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STUDY OF HETEROSIS IN HEAT TOLERANT TOMATO *(Solanum lycopersicum)* DURING SUMMER

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Abstract

An experiment was conducted at the Vegetable Research Field of Olericulture Division, Horticulture Research Cente, Bangladesh Agricultural Research Institute (BARI), Gazipur during May to October 2008 to study heterosis using eight parents viz., P_1, P_2, P_3, P_4, P_5, P_6, P_7, and $P_{8.}$ Most of the combinations showed better parent heterosis for earliness. Eight crosses showed positive heterosis for flower production. The highest heterotic effect for fruit set (%) was found in the cross $P_6 \times P_7$ (62.59%) followed by that in $P_7 \times P_8$ (60.49%) and $P_1 \times P_7$ (40.00%). For fruits per plant, 8 crosses provided more than 15 % heterosis over better parent. Considering fruit yield per plant, higher degree of heterosis was manifested by 24 hybrids over better parent ranging from 13.58 to 282.63 %. Cross combination P_4 x P_7 showed the maximum significant positive heterosis followed by P_6 x P_7 (187.84 %), P_4 x P_8 (166.97 %), P_3 x P_7 (146.08 %), P_3 xP_6 (103.92 %), and P_1 X P_7 (100.45 %) and the minimum in P_4 x P_6 (13.58 %). For viable pollens, P_3 x P_5 (20.56 %) exhibited the highest positive heterosis. In case of shelf life, the highest heterosis was observed by the cross P_3 x P_6 (22.78 %) followed by that in P_4 x P_6 (22.29 %) and P_2 x P_6 (14.40 %). For fruit flesh thickness, 12 hybrids exhibited more than 10 % heterosis. Pollen tubes as well as viable pollens showed positive correlation with fruit set.

Keywords: Tomato, heterosis, heat tolerant tomato, summer.

Introduction

Heterosis is an important genetic phenomenon synonymous with hybrid vigour refers to the manifested superiority of the F_1 hybrid resulting from the cross of genetically dissimilar homozygous parents. The classical work of Shull and East during 1905-12 laid the foundations for exciting advances in exploitation of heterosis in crops (Taslim, 2006).

The best way to utilize heterosis in crop is to produce F_1 hybrids, which possess maximum heterozygosity.

The commercial exploitation of heterosis, however, was recorded first in 1930s with maize in USA (Ahmad, 2002). Now a days with many other hybrid

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crops, a lot of hybrid varieties of horticultural crops like tomato, brinjal, cabbage, cauliflower, cucumber, capsicum, broccoli, onion, and radish are frequently grown on large scale all over the world.

The exploitation of heterosis in the breeding and development of crop hybrids has made an enormous contribution to 20th century agriculture, although the genetic basis of the phenomenon remains unclear (Rood *et al.*, 1988; Sinha and Khanna, 1975). Geneticist and plant breeders described heterosis as the manifestation of greater vigour in height, leaf area, growth, dry matter accumulation, and yield in a F_1 hybrid in comparison with the parents (Allard, 1960; Hageman *et al.*, 1967). F_1 hybrid tomatoes are one of the most leading vegetable crops all over the world. But these are absolutely for optimum growing season i.e., like winter season in Bangladesh. There is a bright scope of exploitation of heterosis under high temperature in Bangladesh as many tomato lines introduced from abroad are capable enough to produce a large number of small fruits. But a few attempts in this regard were done in the past. Therefore, the present investigation was an attempt to study the heterosis in tomato under high temperature conditions.

