction of individual component factor of pollen viability, fruit setting and yield attributing parameters aiming to select suitable heat tolerant genotypes. Therefore, considering the present need, the study was under taken to compare genotypic differences in respect of different yield contributing characters during winter and summer seasons for selecting superior heat tolerant genotypes of tomatoes suitable for summer season.

2. Materials and Methods

The experiment was conducted at the Vegetable Research Field of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during October 2006 to March 2007 and May to September 2007. The location of the experiment was at 24 ^{0}N latitude, 92.25 ^{0}E longitude and 8.4 metre elevation from the sea level (Anon., 1995). It was situated in the sub-tropical climatic zone, characterized by heavy rainfall during the month of May to August and scanty rainfall during the rest of the year. Data on temperature and relative humidity during the study period were recorded and were presented in Table 5. Seeds of twenty heat tolerant tomato genotypes as selected on the basis of literatures were collected from Olericulture Division, HRC, Bangladesh Agricultural Research Institute were used as plant materials.

Seeds were sown and seedlings were grown both in winter and summer seasons. For winter and summer seasons seeds were sown on 27 October 2006 and 08 May, 2007, respectively. The seedlings were transplanted in the main experimental field at 35 days after sowing during winter and at 25 days during summer. Plants were given support by bamboo sticks in both seasons.

Winter crops were grown in open field and the summer crops were grown under transparent polytunnel. The polytunnels were 2.3 meter wide. Each polytunnel contained two 1.0 meter wide bed, with 30 cm drain in-between. The experiment was laid out in randomized complete block design (RCBD) with three replications both in summer and winter. The unit plot size was 3.2 m x 1.0 m and the plants were spaced 40x60 cm on beds. The layout for winter crop was also same but without polytunnel. Chemical fertilizers @ 550 kg urea, 450 kg TSP, 250 kg MoP, 120 kg Zypsum, 2 kg Boron and 10 metric ton cow dung per hectare were applied. Half of the cow dung and the entire quantity of TSP were applied during final land preparation. The pits were prepared one week before transplanting seedlings. The remaining cow dung and $^1/_3$ of MoP were applied in pits during prepared. Top-dressing was done in 3 equal installments at 10, 25 and 40 days after transplanting to apply the entire urea and rest 2/3 of MoP. Weeding and mulching were done followed by top-dressing and irrigation at 15 days interval.

Data on days to 50% flowering, flowers per cluster, viable pollen, fruit set (%), fruits per plant (number), TSS content, fruit weight (g), fruit yield per plant (g), fruit length (cm), fruit diameter (cm), branches per plant, plant height (cm), seeds per fruit and 1000 seeds weight were recorded. The recorded data on different characters were analyzed statistically using MSTAT-C programme where means were compared by DMRT to find out the variation among the different genotypes.

3. Results and Discussion

3.1. Days to 50% flowering

Significant variation was observed among the genotypes in respect of days to 50% flowering in both seasons. More days were required for flowering by all the genotypes during summer season compared to that in winter, indicating delayed flower formation under summer seasons condition (Table 1). In summer, 43.33 and 71.3 days were required for 50 % flowering, respectively for C 51 and VRT 001 which reduced to 38.33 and 55.00 days in winter. Kuo *et al*., (1979) also reported that flower formation is influenced by high temperature stress; which is consistent to the present study.

3.2. Flowers per cluster

Marked reduction in flower number per cluster were observed in all the genotypes in summer compared to winter except C 11, VRT, TMS 005, TMS 008, TMS o13 and TMS o17, which varied from 4.18 to 9.92 in summer and 5.09 to 11.09 in winter (Table 1). Charles and Harris (1972) reported decrease of flower production with increased temperature.

