J. Agric. Sci. Mansoura Univ., 29 (11): 6491 - 6506, 2004

GENETICAL STUDIES ON SOME TOMATO CULTIVARS UNDER HIGH TEMPERATURE CONDITION. I: INHERITANCE STUDIES OF SOME CHARACTERS IN TOMATO UNDER HIGH TEMPERATURE CONDITIONS.

Saleba, Faten, S.; M. H. Zaky and A.M. Hewedy
Veg. Res. Dept. Hort. Res. Inst., Cairo, Egypt.

ABSTRACT

This study was carried out during three successive summer seasons of 2002, 2003 and 2004 at Kaha Vegetable Research Station, Kalubia, Egypt. Seven tomato (*Lycopersicon esculentum* Mill.) cultivars were evaluated for heat tolerance and the ability of set fruits under field high- temperature conditions. The cultivars Cal Ace, Castle rock and Mobile were classified as heat-sensitive cultivars, while cultivars Peto 86, Chico III, Super Strain B and Tallalakhin were classified as heat-tolerant cultivars based on their pollen viability, fruit-setting ability, and yielding under high temperatures.

High temperature reduces pollen viability, fruit set percentage and increased stigma elongation, stigma coloration and unmarketable fruits, i.e. cracks, blossom-end rot and small mature fruits. Pollen viability percentage ranged from 41.43% to 50.2 % and 36.97 to 48.65 for heat-sensitive cultivars and 55.10% to 64.32% and 51.53 to 65.28% for heat-tolerant genotypes during 2002 and 2003 seasons respectively. Fruit set percentage at high temperatures ranged from 31.25% to 38.22 % and 37.30% to 40.00% in the heat-sensitive and from 48.47% to 79.00% and 53.42% to 82.92% in the heat-tolerant genotypes, respectively during the successive summer seasons.

Pollen viability and fruit set percentage, total yield and average fruit weight behaved as a quantitative characters and both environment and genetics were involved in the inheritance of this characters. Inheritance of pollen viability (%) under high temperature was governed by absence of dominance or partial dominance toward the lower percentage of pollen viability. While, partial dominance toward the high fruit set (%), over dominance of the high total yield and partial dominance toward the heavy fruit weight were responsible for the inheritance of percentage of fruit set, total yield and average fruit weight under high temperature respectively. Additive effect appeared to be important in the inheritance of the previous characters.

Narrow-sense heritability was high for total yield and average fruit weight under the heat stress of summer in Egypt. Heritability and genetic advance values showed that effective selection might be made for percentage of fruit set, total yield and average fruit weight. Pronounced positive heterosis was observed for fruit set percentage, total yield and average fruit weight, while negative heterosis was observed for pollen viability percentage.

INTRODUCTION

Tomato (*Lycopersicon esculentum Mill)* is one of the most popular vegetable crops in Egypt. However, there are serious problems associated with the summer season of tomato. High temperature is resulting drastic reduction in tomato fruit set (Abdalla and Verkerk, 1968; Rudich *et al* 1977; Dane *et al* 1991; Wessel-Beaver and Scott, 1992; Abdul-Baki and Stommel, 1995 and Lohar and Peat, 1998); yield (Abdul-Baki, 1991 and Wessel-Beaver and Scott, 1992) and fruit quality (Levy *et al* 1978 and Hanna and Hernandez, 1982). High temperature increased also the incidence of unmarketable fruits (Abdul-Baki, 1991).

Heat tolerance levels in the genotypes were established by determining percent fruit set at high temperatures. Abdul-Baki (1991) reported that fruit set was 30% and 52% for heat-sensitive and heat-tolerant cultivars, respectively. While, Abdul-Baki and Stommel (1995) reported that fruit set ranged from 41% to 84% and from 45% to 91% in the heat-sensitive and heat-tolerant genotypes, respectively.

Several factors contribute to reduction in tomato fruit set under high temperatures. These factors include reduction in pollen viability (Shelby *et al* 1978; Dane *et al* 1991 and Sato *et al* 2000), style elongation (Rudich *et al* 1977 and El Ahmadi and Stevens, 1979) and stigma browning (Levy *et al* 1978; El Ahmadi and Stevens, 1979; Dane *et al* 1991 and Lohar and Peat, 1998). At the same time Sugiyama *et al* (1966) found that low fruit setting when flower buds were exposed to high temperature of 40 °C before anthesis, mainly to reduction in the number of fertile pollen. Also Stevens and Rudich (1978) reported that development of tomato cultivars with improved fruit set under high temperatures would be valuable for tomato crop production in region where the temperature during part of the growing season reached above 35 °C or higher. The night temperature was the limited factor for tomato fruit set as reported by Schaible (1962) who mention that tomato fruit set was generally poor when night temperature exceeded 23 °C.

Wide genotypic variation among cultivars has been observed under high temperature as reported by Stoner and Otto (1975) who found that Chico III was heat tolerant cultivar's. Phookan *et al* (1997) reported that fruit set and viable pollen grains were varied with cultivars under high-temperature. Nassar *et al* (1982) found that Peto 86 and Cal Ace cultivars were the earliest and lowest early tomato yield respectively at summer planting in Egypt. He added that cv. Cal Ace produced the largest fruit. Dane *et al* (1991) reported that small- fruited cultivars were less affected by heat stress than larger-fruited cultivars. Lohar and Peat (1998) found that the anthesis was earlier in heat- tolerant cultivars than in heat-sensitive cultivars.

Inheritance of tomato fruit set under high temperature was governed by additive gene effects (Hanna and Hernandez 1982 and Dane *et al*, 1991); additive and non-additive genetic variances (Sherif and Hussein, 1992) and simple additive-dominance effects or epistatic component (Hanson *et al*, 2002). Heritabilities of fruit set under high temperatures were 0.31 and 0.21 as reported by Hanson *et al* (2002). Dane *et al* (1991) stated that under heat stress additive gene effects governed the pollen fertility.

Inheritance of tomato yield under high temperature was governed by additive gene effects (Sherif and Hussein, 1992 and Chadha *et al*, 2001) and non-additive gene effects (Roopa *et al,* 2001). Heritability and genetic advance were high for yield/plant as reported by Ghosh *et al* (1995) and Parvinder Singh *et al* (2002).