Materials and Method

The experiment was conducted at the experimental farm of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the month of May to October 2008. The average minimum and maximum temperature during the crop period was 25.22^{0}C and 31.88^{0}C, respectively. A diallel cross of 8 x 8 excluding reciprocals were constructed from the eight heat tolerant parental lines viz., P_1, P_2, P_3, P_4, P_5, P_6, P_7, and P_8 collected from HRC, BARI, Gazipur. The basic seeds of the 8 x 8 half-diallel mating were produced in the vegetable research field, HRC, BARI during October 2007 to March 2008. Seeds of the eight selfed parents and their 28 F_1 hybrids were sown in seed bed on 5 May 2008. At the age of 30 days, seedlings were transplanted in the main experimental plots. The experiment was set up in a randomized complete block design (RCBD) with three replications. Thirty-six genotypes (28 F_1s + 8 parents) of tomato were considered as the 36 treatments of the experiment. The experimental plots were covered by transparent polythene with minimum interruption of photosynthesis. The polytunnel was 2.3 meter wide having two 1.0 meter wide bed with 30 cm drain in between, which serves as irrigation channel. Chemical fertilizers @ of 550 kg urea, 450 kg TSP, 250 kg MoP, 120 kg Gypsum, 2 kg boron, and 10 tons cowdung per hectare were applied. Half of the cowdung and the entire amount of TSP, Gypsum, and Boron were applied during final land preparation. The pits were prepared one week before planting. The remaining cowdung and $^1/_3$ of MoP were applied at that time. Top dressings were done in three 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 pollens, fruit set (%), fruited cluster/plant, fruits/plant, fruit weight (g), fruit yield/plant (g), viable pollens, fruit length (cm), fruit diameter (cm), branches/plant, plant height (cm), seeds/fruit, 1000-seed weight, TSS, shelf life, locules/fruit, fruit firmness and fruit flesh thickness were recorded. All the recorded quantitative data were subjected to ANOVA. The significance of increase or decrease in F_1 hybrids over their corresponding mid parent and better parent were tested by comparing their means with the help of appropriate standard error values in percentage. For estimation of heterosis in each character the mean values of the 28 F_1s have been compared with better parent (BP) for heterobeltiosis.

Results and Discussion

Analysis of variance for parents and crosses showed highly significant differences for all the characters studied (Table 1). The estimates of better parent heterosis observed in F_1 generation are presented in Table 2 to 4.

Days to 50% flowering

Negative heterosis over better parent was observed in case of days to 50% flowering showing earliness in the flowering and it was significant for almost all the cross combinations except one (Table 2). As the consumers prefer to eat tomato earlier, therefore, negative heterosis for this trait is preferable. This study is in accordance with the findings of Baishya *et al.* (2001) and Ahmad (2002) who also reported negative heterosis for this trait over the better parent in many of the crosses in their diallel progenies.

Table 1. Analysis of variance for genotypes (parents and crosses).

Source of variation	d.f.	Mean sum of square						
		Days to 50% flowering	Flowers/ cluster	Fruit set	Fruit cluster/ plant	Number of fruits/ plant	Fruit wt	Yield/ plant
Blocks	3	10.58	0.11	1.60	1.40	27.46	2.65	44334.76
Genotypes (Parents & F_1s)	35	31.25**	4.20**	194.59**	15.04**	128.58**	1578.09**	346133.11**
Error	105	1.00	0.27	6.05	0.47	3.31	6.02	8703.82

** Significant at 1% level of probability.

Table 1. Cont'd.

Source of variation	d.f.	Mean sum of square						
		Fruit length	Fruit diameter	Branches/ plant	Plant height	Viable pollens	Seeds / fruit	1000-seed wt
Blocks	3	0.01	0.02	5.83	30.57	18.67	5.98	0.02
Genotypes (Parents & F_1's)	35	1.04**	1.59**	14.40**	927.94**	401.97**	553.60**	0.43**
Error	105	0.02	0.01	1.06	134.76	37.59	8.16	0.01

** Significant at 1% level of probability.

Table 1. Cont'd.

Source of variation	d.f.	Mean sum square				
		TSS (%)	Shelf life	Firmness	Locules/fruit	Thickness
Replication	2	0.04	0.14	0.02	0.04	0.02
Genotypes (Parents and Crosses)	35	0.27**	4.23**	0.40**	8.23**	3.99**
Error	70	0.02	0.46	0.01	0.04	0.05

** Significant at 1% level of probability.

Flowers per cluster

Out of 28 crosses, only eight crosses showed positive heterosis for flower production and 20 showed significant negative heterosis over better parents. It indicated that flower production under high temperature have a minimum heterotic effect as most of the crosses showed significant negative heterosis (Table 2). Ahmad (2002) also found similar positive heterosis for this trait in a few cross combinations.

Fruit set

Significant heterosis either positive or negative was exhibited in relation to percent fruit set in almost all the cross combinations studied. Increased fruit set was observed in 50 % crosses showing positive heterosis ranging from 0.08 to 62.59 %. The highest heterotic effect was found in the cross $P_6 \times P_7$ (62.59%) followed by the cross P_7 x P_8 (60.49%), $P_1 \times P_7$ (40.00%), P_6 x P_8 (39.33%) and $P_2 \times P_3$ (31.80%) (Table 2). These findings of the present investigation are in conformity with the findings of Opena *et al.* (1987 a) and El-Ahmadi and Stevens (1979 b).