3.3. Viable pollen (%)

Seasonal variation greatly influenced the viability of pollen grains in all the genotypes. The differences regarding viable pollens during winter and summer are presented in Table 1 and Figure 1. In summer, pollen viability reduced greatly irrespective of genotypes and the maximum viability of the pollen grains was observed in C 11 (86.08 %) followed by HT 019 (82.47 %), C 41 (77.40 %), HT 017 (76.40 %) and C 21 (74.40 %) and the minimum was recorded in TMS 003 (30.44 %). The pollen viability was sharply increased in all the genotypes with a significant manner during winter under optimum temperature ranging from 70.33 % in C 61 to 100.00 % in VRT 002. Bodo (1991) mentioned decreased viability of pollen grains of potato under high temperature compared to optimum temperature. Our result confirms the reported findings.

3.4. Fruit set (%)

Wide **v**ariation was observed among the genotypes in reflect of number of fruit set in both the seasons. Marked increase in fruit set for all the genotypes was observed during winter ranging from 49.00 % in TMS 008 to 90.01 % in HT 017 whereas the range was far below during summer, which was 4.69 % in TMS 017 to 39.15 % in C 51 (Table 1).

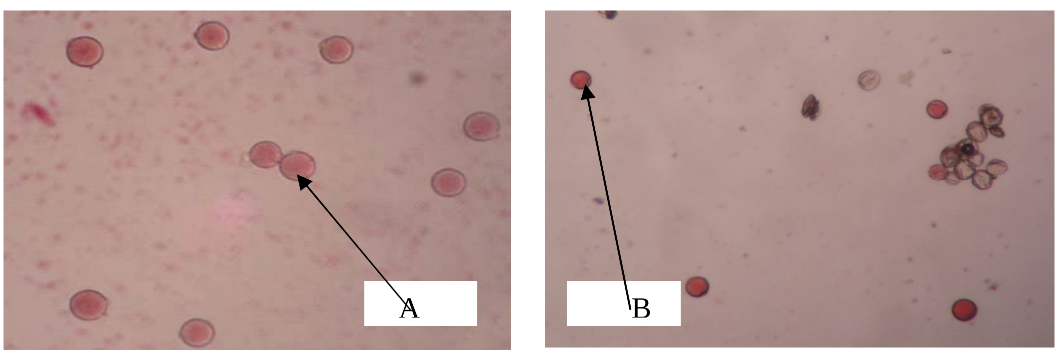

Figure. 1. Pollen grains: **A**. More viable pollens during winter; **B**. Less viable pollens during summer

Table 1. Yield contributing parameters of tomato genotypes during winter and summer seasons