Inheritance of fruit weight under high temperature was governed by additive gene system effects (Sherif and Hussein, 1992); non- additive gene effect (Roopa *et al*, 2001) and partial dominance for the small over the high fruit weight (Abdel-Ati *et al*, 2000).

Narrow-sense heritability was high for fruit weight under the heat stress of late summer in Upper Egypt (Sherif and Hussein, 1992). Broad sense heritability was 84.9% for average fruit weight (Abdel-Ati *et al*, 2000).

The present study was undertaken to 1) evaluate some tomato cultivars for their response to heat tolerance under field conditions, to select the best heat-set genotypes as genetic sources for incorporation in a breeding program; 2) determine the inheritance of Pollen viability, fruit set, yielding ability and average fruit yield under high temperatures.

MATERIALS AND METHODS

This investigation was carried out at Kaha Vegetable Research Station, Kalubia, Egypt, during three successive summer seasons of 2002,2003 and 2004 through two parts as the following:

A- Evaluation of tomato genotypes for heat tolerance:

Seven tomato cultivars viz., Cal Ace; Castle rock, Peto 86 (Petoseed Company, USA); Chico III; Super Strain B (Castle Company); Mobile (U.S.A.) and Tallalakhin (Russia) were evaluated under open field during the 2002 and 2003 summer seasons for heat tolerance and the ability of fruits set (FS%) under high temperatures. In each year seeds were sown on April 8, and transplanting on May 12. A randomized complete block design with four replications and 25 plants per replication were used. Plant was spaced 35 cm apart within the row with 1 m wide. All cultural operation were similar to those practiced in commercial field production. The statistical analysis was done according to Stell and Torrie (1960). Data were recorded for the following characters:

1- Number of days to anthesis.
2- Pollen viability: anthers from six flowers per replication were collected at biweekly intervals and squashed in acetocarmine and at least 100 pollen grains per flower were used to determine the percent of pollen viability as recorded by Tsuchiya (1971).
3- Stigma elongation percentage: the stigma position was determined in relation to the antheridial cone.
4- Stigma coloration percentage.
5- Fruit set percentage: percent fruit set was determined by scoring flower counts on inflorescences present and fruit produced. A fruit was considered set when its diameter reached > or = 5 mm as described by Abdul-Baki, (1991).
6- yield: early yield (Kg/ plant) estimated as the weight of fruits harvested during the first 2 weeks of harvesting period. Total yield (Kg/ plant) measured as the weight of all fruits harvested at the red ripe stage. Number of fruits per plant was recorded from all harvesting fruits.
7- Average fruit weight (gm).
8- Unmarketable fruits: fruits defects such as cracks, blossom-end rot and small mature fruits were accounted from all harvesting fruits.

B- Inheritance of heat tolerance

Based on a previous evaluation trial during the summer season of 2002, four cultivars were selected to serve as parents, i.e. Cal Ace and Castle rock as heat-sensitive cultivars, while Super Strain B and Chico III as heat-tolerant cultivars, for made two crosses as following: Cal Ace x Super Strain B and Castle rock x Chico III.

In winter 2002 seeds of parents were sown under plastic house to get the previous crosses. In summer 2003 F_1 hybrid plants from each cross were sown and self-pollinated were done to produce F_2 population seeds. Each F_1 hybrid was crossed to both parents to produce Bc_1 (F_1 x P_1) and Bc_2 (F_1 x P_2). Self- pollination was also made for the parents to get parents selfed seeds. Moreover, the parents were crossed to produce more F_1 hybrid seeds.

Parents, F_1, F_2 and backcrosses to both parents were sown on April 15, 2004 and transplanted in field experiment on May 15, 2004. The experimental design was a complete randomized block design with three replications. Each replicate consisted of 15 plants for each non–segregation generation (P_1, P_2 and F_1) and consisted of 65, 20 and 20 plants for each segregation generation (F_2, Bc_1 and Bc_2) respectively. Drip irrigation system and fertigation were carried out according to the recommendations. The following characters were recorded on an individual plant basis of the six populations for each cross: Pollen viability (%); fruit set (%); average fruit weight (gm) and total yield (Kg/plant). Data were analyzed according to the following:

1- Nature of dominance: this is calculated from the relative potency of gene set (P) according to the formula given by Mather and Jinks (1982) as follow: $P = \{F_1 - MP\} / \{½ (P_2 - P_1\}$ where: F_1 = first generation mean, P_1 = mean of the smaller parent, P_2 = mean of the larger parent and MP = mid parent value = $½ (P_1 + P_2)$.

2- Scaling test I: Scaling test 1 provides information regarding absence or presence of gene interaction, was carried out according to Mather and Jinks (1982). The parameters A, B and C of epistatic deviation were calculated as follows: $A = 2\ B_1 - P_1 - F_1$ $\quad B = 2\ B_2 - P_2 - F_1$ $\quad C = 4\ F_2 - 2\ F_1 - P_1 - P_2$

$VA = 4\ VB_1 + VP_1 + VF_1$ $\quad VB = 4\ VB_2 + VP_2 + VF_1$

$VC = 16VF_2 + 4\ F_{1\,+}\ VP_1 + VP_2$

Where, V: variance; P_1, P_2, F_1, B_1, B_2 and F_2: means of parents1 and 2, first generation mean, backcrosses to parent 1 and 2 and second generation mean respectively.

Standard errors of A, B and C were obtained to test significant departures from zero. Significant deviations from zero indicate non- additive of gene effects.

3- Gene action: estimation of the type of gene effects (m, d and h) in the absence of non-allelic interaction was obtained using the relationships given by Jinks and Jones (1958).

4- Heterosis based on the mid parent was estimated according to the formula given by Mather and Jinks (1982) as follow: Heterosis $= \{(F_1 - MP) / MP\}$ x 100

Where: F_1 = the first hybrid generation, MP = mid parent

5- Heritability, in broad sense (h^2b) and in narrow sense heritability (h^2n) was estimating according to Sheppard (1973).
6- The expected genetic advance at 5% selection of F_2 intensity was computed by using formula suggested by Allard (1960).
7- Scaling test II: this is the ratio between the large variance of one parent to small variance of the other parent to check the response of interaction between genetic and environmental effects according to Sheppard (1973).