Fruit clusters per plant

Like fruit set, 14 hybrids i.e. 50 % of total crosses provided significantly heterosis positively, while the rest 50 % hybrids exhibited significant negative heterosis except one. Positive heterosis for this character ranged from 1.20 to 79.52 % over better parent in the crosses P_2 x P_7 and P_6 x P_7, respectively. More than 15 % positive heterosis was manifested in 6 crosses (Table 2). Similar results were achieved by Ahmad (2002) while investigating heterosis for this trait. He observed more than 20 % heterosis over better parent in 12 crosses.

Fruits per plant

Eleven crosses expressed significant positive heterosis for this trait. Out of them, more than 15 % heterosis was manifested by eight crosses. Among them, hybrid $P_6 \times P_7$ exhibited the highest (105.69 %) significant positive heterosis followed by 42.52 %, 40.78 %, 39.86 %, 24.54 %, and 23.81 % heterosis in the crosses P_2 x P_3, $P_4 \times P_8$, $P_3 \times P_4$, $P_3 \times P_6$, and $P_3 \times P_7$, respectively. The range of positive heterosis for this trait was 3.38 to 105.69 % over better parent (Table 2). Maximum positive heterosis was observed in the cross $P_6 \times P_7$ followed by that in $P_2 \times P_3$ which were 105.69 and 42.52 percent, respectively. Similar findings of higher number of fruits per plant between several crosses were reported by Bhatt *et al*. (1999) and Sekar (2001).

Fruit weight

Fourteen F_1s out of 28 showed positive heterosis for fruit weight indicated this trait can be improved through heterosis breeding. The rest 14 combinations expressed significant negative heterosis (Table 2).The highest positive heterosis over better parent was observed in the hybrid P_4 x P_5 (66.38 %) followed by that of P_5 x P_6 (41.06 %), P_6 x P_7 (39.67 %), P_1 x P_8 (33.32 %) and the lowest positive heterosis was recorded by the cross P_4 x P_6 (1.32 %). Nine hybrids showed more than 15 % positive heterosis for this trait. Heterosis for single fruit weight/plant under high temperature environments were reported by Fageria *et al.* (2001).

Fruit yield per plant

A high amount of heterosis was manifested by 24 hybrids over better parent ranging from 13.58 to 282.63 % (Table 2). The cross combination P_4 x P_7 showed the maximum significant positive heterosis followed by P_6 x P_7 (187.84 %), P_4 x P_8 (166.97 %), $P_3 \times P_7$ (146.08 %), P_3 xP_6 (103.92 %), and $P_1 \times P_7$ (100.45 %) (Table 2). Hassan *et al.* (2000) and Dharmatti *et al.* (2001) reported appreciable heterobeltiosis for yield per plant. Mahdy *et al.* (1990) and Ahmad (2002) also reported higher yield in the maximum cross combinations while studying heterosis in tomato.

Table 2. Percent heterosis over better parent for days to 50 % flowering, flowers/ cluster, fruit set (%), fruit clusters/plant, fruits/ plant, fruit weight, yield/plant and viable pollens (%).