Genotypes	Days to 50 % flowering		No. of flowers/cluster		No. of viable pollens (%)		No. of fruit set (%)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
C 11	44.7 e-h	56.3 d	7.74 e-h	8.11 b-d	89.66 a-d	86.08 a	81.33 a-d	29.46 b
C 21	42.3 g-i	48.3 fg	8.62 c-d	7.40 b-g	92.67 a-c	74.40 ab	83.33 a-c	37.47 a
C 41	41.3 hi	52.7 d-f	8.95 cd	7.61 b-f	95.00 a-c	77.40 ab	75.67 b-e	27.05 bc
C 51	38.3 i	43.3 h	6.03 jk	5.41 h-k	98.00 ab	68.20 bc	81.67 a-d	39.15 a
C 61	42.3 g-i	55.3 d-e	7.87 e-h	6.01 f-j	70.33 e	53.89 d-f	72.00 d-f	21.33 cd
C 71	43.7 f-i	50.7 ef	9.43 bc	7.97 b-e	90.33 a-d	46.09 f	74.67 b-e	20.63 cd
HT 016	44.7 e-h	52.0 d-f	11.09 a	9.92 a	97.33 a-c	68.40 bc	84.67 ab	25.30 bc
HT 017	43.7 f-i	48.0 fg	9.30 bc	8.75 ab	88.00 b-d	76.40 ab	90.01 a	24.66 bc
HT 019	39.0 i	46.0 gh	10.06 b	8.34 a-c	99.00 ab	82.47 a	81.33 a-d	29.27 b
VRT 001	55.0 a	71.3 a	6.08 jk	4.55 jk	94.66 a-c	51.40d-e	77.00 b-e	12.63 e-g
VRT 002	49.7 a-e	67.3 a-c	7.78 e-h	8.52 a-c	100.00 a	56.00c-f	70.00ef	9.17 f-h
VRT 003	49.7 a-e	66.0 bc	8.17 d-g	5.71 g- k	94.67 a-c	59.25 c-f	74.33 b-e	13.58 ef
TMS 003	46.3 d-h	68.0 ab	5.67 k-l	5.20 i-k	94.33 a-c	30.44 g	78.00 b-e	6.01 h
TMS 005	47.7 c-g	53.3 de	7.14 h-i	8.37 a-c	86.33 cd	50.55 ef	56.00 gh	5.48 h
TMS 008	54.3 ab	68.3 ab	5.09 l	7.01 c-h	94.67 a-c	60.80c-e	49.00 h	13.89 ef
TMS 011	52.3 a-c	68.3 ab	7.30 g-i	6.52 d-i	97.33 a-c	58.16c-f	63.67 fg	5.47 h
TMS 013	49.7 a-e	55.0 de	7.43 f-i	7.59 b-f	95.00 a-c	48.12ef	59.00 g	5.99 gh
TMS 015	47.0 c-g	67.7 ab	6.59 ij	4.18 k	81.33 d	46.30 f	78.00 b-e	10.67 f-h
TMS 017	48.0 c-f	69.0 ab	5.59 kl	6.98 c-h	92.00 a-c	51.10d-f	78.00 b-e	4.69 h
BARI 6	50.7 a-d	63.0 c	8.37 d-f	6.29 e-i	93.33 a-c	64.91b-d	74.00 c-e	17.87 de
CV (%)	6.08	4.37	6.63	12.78	6.17	12.20	10.19	7.19
Level of significance	**	**	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1 % level of probability by DMRT

The genotypes C 51, C 21, C 11, HT 019 and C 41 had high number of fruit set during summer (39.15, 37.47, 29.46, 29.27 and 27.05 %, respectively) among the genotypes (Table 1). In winter, the highest fruit set (90.01 %) was observed in the genotype HT 017 closely followed by HT 016 (84.67 %), C 21 (83.33 %), and C 51 (81.67 %), while the lowest (49.00 %) was observed in the genotype TMS 008. These findings in agreement with the results reported by Hanna and Hernandez (1979), who reported that fruit set in a particular genotype viz., L 401 dropped from 78.1 % in spring to as low as 1.2 % in summer.

In these study 50 % genotypes viz., C 51, C 21, C 11, HT 019, C 41, HT 016, HT 017, C 61, C 71 and BARI 6 provided more than 17 % fruit set. Remaining 50 % genotypes produced less than 14 % fruit as they flowered. Out of them, only 4 lines such as TMS 008, VRT 003, TMS 003 and TMS 005 ranged from 13.89 % to 10.67 % and the rest genotypes set fruit ranging from 4.69 % to 9.17 %, in these genotypes. Ahmad (2002) also observed varying level of fruit set in both the seasons.

3.5. Fruits per plant

The genotypes differed significantly with respect to number of fruits per plant in both the seasons. In winter, the number of fruit per plant was higher (16.9-89.3 per plant) and it was only 1.13-30.2 per plant in summer (Table 2), whereas in winter it was 16.93 to 89.33.

Table 2. Performances of tomato genotypes during winter and summer seasons for fruits per plant and TSS