RESULT AND DISCUSSION

It is appeared from table (1) that maximum and minimum temperatures during flowering and fruit setting (June and July) were (≥ 35 °C) and (≥ 23 °C) respectively which, reduced the pollen viability and fruit set as recorded by Schaible (1962), Sugiyama *et al* (1966) and Stevens and Rudich (1978).

Table 1: Number of days for the minimum and maximum temperatures which affecting on flowering and fruit setting during the summer seasons.

Month	2002					2003					2004				
	Minimum temperatures		Maximum temperatures			Minimum temperatures		Maximum temperatures			Minimum temperatures		Maximum temperatures		
	23- 25 °C	≥ 25 °C	34-36 °C	36-38 °C	≥ 38 °C	23- 25 °C	≥ 25 °C	34-36 °C	36-38 °C	≥ 38 °C	23- 25 °C	≥ 25 °C	34-36 °C	36-38 °C	≥ 38 °C
April	-	-	2	1		-	-	1	1	2	-	-	1	-	-
May	-	-	5	2	2	-	-	9	3	2	1	-	9	1	1
June	10	-	9	12	2	-	1	5	1	2	2	-	11	1	5
July	18	11	11	-	5	7	-	13	1	-	19	-	18	7	1
August	17	2	10	14	7	14	-	23	1	-	10	-	19	5	-

* Source: Central Laboratory of Climate, Ministry of Agriculture, Dokki, Giza.

A- Evaluation of cultivars for heat tolerance:

1) Number of days to anthesis:

The number of days initiated in the inflorescences as shown in Table (2) was significantly between the different varieties. This could be attributed to the high air temperature, which affected the number of days to anthesis. The anthesis was earlier in a heat- tolerant than in heat- sensitive cultivars as reported by Lohar and Peat (1998). So, the genotypes i.e. Chico III; Peto 86; Super Strain B and Tallalakhin required 73.28 - 74.49 - 77.95 - 76.16 days in 2002 and 74.79 - 74.35 - 78.81 - 77.56 days in 2003 to flower and classified as heat-tolerant cultivars. While the genotypes i.e. Cal Ace; Castle rock and Mobile required 82.75 - 81.83 - 80.33 and 83.12 - 83.83 - 81.66 days to flower during summer season, 2002 and 2003 respectively and classified as heat-sensitive cultivars.

2) Pollen viability percentage:

Chico III; Peto 86; Super Strain B and Tallalakhin cultivars had given the highest percentage pollen viability (Table 2) and classified as heat-tolerant. Moreover, the obtained results indicated that under heat stress condition, both of tolerant and sensitive (Cal Ace; Castle rock and Mobile) cultivars were affected. Percentage pollen viability ranged from 41.43% to 50.2% and 36.97 to 48.65 for heat-sensitive cultivars and 55.10% to 64.32% and 51.53 to 65.28% for heat-tolerant genotypes during the successive seasons respectively. Similar results were obtained by Phookan *et al* (1997) who found that pollen viability was varied with cultivars under high-temperature.

3) Stigma elongation and coloration percentage:

Stigma elongation (stigma extends beyond the tip of the anthredial cone) and coloration (browning) percentage were commonly occurred in heat-sensitive as well as heat tolerant cultivars under heat-stress condition (Table 2). The stigma elongation was usually reduced the self-pollination. Chico III and Peto 86 cultivars were tolerant to stigma elongation and coloration, whereas Cal Ace, Castle rock and Mobile cultivars were sensitive for these characters under high temperature. Similar results were obtained by Rudich *et al* 1977 and El Ahmadi and Stevens, 1979 on the stigma elongation and Levy *et al* 1978; El Ahmadi and Stevens, 1979; Dane *et al* 1991 and Lohar and Peat, 1998 on the stigma elongation and coloration.

4) Percentage fruit set:

Heat-stress conditions reduced the percent fruit set in all cultivars tested (Table 2). Percentage fruit set ranged from 31.25 to 79.00 and from 37.30 to 82.92 during the successive summer season respectively. The highest cultivars in fruit set were Peto 86 and Chico III with no significantly differences between them. These cultivars were classified as heat tolerant genotypes based on their fruit-setting ability under high temperatures. In comparison, the lowest cultivars in fruit set were Cal Ace; Castle rock and Mobile, which classified as heat sensitive genotypes. Similar results were obtained by Stoner and Otto (1975) and Phookan *et al* (1997) who found wide variation among cultivars in the ability to fruit set under high temperature. Prior studies also have noted a decline in percent fruit set of heat-sensitive tomato genotypes under high-temperature stress as recorded by Abdalla and Verkerk (1968); Rudich *et al* (1977); Abdul-Baki (1991); Dane *et al* (1991); Wessel-Beaver and Scott (1992); Abdul-Baki and Stommel (1995) and Lohar and Peat (1998). The reduction in fruit set may be due to the reduction on pollen viability and the increasing of stigma elongation and coloration as shown in previous results and which reported by Rudich *et al* (1977); Levy *et al* 1978; Shelby *et al* (1978); El Ahmadi and Stevens (1979a); Dane *et al* (1991); Lohar and Peat (1998) and Sato *et al* (2000).

5) Early and total yield.

Genotypes and environment affect on the early and total yield of tomato (Table 3). The highest early yielding cultivars were Peto 86 and Chico III, while the lowest early yielding cultivars were Cal Ace and Mobile. These results agree with those of Nassar *et al* (1982) who found that Cal Ace cultivar was the lowest early tomato yield at summer planting in Egypt.

The heat-sensitive cultivars gave poorly total yield under high temperature conditions compared with the heat-tolerant cultivars (Table 3).

The least cultivars in yielding were Cal Ace, Castle rock and Mobile, while the highest yielding cultivars were Chico III, Peto 86 and Super Strain B during the two summer seasons. The results showed that small-fruited cultivars generally produced more fruits. The increasing of early and total yield of the heat-tolerant cultivars was due to the increasing of pollen viability, fruit set and fruit number as shown in previous results.

6) Average fruit weight:

The average fruit weight differed significantly between varieties during the summer season (Table 3). Data showed that the heat-tolerant cultivars, i.e. Peto 86 and Chico III produced small average fruit weight. These results agreed with those of Dane *et al* (1991) who found that small-fruited was less affected by heat stress than larger-fruited cultivars.

Table 2: Number of days to anthesis, pollen viability %, stigma elongation % and coloration and fruit set % of evaluated cultivars during summer seasons, 2002 and 2003.

Cultivars	Days to anthesis		Pollen viability (%)		Stigma elongation (%)		Stigma coloration (%)		Fruit set (%)	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Cal Ace	82.75	83.12	47.65	36.97	47.20	50.85	23.48	28.44	31.25	37.30
Castle rock	81.83	83.83	41.43	39.19	48.17	51.06	25.70	29.33	38.19	37.71
Chico III	73.28	74.79	64.32	65.28	15.74	17.20	12.14	14.43	79.00	82.92
Mobile	80.33	81.66	50.2	48.65	46.35	48.31	30.64	30.78	38.22	40.00
Peto 86	74.49	74.35	61.43	63.76	27.14	30.29	14.83	14.34	76.94	76.00
Super Strain B	77.95	78.81	59.38	54.38	38.12	42.37	19.82	20.24	69.99	72.75
Tallalakhin	76.16	77.56	55.10	51.53	31.89	44.37	13.73	19.67	48.47	53.42
L.S.D. (0.05)	5.67	5.89	12.79	10.11	10.43	9.91	3.89	5.73	8.34	9.74

7) unmarketable fruits:

High temperature increased the incidence of unmarketable fruits (Table 4), which included cracks, blossom end rot, and small mature fruits.

Unmarketable fruits were rare in the heat tolerant cultivars compared with the heat-sensitive cultivars. Defected fruits of heat-sensitive cultivars were ranged from 17.43 to 25.10% and 22.20 to 27.88%, while those of heat-tolerant cultivars ranged from 8.81 to 11.26% and 12.63 to 19.95% of the total fruits during the successive seasons respectively. Similar results were obtained by Abdul-Baki (1991) who found that high temperature increased also the incidence of fruit defect and reduce the fruit quality. These results also agreed with those of Levy *et al* (1978), Hanna and Hernandez (1982) and Wessel-Beaver and Scott (1992) who found that high temperature was caused drastic reduction in fruit quality.

Table 3: Yield and average fruit weight of evaluated cultivars during summer seasons, 2002 and 2003.

Cultivars	Early yield (Kg\ plant)		Number of fruits per plant		Total yield (Kg\ plant)		Average fruit weight (gm)	
	2002	2003	2002	2003	2002	2003	2002	2003
Cal Ace	0.31	0.26	20.10	19.30	1.48	1.45	102.07	98.61
Castle rock	0.34	0.43	23.23	24.9	1.50	1.53	96.61	97.45
Chico III	0.64	0.52	43.41	43.23	1.73	1.79	43.26	45.29
Mobile	0.31	0.20	19.77	19.91	1.38	1.39	95.32	93.86
Peto 86	0.69	0.55	28.41	27.89	1.70	1.85	68.67	69.61
Super Strain B	0.53	0.45	25.81	23.79	1.72	1.67	94.32	94.39
Tallalakhin	0.52	0.43	26.26	25.69	1.62	1.66	75.07	79.98
L.S.D. (0.05)	0.07	0.21	2.06	3.43	0.09	0.12	8.34	6.59

Table 4: Fruits defect (%) of evaluated cultivars during summer seasons, 2002 and 2003.

Cultivars	Cracks %		Blossom-end rot %		Small mature fruits %	
	2002	2003	2002	2003	2002	2003
Cal Ace	10.64	12.8	4.02	5.71	7.77	9.37
Castle rock	7.21	9.30	3.58	4.32	6.64	8.58
Chico III	2.01	3.48	1.93	3.10	4.87	6.41
Mobile	11.73	13.48	5.09	3.69	8.28	10.25
Peto 86	2.72	4.14	2.35	2.45	4.38	6.04
Super Strain B	3.08	5.28	2.93	3.14	5.25	6.59
Tallalakhin	5.55	6.40	2.49	6.94	5.51	6.61
L.S.D. (0.05)	1.9	0.74	0.48	0.94	0.28	0.70

B- Genetics of heat toerance:

1- Pollen viability percentage

Data of the inheritance of the percent pollen viability in the crosses Cal Ace x Super Strain B and Castle rock x Chico III are shown in Table (5). Data revealed that there were wide differences between the two parents in the two crosses for this character. The greater coefficient of variability (CV%) in the previous crosses was obtained from segregating populations, i.e. F_2 and Bc_1 in the first cross and F_2 in the second cross respectively. These data indicated the effects of both environment and genetics in the inheritance of this trait. Moreover, the continuous distribution of the F_2 in the two crosses indicated that percent pollen viability behaved as a quantitative character.

The potency ratio (P) oı the two previous crosses was 0 and – 0.11 respectively (Table 6) which indicating, the absence of dominance in the first cross and partial dominance toward the lower pollen viability percentage in the second cross.

The A, B, and C values of scaling test of the previous crosses (Table 7) were not significant which indicating the absence of non-allelic interaction. The component of generation mean (Table 8) indicated that the additive effect appeared to be important in the inheritance of this character during the two previous crosses. This result agreed with that obtained by Dane *et al* (1991) who obtained that pollen fertility under heat stress was governed by an additive gene system.

Estimates of broad and narrow sense heritability were 58.23, 58.23 and 54.50, 54.31 % in the two previous crosses respectively (Table 6). These results indicated that, prevailing environment had moderate effects on the expression of this character. Moreover, the scaling test II in the first cross was not significant, indicating that the environmental conditions act independently. While in the cross Castle rock x Chico III the scaling test II was significant, indicating the presence of interaction between genotype and environment for this character.

The expected genetic advance (EGA) in selection for pollen viability percentage in 5% F_2 mean was 20.34 and 16.15 % in the two previous crosses respectively (Table 6). Negative heterosis was estimated as –2.10 % in the cross Castle rock x Chico III (Table 6).