Genotype	Number of fruits / plant		TSS (%)	
	Winter	Summer	Winter	Summer
C 11	39.33 cd	23.42 b	4.89 de	4.43 a-c
C 21	46.93 c	21.13bc	4.98 c-e	4.28 b-d
C 41	47.20 c	18.20 cd	4.81 e	4.23 b-e
C 51	36.00 de	19.13 cd	5.28 bc	4.08 c-f
C 61	35.13 d-f	15.33 d	5.08 c-e	3.76 fg
C 71	32.73 d-g	10.95 e	4.93 c-e	4.37 bc
HT 016	81.67 b	30.20 a	4.40 f	4.23 b-e
HT 017	89.33 a	24.80 b	4.97 c-e	4.61 ab
HT 019	43.72 c	21.77 bc	5.01 c-e	4.53 ab
VRT 001	26.27 g-i	1.53 f	4.95 c-e	3.89 d-g
VRT 002	28.67 e-i	2.80 f	4.83 e	4.11 c-f
VRT 003	30.67 e-h	2.60 f	5.21 b-d	4.24 b-e
TMS 003	28.80 e-i	1.40 f	5.07 c-e	3.93 d-g
TMS 005	26.87 f-i	1.67 f	5.66 a	3.87 e-g
TMS 008	16.93 j	3.03 f	4.37 f	3.97 d-g
TMS 011	21.93 ij	1.87 f	5.03 c-e	3.89 d-g
TMS 013	24.00 h-j	2.00 f	5.47 ab	3.39 h
TMS 015	30.73 e-h	1.13 f	5.13 c-e	3.72 f-h
TMS 017	25.20 g-i	1.93 f	5.67 a	3.63 gh
BARI 6	25.07 g-i	5.47 f	5.52 ab	4.77 a
CV (%)	12.01	22.11	3.66	5.02
Level of significance	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1 % level of probability by DMRT

The maximum fruits were recorded from the genotype HT 016 (30.20) followed by HT 017 (24.80), C 11 (23.42), HT 019 (21.77), C 21 (21.13), C 51 (19.13) and C 41 (18.20) showing high degree of heat tolerance during summer. These genotypes also produced considerable number of fruits/plant during winter. On the other hand though the number of fruits /plant during summer was very low in the genotypes TMS 013, TMS 013, VRT 001, VRT 002, VRT 003, TMS 005, TMS 003, TMS 015 and TMS 008, they produced larger number of fruits per plant during winter. Therefore, these genotypes could be treated as moderate to highly sensitive to high temperature. These results are also inconformity with the findings of Ahmad (2002).

3.6. Total soluble solids (%)

Seasonal variations significantly influenced the total soluble solids (TSS) content of fruits in all genotypes. Higher TSS % was recorded in winter compared to summer season. The results from winter season showed the variation from 4.37 % in TMS 008 to 5.67 % in TMS 017, while it was 3.39 % in TMS 013 to 4.77 % in BARI Tomato-6 during summer (Table 2). Ahmad (2002) also found higher TSS (%) during winter compared to summer.

3.7. Fruit weight (g)

Significant variations were exhibited in fruit weight in both the seasons (Table 3). In winter, larger fruits were produced by all the genotypes compared to summer. Went (1957) obtained three times larger fruits at 14 ^{0}C night temperature compared to 26 ^{0}C which are in consonance with the findings of the present investigation. The result obtained in the study showed that weight per fruit ranged from 11.46 to 98.50 g in summer, while it varied from 20.00 to 148.3 g in winter. The heaviest fruits were recorded from TMS 008 (98.50 g) followed by 71.58 g in VRT 001, 63.42 g in VRT 003. The genotype TMS 008 and HT 016 also produced the heaviest (148.3 g) and smallest (20.00 g) fruit, respectively during winter.

3.8. Fruit yield / plant (g)

As yield per plant was attributed with fruit weight, it varied significantly in both the seasons. In summer, the maximum (940.8 g) yield was recorded from the genotype C 11 followed by C 51 (738.5 g), C 21 (717 g), C 41 (692.7 g) and HT 019 (619.0 g) showing higher degree of heat tolerance among the genotypes (Table 3). On the other hand genotypes TMS 005, TMS 013, TMS 017 and TMS 011 produced lower fruit yield per plant indicating high degree of heat sensitivity (Table 5). The situation was reverse during winter. The maximum (2670 g) fruit yield per plant was recorded from the genotype VRT 003 followed by VRT 002 (2545 g) and TMS 008 (2513 g) (Table 3). These heat sensitive lines were found to produce 168.5 g, 129.4 g and 313.6 g fruits per plant, respectively during summer showing moderate degree of heat sensitivity (Table 3). Baki (1991) reported a yield of 410, 173 and 11 g under high temperature conditions (39^{0}C day/28^{0}C night) depending on the level of heat tolerance of the genotypes.