Table 5: Frequency distribution for pollen viability percentage of parental, F_1, F_2, BCP_1 and BCP_2 populations in the crosses Cal Ace x Super Strain B and Castle rock x Chico III.

Class	Cal Ace x Super Strain B						Castle rock x Chico III					
center	P_1	P_2	F_1	F_2	BCP_1	BCP_2	P_1	P_2	F_1	F_2	BCP_1	BCP_2
18	3			9	7		5			11		
23	5			14	5		4			8	8	
28	4			17	10		6		4	14	10	
33	8		4	25	8		6		8	29	9	
33	4		7	18	5	6	7	3	7	12	10	6
43	5	2	5	12	7	8	6	5	7	20	10	12
48	7	3	7	14	6	4	8	6	7	22	5	10
53	6	4	6	12	5	7	3	12	4	25	8	7
58	3	6	4	13	7	11		10	6	21		15
63		12	6	24		9		9	2	15		10
68		9	6	24		8				18		
73		6		13		7						
78		3										
NO.P(1)	45	45	45	195	60	60	45	45	45	195	60	60
Mean	38.66	62.88	50.77	46.87	37.25	56.58	35.88	53.33	43.66	45.20	37.25	51.58
Sx	11.94	8.94	11.35	16.96	12.88	11.08	10.73	7.49	10.20	14.44	9.69	8.28
S^2	142.72	80.10	129.04	287.89	165.95	122.95	115.33	56.13	104.09	208.77	93.91	68.72
C.V%	30.88	14.21	22.35	36.18	34.57	19.58	29.90	14.04	23.36	31.94	26.01	16.05
P.d. (2)	10.90**						8.99**					

NO.P(1) : No. of plants P.d. (2) : Parental differences

2- Fruit set percentage:

The inheritance of the fruit set percentage in the crosses Cal Ace x Super Strain B and Castle rock x Chico III are shown in Table (9). Data revealed that there were wide differences between the two parents in the two crosses for the percentage of fruit set. The greater coefficient of variability in the two crosses was obtained from segregating populations, i.e. F_2 indicating that, both environment and genetics were involved in the inheritance of the fruit set percentage. The frequency distribution of F2 plants in two crosses was continuous, indicating that this character was quantitatively inherited.

The potency ratio of the two previous crosses was 0.97 and 0.82 respectively (Table 6) which indicating, the partial dominance toward the high percent fruit set.

The values of scaling test I of the two previous crosses (Table 7) was not significant, indicating the absence of non-allelic interaction. The component of generation mean (Table 8) indicated that the additive effect appeared to be important in the inheritance of percentage fruit set during the two previous crosses. This result agreed with that obtained by Hanna and Hernandez (1982) and Dane *et al* (1991) who mentioned that fruit set percentage under heat stress was governed by an additive gene system. This result disagreed also with that obtained by Sherif and Hussein, 1992. The different results may be due to the different genetic materials studied.

Table 6: Potence ratio (p), broad sense heritability (h^2b), narrow sense heritability (h^2n), Heterosis (H%), scaling test II (ST II) and Expected genetic advance (EGA) for some economic characters in tomato for the cross Cal Ace x Super Strain B and Castle rock x Chico III.

Characters	Pollen viability %		Fruit set %		Total yield (Kg/ Plant)		Average fruit weight (gm)
	1	2	1	2	1	2	2
P	0	− 0.11	0.97	0.82	3.39	11.47	0.85
h^2b%	58.23	54.50	58.28	77.42	70.38	86.15	64.87
h^2n%	58.23	54.31	58.93	78.83	70.42	86.21	65.35
H%	0	-2.10	27.75	26.74	28.11	97.26	29.65
ST II	1.78	2.05**	1.02	2.15**	1.06	2.79**	1.39
EGA	20.34	16.15	28.05	24.42	699.34	1377.04	40.37

1: Cal Ace x Super Strain B 2: Castle rock x Chico III

Table 7: Scaling tests (A, B and C) for some economic characters in tomato for the cross Cal Ace x Super Strain B and Castle rock x Chico III.

Characters	Cal Ace x Super Strain B			Castle rock x Chico III		
	A	B	C	A	B	C
pollen viability %	-14.93	-0.27	-15.38	-5.04	6.17	4.27
Fruit set %	-9.42	4.01	-19.87	6.3	0.36	-8.44
Total yield	304.35	441.47	833.02	-702.33	-133.77	-300.40
Average fruit weight				-17.06	3.06	24.42

Estimates of broad and narrow sense heritability were 58.28, 58.93 and 77.42, 78.83 % in the two previous crosses respectively (Table 6). These results indicated that, the genetic variance was greater than the environmental one. Moreover, the scaling test II in the first cross was not significant which means that the environmental conditions act independently. While in the cross Castle rock x Chico III the scaling test II was significant indicating the interaction between genotype and environment for this character.

The expected genetic advance in selection for fruit set percentage in 5% F_2 mean (Table 6) was 28.05% and 24.42% in the two previous crosses respectively. The high heritability and genetic advance values for percentage of fruit set on the previous crosses showed that effective selection may be made for percentage of fruit set during this crosses. Positive heterosis was estimated as 27.75 and 26.74 % in the two previous crosses respectively (Table 6). Similar result was obtained by Hanson *et al* (2002) who estimated the heritabilities of fruit set under high temperatures as 31% and 21%.

Table 8: Components of generation mean for some economic characters in tomato for the cross Cal Ace x Super Strain B and Castle rock x Chico III.

Characters	Pollen viability %		Fruit set %		Total yield (Kg/ Plant)		Average fruit weight (gm)
	1	2	1	2	1	2	2
M	50.59	47.74	37.45	33.44	1502.74	2034.85	96.58
D	50.77**	44.60**	51.91**	-15.64**	1415.54**	1499.15**	58.16**
H	-15.06	-36.09	38.44	49.84	969.41	1585.53	-73.59

1: Cal Ace x Super Strain B 2: Castle rock x Chico III

Table 9: Frequency distribution for fruit set percentage of parental, F_1, F_2, BCP_1 and BCP_2 populations in the crosses Cal Ace x Super Strain B and Castle rock x Chico III.

Class center	Cal Ace x Super Strain B						Castle rock x Chico III					
	P_1	P_2	F_1	F_2	BCP_1	BCP_2	P_1	P_2	F_1	F_2	BCP_1	BCP_2
18.5	9			19	6					6		
26.5	7			25	8		23			14		
34.5	9		2	20	11		9			19	10	
42.5	9	7	4	14	6	12	12		3	18	15	10
50.5	5	4	5	25	8	4	1	4	4	38	8	6
58.5	4	5	6	12	4	6		5	15	43	20	6
66.5	1	8	9	16	7	7		36	19	39	7	16
74.5	1	7	8	22	8	9			4	12		22
82.5		4	6	26	2	10				6		
90.5			5	16		12						
NO.P(1)	45	45	45	195	60	60	45	45	45	195	60	60
Mean	37.16	66.67	66.32	54.15	47.03	68.5	32.90	64.18	61.52	52.92	50.36	63.03
Sx	2.15	2.17	2.35	1.68	2.49	2.26	7.35	5.00	8.05	15.20	10.56	11.90
S^2	209.45	213.78	248.69	551.71	371.77	307.25	54.10	25.08	64.84	231.3	111.71	141.81
C.V%	38.93	21.92	23.77	43.36	40.99	25.57	22.35	7.80	13.08	28.72	20.96	18.87
P.d. (2)	9.64**						23.69**					

NO.P(1) : No. of plants P.d. (2) : Parental differences

Total yield (gm/ plant):

The inheritance of total yield in the crosses Cal Ace x Super Strain B and Castle rock x Chico III are shown in Table (10). Data revealed that there were wide differences between the two parents in the two crosses for this character. The greater coefficient of variability was obtained from segregating populations, i.e. F2 in the two previous crosses. These data indicated the effects of both environment and genetics in the inheritance of this trait. Moreover, the continuous distribution of the F2 population in the two crosses indicated that the total yield behaved as a quantitative character.

The potency ratio of the two previous crosses was 3.39 and 11.47 respectively (Table 6) which indicates over dominance of the high total yield was responsible for the inheritance of total yield.

The values of scaling test of the two previous crosses (Table 7) were no significant, indicating the absence of non-allelic interaction. The component of generation mean (Table 8) indicated that the additive effect appeared to be important in the inheritance of total yield during the two previous crosses.

Table 10: Frequency distribution for total yield (gm/ Plant) of parental, F_1, F_2, BCP_1 and BCP_2 populations in the crosses Cal Ace x Super Strain B and Castle rock x Chico III.

Class center	Cal Ace x Super Strain B					
	P_1	P_2	F_1	F_2	BCP_1	BCP_2
750	3			2		
1051	12	4		18		
1352	20	18	6	35	10	15
1653	10	15	14	39	33	18
1954		8	20	42	13	3
2255			5	41	4	12
2556				11		12
2857				5		
3158				2		
NO.P(1)	45	45	45	195	60	60
Mean	1298.48	1532.60	1813.53	1822.79	1708.18	1893.8
Sx	259.00	267.68	261.46	482.23	238.31	456.32
S^2	67081.36	71657.15	68362.57	232549.75	56791.98	208228.73
C.V%	19.94	17.46	14.41	26.45	13.95	24.09
P.d. (2)	4.21**					
Class center	Castle rock x Chico III					
	P_1	P_2	F_1	F_2	BCP_1	BCP_2
750	6			4		
1051	12	4		19		
1352	10	5		25	9	
1653	7	27		22	21	10
1954	10	9		25	19	18
2255			2	23	11	8
2556			1	24		16
2857			22	21		8
3158			20	16		
3459				16		
NO.P(1)	45	45	45	195	60	60
Mean	1372.06	1626.24	2957.33	2153.14	1813.53	222.49
Sx	412.90	247.06	222.30	775.39	290.44	402.31
S^2	170494.61	61041.28	49418.72	601238.03	84356.18	161853.31
C.V%	30.09	15.19	7.52	36.01	16.01	18.08
P.d. (2)	3.5**					

NO.P(1) : No. of plants P.d. (2) : Parental differences

This result agreed with that obtained by Sherif and Hussein (1992) and Chadha *et al* (2001) who obtained that total yield under heat stress was governed by an additive gene system. On the contrary results disagreed with that obtained by Roopa *et al* (2001). The differed results may be due to the different genetic materials under studies. The ratio of broad and narrow sense heritability were 70.38, 70.42, and 86.15, 86.21 % in the two previous crosses respectively (Table 6). These results indicated that, the genetic variance was greater than the environmental one. This was confirmed by scaling test II which indicated that the environmental conditions act independently in the first cross while, in the cross Castle rock x Chico III pointed to the existing of interaction between genotype and environment for this character. Estimating of the expected genetic advance values in selection the total yield in 5% of F_2 plants were 699.34 and 1377.04 gm of F_2 means in the two previous crosses respectively (Table 6). The high heritability and genetic advance values for total yield on these crosses showed that effective selection may be made for percentage of total yield. Similar result was obtained by Ghosh *et al* (1995) and Parvinder Singh *et al* (2002) who found that heritability and genetic advance were high for yield /plant.

Positive heterosis was estimated as 28.11 and 97.26 % in the two previous crosses respectively (Table 6).

Average fruit weight(gm):

Depending on the results of the evaluation trail (Table 3) Cross Castle rock x Chico III was used according significance between parents while, the cross Cal Ace x Super Strain B excluded regarding of insignificance between his parents. Data presented in Table (11) revealed that, average fruit weight between both parents (Castle rock and Chico III) used differed significantly. The greater coefficient of variability was obtained from segregating populations, i.e. F_2 and Bc_2 indicating that, both environment and genetics were involved in the inheritance of this character. Moreover, the continuous distribution of the F2 population indicated that the average fruit weight behaved as a quantitative character.

The potency ratio (Table 6) was 0.85 which indicating, the partial dominance toward the high fruited character. Different types of dominance were recorded by Abdel-Ati *et al* (2000). The differed results may be due to the different genetic materials studied.