3.9. Fruit length (cm)

Fruit length varied significantly irrespective of season but the increased length was observed in winter and it was much pronounced in heat sensitive genotypes compared to heat tolerant ones. In winter it varied from 3.24 to 6.09 cm and the longest fruit was found in the genotype VRT 001 followed by VRT 003 (5.62 cm) and TMS 008 (5.47 cm) while in summer the height fruit length (5.03 cm) was recorded from VRT 003 and the lowest (1.47 cm) was in HT 016 (Table 3). Sawhney and Polowick (1985) mentioned reduced fruit length under high temperature.

3.10. Fruit diameter (cm)

Trend in fruit diameter was almost similar as in fruit length. The widest (6.80 cm) and narrowest (2.99 cm) fruits were recorded from TMS 008 and HT 016, respectively in winter while during summer the widest (4.14 cm) fruit was found in VRT 001 followed by 4.08 cm in TMS 008, and the narrowest (1.33 cm) fruit was recorded in HT 016 (Table 3).

Table 3. Yield attributing performances of tomato genotypes during winter and summer seasons

Genotype	Fruit weight (g)		Fruit yield / plant (g)		Fruit length (cm)		Fruit Diameter (cm)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
C 11	49.00 fg	40.08 e-h	1929 c-g	940.8 a	4.28 f	3.07 g-i	4.27 fg	2.63 ef
C 21	37.00 hi	33.58 h-k	1725 d-h	717.0 b	4.03 f-h	2.86 i	3.95 f-h	2.81 de
C 41	35.00 i	37.33 f-j	1659 e-h	692.7 b	3.83 gh	2.05 j	3.86 gh	2.46ef
C 51	59.50 ef	38.45 e-i	2139 a-f	738.5 b	4.00 f-h	1.97 jk	4.94 e	2.86 c-e
C 61	34.67 e	28.34h-l	1224 h	438.6 de	4.14 fg	2.92 hi	3.97 f-h	2.60 ef
C 71	57.67 ef	39.91 e-h	1878 c-g	436.0 de	5.23 cd	4.65 ab	4.39 f	2.88 b-e
HT 016	20.00 j	11.46 m	1627 f-h	345.8 d-f	3.32 i	1.47 k	2.99 i	1.33 g
HT 017	22.33 j	19.30 lm	1985 b-g	483.4 cd	3.24 i	2.14 j	3.24 i	2.03 f
HT 019	33.33 i	32.23 h-l	1456 gh	619.0 bc	3.97 f-h	2.91 hi	3.70 h	2.46 ef
VRT 001	89.26 c	71.58 b	2358 a-c	109.4 gh	6.09 a	4.33 bc	5.42 cd	4.14 a
VRT 002	88.67 cd	48.28 d-g	2545 a	129.4 gh	5.40 bc	3.77 d-f	5.46 cd	2.57 ef
VRT 003	87.33 cd	63.42 bc	2670 a	168.5 f-h	5.62 b	5.03 a	5.14 de	2.78 de
TMS 003	78.67 d	55.83 cd	2265 a-c	95.5 h	4.76 e	3.47 e-h	5.19 c-e	3.55 ab
TMS 005	45.67 gh	24.75 j-l	1252 h	42.2 h	3.69 h	2.23 j	4.33 f	2.58 ef
TMS 008	148.33 a	98.50 a	2513 ab	313.6 d-f	5.47 bc	4.22 b-d	6.80 a	4.08 a
TMS 011	99.33 b	50.18 d-f	2183 a-e	92.25 h	4.98 de	3.30 f-i	5.99 b	3.50 abc
TMS 013	51.00 c-g	21.71 k-m	1241 h	42.95 h	3.69 h	1.82 jk	4.34 f	2.34 ef
TMS 015	50.24 c-g	35.50 g-j	1546 gh	37.3 h	5.17 cd	3.98 c-e	4.25 fg	2.93 b-e
TMS 017	88.33 c-d	25.33 i-l	2230 a-d	49.2 h	5.37 bc	2.78 i	5.18 c-e	2.38 ef
BARI 6	92.67 bc	51.44 c-e	2318 a-c	282.3 e-g	5.01 de	3.58 e-g	5.58 c	3.36 b-d
CV (%)	8.81	16.93	4.56	29.64	4.17	9.93	5.00	13.3
Level of significance	**	**	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1 % level of probability by DMRT.