The values of scaling test (Table 7) were not significant, indicating the absence of non-allelic interaction. The component of generation mean (Table 8) indicated that the additive effect appeared to be important in the inheritance of average fruit weight during the two previous crosses. This result agreed with that obtained by Sherif and Hussein (1992) who found that average fruit weight under heat stress was governed by an additive gene system. This result disagreed with that obtained by Roopa *et al* (2001).

The broad and narrow sense heritability reached to 64.87, 65.35% in this cross (Table 6). These results indicated that, the genetic variance was greater than the environmental one. This was confirmed by scaling test II indicated that the environmental conditions act independently. Similar result was obtained by Sherif and Hussein (1992) and Abdel-Ati *et al* (2000) on narrow and broad sense heritability respectively. Estimation of the expected genetic advance value in selection the average fruit weight in 5% of F_2 plants were 40.37 gm (Table 6). The high heritability and genetic advance values for average fruit weight on this cross-showed that effective selection might be made for average fruit weight. Positive heterosis (Table 6) was estimated as 29.65 % in this cross.

CONCLUSION

In general, it can be concluded that Peto 86, Chico III, Super Strain B and Tallalakhin cultivars were classified as heat-tolerant cultivars. Moreover the hybrid Castle rock x Chico III were recommended for the development of high fruit setting ability and total yield under summer season.

Table 11: Frequency distribution for average fruit weight (gm) of parental, F_1, F_2, BCP_1 and BCP_2 populations in the crosses Castle rock x Chico III.

Class center	Castle rock x Chico III					
	P_1	P_2	F_1	F_2	BCP_1	BCP_2
23.5		14		18		5
39.5		21	5	23	9	15
55.5	6	10	11	35	19	14
71.5	19		7	44	12	18
87.5	15		12	23	15	11
103.5	5		10	28	5	
119.5				17		
135.5				5		
151.5				2		
NO.P(1)	45	45	45	195	60	60
Mean	78.25	38.07	75.41	72.89	68.30	58.27
Sx	13.85	11.72	21.60	29.99	19.49	26.60
S^2	191.87	137.56	467.26	899.61	380.09	707.95
C.V%	17.69	30.78	28.64	41.44	28.53	45.64
P.d. (2)	14.80**					

NO.P(1) : No. of plants　　P.d. (2) : Parental differences

REFERENCES

Abdalla, A.A. and K. Verkerk (1968). Growth flowering and fruit set of the tomato at high temperature. Neth. J. Agr. Sci. 16: 71-76.

Abdel-Ati, K. E. A.; A. A. Hassan, S. E. S. Moustafa and A. A. Mohammed (2000). Genetics of some tomato fruit quality characters. I. Physical characters. Egyptian Journal of Horticulture 27 (2): 249- 264.

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

Abdul-Baki, A. and J.R. Stommel (1995). Pollen viability and fruit set of tomato genotypes under optimum and high-temperature regimes. HortScience 30 (1): 115-117.

Allard, R. W. (1960). Principle of plant breeding. John willey and Sons, Inc. New York.

Chadha, S.; J. Kumar and Vidyasagar (2001). Combining ability over environments in tomato. Indian Journal of Agricultural Research 35 (3): 171 – 175.

Dane, F.; A.G. Hunter and O.L. Chambliss (1991). Fruit set, pollen fertility and combining ability of selected tomato genotypes under high-temperature field conditions. J. Amer. Soc. Hort. Sci. 116 (.5): 906-910.

El Ahmadi, A.B. and M.A. Stevens (1979). Reproductive responses of heat-tolerant tomatoes to high temperatures. J. Amer. Soc. Hort. Sci. 104: 686-691.

Ghosh, P. K.; M. M. Syamal; N. Rai and A. K. Joshi (1995). Improvement of hybrid tomatoes. Advances in Plant Sciences 8 (1): 207-213.

Hanna, H.Y. and T.F. Hernandez (1982). Response of six tomato genotypes under summer and spring weather conditions in Louisiana. HortScience 17(5): 758 – 759.

Hanson, P. M.; JenTzu Chen and G. Kuo (2002). Gene action and heritability of high-temperature fruit set in tomato line CL5915. HortScience 37 (1): 172-175.

Jinks, J. L. and R.M. Jones (1958). Estimation of the components of heterosis genetics, 43: 233-34.

Levy, A., H.D. Rabinowich and N. kedar (1978). Morphological and physiological characters affecting flower drop and fruit set of to tomatoes at high temperatures. Euphytica 27: 211–218.

Lohar, D. P. and W. E. Peat (1998). Floral characteristics of heat-tolerant and heat-sensitive tomato (*Lycopersicon esculentum* Mill.) cultivars at high temperature. Scientia Horticulturae 73 (1): 53-60.

Mather, K. and J.L. Jinks (1982). Biometrical Genetics. Great Britain, Univ. Press, 3 rd. Ed., 396 pp.

Nassar, S.H., W.L. Stims and A.A. Hassan (1982). Nation-wide programme of tomato cultivar evaluation in Egypt: 1980 summer planting. Egypt. J. Hort. 9 (2): 131-137.

Parvinder Singh; Surjan Singh; D.S. Cheema and M.S. Dhaliwal (2002). Geneti variability and correlation study of some heat tolerant tomato genotypes. Vegetable Science 29 (1): 68-70.

Phookan, D. B.; A. Shadeque and B. K. Chakravarty (1997). Sensitivity of tomato (*Lycopersicon esculentum*) cultivars to high-temperature pollination and fruit-set under plastic rain shelter. Indian Journal of Agricultural Sciences 67 (8): 312-313.

Roopa, L.; A. T. Sadashiva, K. M. Reddy; K. P. G. Rao. and B . C. N. Prasad (2001). Combining ability studies for long shelf life in tomato. Vegetable Science 28 (1): 24 – 26.

Rudich, J., E. Zamski and Y. Regev (1977). Genotypic variation for sensitivity to high temperature in the tomato: Pollination and fruit set. Bot. Gaz. 138: 448-452.

Sato, S., M. M. Peet and J. F. Thomas (2000). Physiological factors limit fruit set of tomato (*Lycopersicon esculentum* Mill.) under chronic, mild heat stress. Plant, Cell and Environment 23 (7): 719-726.