Table 4. Performance of tomato genotypes during winter and summer seasons for primary branches per plant, plant height, seed /fruit and 1000 seed weight

Genotype	primary branches/plant		Plant height (cm)		Seeds/fruit		1000 seed weight (g)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
C 11	3.55 ab	4.60 a-e	83.33 ef	140.5 e-g	46.90 h	19.18 de	2.44 e-h	2.28 de
C 21	3.67 a	4.77 a-e	68.40 g	127.9 fg	51.30 gh	24.74 bc	2.76 cd	2.17 e-g
C 41	3.42 a-c	4.25 b-e	96.53 b-e	151.6 c-g	31.30 j	15.96 ef	2.80 bc	2.68 b
C 51	3.47 ab	4.27 b-e	81.53 f	151.8 c-g	84.30 d	22.67 b-d	3.21 a	3.02 a
C 61	3.53ab	5.07 a-e	90.67 b-f	170.1 b-e	40.10 i	11.05 gh	3.16 a	2.93 a
C 71	2.47 de	4.18 c-e	87.20 c-f	158.9 c-f	60.60 f	7.17 h-j	2.43 e-h	2.45 cd
HT 016	3.20 a-e	4.88 a-e	102.60 b	203.5 ab	26.00 j	4.50 ij	2.40 f-h	2.12 e-g
HT 017	3.40 a-c	4.80 a-e	101.67 b	198.9 ab	31.20 j	21.56 cd	2.82 bc	2.24 ef
HT 019	3.53 ab	4.35 b-e	69.53 g	145.0 d-g	63.20 f	14.27 fg	2.59 de	2.06 fg
VRT 001	3.27 a-d	3.95 e	85.87 d-f	147.4 c-g	71.20 e	11.67 f-h	2.86 bc	2.05 g
VRT 002	3.02 a-e	4.80 a-e	91.07 b-f	153.6 c-g	80.13 d	13.98fg	2.60 de	2.60 bc
VRT 003	2.80 b-e	5.07 a-e	96.33 b-e	181.6 bc	72.30 e	10.74 gh	2.57 ef	2.48 c
TMS 003	3.20 a-e	4.82 a-e	100.47 bc	181.2 bc	100.80 b	26.97 b	2.80 bc	1.60 h
TMS 005	2.40 e	5.53 a	97.93 b-d	176.3b-d	107.70 a	14.90 e-g	2.29 h	2.30 de
TMS 008	2.80 b-e	5.28 a-c	102.47 b	176.7 b-d	106.30 a	49.39 a	2.30 h	2.23 e-g
TMS 011	3.33 a-c	5.33 ab	149.8 a	218.3 a	53.30 g	9.00 hi	2.50 e-g	2.24 ef
TMS 013	3.13 a-e	5.20 a-d	87.73 c-f	172.2 b-e	90.20 c	11.30 f-h	2.35 gh	2.23 ef
TMS 015	2.82 b-e	5.13 a-d	92.44 b-f	121.3 g	28.50 j	5.66 ij	2.89 bc	2.28 de
TMS 017	3.27 a-d	4.72	84.60 d-f	145.6 d-g	64.80 f	4.02 j	2.96 b	1.53 h
BARI 6	2.63 c-e	4.13 de	146.20 a	173.1 b-e	50.30 gh	8.39 h-j	3.28 a	2.67 b
CV (%)	13.23	12.13	7.49	10.9	5.25	8.60	3.72	4.26
Level of significance	**	**	**	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1 % level of probability by DMRT.

Table 5. Monthly mean temperature and relative humidity during the crop period

Year	Month	Temperature (^{0}C)		Relative humidity (%)	
		Maximum	Minimum	Average	Rainfall (mm)
2006	September	32.2	25.6	75.7	572.4
	October	32.7	24.3	68.4	33.6
	November	29.9	19.3	65.35	0.0
	December	27.40	14.3	55.55	0.0
2007	January	24.8	11.4	61.65	0.0
	February	27.2	15.9	64.35	76.6
	March	31.4	17.8	60.25	14.8
	May	34.70	25.40	67.30	191.60
	June	32.3	25.5	75.70	726.2
	July	31.6	25.70	80.45	687.80
	August	32.30	26.70	74.95	299.00
	September	32.00	26.40	75.50	145.80
	October	32.10	23.50	38.85	393.30
	November	29.40	19.5	37.30	63.0
	December	26.00	13.80	62.10	0.0
2008	January	24.60	13.40	64.75	91.40
	February	25.9	14.50	61.10	67.80
	March	31.10	20.70	65.20	20.00
	April	34.00	23.90	60.55	19.80
	May	33.80	24.30	64.30	312.40
	June	31.4	25.8	77.00	391.40
	July	31.01	26.1	79.8	440.20
	August	31.28	25.88	82.18	887.15
	September	32.32	25.8	77.90	871.95
	October	31.45	23.42	79.36	850.6

3.11. Primary branches / plant

Like other parameters, the genotypes differed significantly in both the season in respect of primary branches per plant (Table 4). All the genotypes produced higher number of primary branches in summer compared to those in winter. This might be due to taller plants at high temperature under polytunnel during summer. In summer primary branches per plant ranged from 3.95 in VRT 001 to 5.53 in TMS 005 while, in winter it ranged from 2.40 in TMS 005 to 3.67 in C 21.

3.12. Plant height (cm)

Wide variation among the genotypes was observed in respect of plant height in both the seasons, but increased plant height was found in summer (Table 4). The tallest plants 149.8 cm in winter and 218.3 cm in summer were recorded from the same genotype (TMS 008) but the shortest (68.40 cm) was recorded from C 21 in winter and 121.3 cm from TMS 015 in summer.

3.13. Seeds per fruit

Table 4 shows highly significant variations in number of seeds per fruit in both the seasons among the genotypes. Number of seeds per fruit was many folds higher during winter compared to that in summer in all the genotypes. This might be due to increased pollen viability during winter which facilitated the maximum pollen tube growth through the style into the ovary along with other favorable physiological factors for embryological process under optimum temperature (Table 5). In winter it ranged from 26.00 to 107.70 in the genotypes HT 016 and TMS 005, respectively while it varied from 4.02 to 49.39 in the genotypes TMS 017 and TMS 008, respectively. The results revealed from the present investigation are in agreement with the findings of Ahmad (2002).

3.14. 1000 seed weight (g)

All the genotypes varied significantly in respect of 1000 seed weight in both the seasons (Table 4) but it was higher during winter with few exceptions (C 71 and TMS 008) compared to that in summer. The ranges of 1000 seed weight were from 2.29 to 3.28 g during winter and it was 1.53 to 3.02 g during summer. Higher seed weight during winter might be due to increased synthesis of plant hormones along with other favourable factors for seed formation under optimum temperature.

4. Conclusions

From the above results it was revealed that wide ranges of variabilities were existed among the 20 genotypes in respect of tomato for yield and yield contributing characters. The genotypes also showed seasonal variations for all the parameters. In summer, the maximum (940.8 g) yield was recorded from the genotype C 11 followed by C 51 (738.5 g), C 21 (717 g), C 41 (692.7 g) and HT 019 (619.0 g) showing higher degree of heat tolerance among the genotypes. On the other hand, the genotypes TMS 005, TMS 013, TMS 017 and TMS 011 produced lower fruit yield per plant indicating high degree of heat sensitivity. The situation was reverse during winter.

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