Schaible L.W. (1962). Fruit setting responses or tomatoes to high night temperatures. Proc. P1. Sci. Symp. Campbell Soup. Co. pp. 89 – 98.

Shelby, R.A., W.H. Greenleaf, and C.M. Peterson (1978). Comparative floral fertility in heat tolerant and heat sensitive tomatoes. J. Amer. Soc. Hort. Sci. 103: 778-780.

Sheppard, R. A. (1973). Practical genetics. Blackwell Sci. Publications. Oxford. 337 p.

Sherif, T. H. I. and H. A. Hussein (1992). Tomato (*Lycopersicon esculentum* Mill) under the heat stress of late summer in Upper Egypt. Assiut Journal of Agricultural Sciences 23 (2): 3-28.

Stell, R.G.D. and J.H.Torrie (1960). "Principles and Procedures of Statics". Mc.Grow Hill Book comp. Inc. New York, Toronto, London P. 107 – 131, 278.

Stevens, M.A. and J. Rudich (1978). Genetic potential for overcoming physiological limitations on adaptability, yield and quality in the tomato. Hort Science 13: 673 – 676.

Stoner A.K. and B.E. Otto (1975). A greenhouse method to evaluate high temperature setting ability in the tomato. Hort Science 10: 264 – 265.

Sugiyama, T., S. Iwaheri and T. Takahashi (1966). Effect of high temperature on fruit setting of tomato under cover. Acta Hort. 4: 63- 69.

Tsuchiya, T. (1971). An improved acetocarmine squash method, with special reference to the modified Rattenburg`s method of making a preparation permanent. Barley Genet. Nwsl. 1:71-73.

Wessel-Beaver, L. and J.W. Scott (1992). Genetic variability of fruit set, fruit weight and yield in a tomato population grown in two high-temperature environments. J. Amer. Soc. Hort. Sci. 117: 867-870.

دراسات وراثية على بعض أصناف الطماطم تحت ظروف درجات الحرارة العالية.
١- دراسة توريث بعض صفات الطماطم تحت ظروف درجات الحرارة العالية.

فاتن شفيق صليب، ميلاد حلمي زكى وعبد الرؤوف هويدى

أقسام بحوث الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – القاهرة – مصر.

أقيمت هذه الدراسة خلال ٣ مواسم صيفية متتابعة وهى ٢٠٠٢، ٢٠٠٣، ٢٠٠٤ بمحطة أبحاث الخضر بقها – قليوبية– مصر. وتم تقييم ٧أصناف من الطماطم (ليكون بريسكون ايسكيولينتم ميللى) لمدى تحملها لدرجات الحرارة العالية والقابلية على عقد الثمار بالحقل المكشوف تحت ظروف درجات الحرارة العالية. تم تصنيف الأصناف كال إس و كاسيل روك وموبيل كأصناف غير متحملة لدرجات الحرارة العالية بينما كانت الأصناف بيتو وشيكو وسوبر استرين بى وتلاليخين أصناف متحملة لدرجات الحرارة العالية وذلك بناء على حيوية حبوب اللقاح والقدرة على عقد الثمار والمحصول تحت ظروف درجات الحرارة العالية.

وقد أدت درجات الحرارة إلى خفض النسبة المئوية لكل من حيوية حبوب اللقاح ونسبة عقد الثمار وزيادة استطالة واحتراق الميسم وزيادة الثمار الغير صالحة للتسويق والتي تشتمل على الثمار المتشققة والثمار التي بها عفن الطرف الزهري والثمار الصغيرة الناضجة. وقد تراوحت نسبة حيوية حبوب اللقاح من ٤١,٤٣ – ٥٠,٢ % و ٣٦,٩٧ – ٤٨,٦٥ % للأصناف الغير متحملة لدرجات الحرارة العالية، ومن ٥١,١٠ – ٦٤,٣٢ % و ٥٥,١٠ – ٦٥,٢٨ % في الأصناف المتحملة لدرجات الحرارة العالية خلال موسم ٢٠٠٢ و ٢٠٠٣ بالتتابع. وتراوحت نسبة عقد الثمار من ٣١,٢٥ – ٣٨,٢٢ % و ٣٧,٣٠ – ٤٠,٠٠ % للأصناف الغير متحملة لدرجات الحرارة العالية، ومن ٤٨,٤٧ – ٧٩,٠٠% و ٥٣,٤٢ – ٨٢,٩٢% % في الأصناف المتحملة لدرجات الحرارة العالية خلال موسمي الصيف بالتتابع.

ويتبع كل من وراثة نسبة حيوية حبوب اللقاح ونسبة عقد الثمار والمحصول الكلى ومتوسط وزن الثمرة التوريث الكمي وتؤثر في توريث هذه الصفات كل من الظروف الجوية والعوامل الوراثية. وبالنسبة لتوريث نسبة حيوية حبوب اللقاح تحت درجات الحرارة العالية فأن هناك عدم سيادة أو سيادة جزئية نحو الأب الأقل في حيوية حبوب اللقاح. بينما كان هناك سيادة جزئية نحو الأب الأعلى في قيمة نسبة عقد الثمار، وسيادة متفوقة للمحصول الأكثر وزناً، وسيادة جزئية نحو الثمار الأثقل وزناً وذلك لتوريث كل من نسبة عقد الثمار والمحصول الكلى ومتوسط وزن الثمار تحت درجات الحرارة المرتفعة. وكان لتأثير الإضافة فعل هام بالنسبة لتوريث كل من الصفات السابقة.

وكانت نسب التوريث على النطاق الضيق عالية بالنسبة لكل من المحصول الكلى ومتوسط وزن الثمرة تحت ظروف تأثير درجات الحرارة خلال الصيف بمصر. وتشير قيم التوريث والقيمة المتوقعة للتحسين الناتج بالانتخاب على كفاءة الانتخاب لكل من نسبة عقد الثمار و المحصول الكلى ومتوسط وزن الثمرة. كما وجد هناك قوة هجين موجبة لكل من عقد الثمار و المحصول الكلى ومتوسط وزن الثمرة بينما كان هناك قوة هجين سالبة لنسبة حيوية حبوب اللقاح.