Cross combinations	Days to 50% flowering	Flowers/ cluster	Fruit set (%)	Fruit clusters/ plant	Fruits / plant	Fruit wt (g)	Fruit yield / plant (g)	Viable pollens (%)
P_1 x P_2	-1.58*	8.94**	-14.21**	-21.58**	-17.61**	3.50*	-12.75	13.34**
P_3	-5.92**	14.13**	-6.27**	-0.43	19.88**	-2.78*	30.96	-0.58
P_4	-9.36**	-8.57**	-16.33**	-4.06**	3.38**	9.83**	13.76	5.97
P_5	-1.02	-25.60**	30.23**	-3.64**	-10.15**	21.75**	21.34	-35.24**
P_6	-11.76**	-4.23**	0.92	13.86**	-15.08**	-4.21*	60.25	-0.05
P_7	-26.77**	-8.21**	40.00**	-2.64**	-1.38	-33.56**	100.45	7.14
P_8	-8.71**	10.27**	13.81**	-34.15**	5.99**	33.32**	-1.31	-41.25**
P_2 x P_3	-7.88**	9.23**	31.80**	25.25**	42.52**	17.18**	80.44	3.66
P_4	-8.72**	-2.41**	-5.19**	4.71**	-17.21**	14.61**	-3.26	9.63*
P_5	-2.30**	-11.82**	-4.60*	3.00**	-8.42**	23.49**	22.35	-17.82**
P_6	-10.73**	-9.97**	-18.54**	8.22**	-14.99**	-15.79**	36.62	14.34**
P_7	-27.65**	-10.70**	17.17**	1.20*	-4.67**	-37.90**	74.71	8.04
P_8	-7.88**	6.58**	-1.41	-32.80**	7.62**	5.01**	29.90	-15.23**
P_3 x P_4	-11.57**	-10.76**	21.43**	19.77**	39.86**	16.38**	62.48	-6.78
P_5	-12.40**	-29.37**	0.08	2.27**	15.90**	20.01**	39.56	20.65**
P_6	-12.34**	-7.92**	1.65	17.15**	24.54**	-6.84**	103.92	-10.12*
P_7	-25.73**	-11.60**	8.21**	13.49**	23.81**	-27.46**	146.08*	14.59**
P_8	-7.36**	-4.65**	-9.9688	-27.88**	-3.79**	-9.26**	17.39	-2.97
P_4 x P_5	-9.73**	-18.99**	-4.12*	-4.03**	-10.27**	66.38**	49.25	-20.68**

Table 2. Cont'd.

P_6	-8.71**	-13.16**	-19.56**	19.57**	-27.76**	1.32	13.58	-2.11
P_7	-25.04**	-25.82**	0.50	15.94**	-16.34**	-28.13**	282.63**	-4.91
P_8	-11.25**	7.72**	-9.75**	-24.37**	40.78**	-5.75**	166.97*	-15.14**
P_5 x P_6	-16.39**	-27.05**	-32.05**	-11.64**	-33.94**	41.06**	54.02	-24.38**
P_7	-22.16**	-38.14**	-11.76**	2.27**	-2.86*	-18.30**	103.31	-10.71*
P_8	-10.16**	0.26	-11.75**	-38.95**	-17.38**	-19.56**	-17.35	-24.95**
P_6 x P_7	-18.31**	-21.65**	62.59**	79.52**	105.69**	39.67**	187.84**	9.38*
P_8	-15.36**	0.13	39.33**	-35.38**	-31.51**	-22.10**	66.61	-4.89
P_7 x P_8	-17.49**	-15.08**	60.49**	-34.89**	-33.28**	-45.08	78.54	0.28
SE	0.71	0.37	1.74	0.48	1.29	1.74	65.97	4.34
CD (5%)	1.44	0.75	3.54	0.99	2.62	3.53	134.12	8.81
CD (1%)	1.93	1.01	4.75	1.32	3.52	4.74	180.16	11.84

* Significant at 5% level of probability

** Significant at 1% level of probability

Viable pollens

For viable pollen grains, 11 F_1s out of 28 showed better parent heterosis positively. The cross combination P_3 x P_5 (20.65 %) exhibited the maximum positive heterosis followed by P_3 x P_7 (14.59 %) and P_2 x P_6 (14.34 %) and the lowest positive heterosis was recorded from P_7 x P_8 (0.28 %) (Table 2). Ahmad (2002) also found similar heterosis for this trait but the degree of positive heterosis was several folds higher. This might be due to seasonal variations as well as genetical differences among the germplasm under studied.

Fruit length

Eighteen crosses showed positive heterosis for this trait over better parents ranged from 0.88 % (P_2 x P_5) to 14.12 % (P_4 x P_6) (Table 3). Sharma *et al.* (2001) reported hybrid vigour over better parent for fruit length.

Fruit diameter (cm)

Fifteen hybrids provided positive heterosis of which 14 hybrids were significant for fruit diameter except one, while 13 hybrids showed significant negative heterosis (Table 3). The range of positive heterosis varied from 0.16 % to 21.22 % by the hybrids P_6 x P_7 and $P_5 \times P_6$, respectively This result coincides with the findings of Alvarez (1985) and Susic (1998).

Branches per plant

It is evident from the Table 3 that 19 hybrids performed positive heterosis indicating the number of branches per plant can be increased significantly through heterosis breeding. The highest heterosis was achieved by the hybrid $P_3 \times P_7$ (29.37%). Singh and Singh (1993) and Ahmad (2002) reported heterosis for the number of branches per plant over the better parent in the maximum hybrids in tomato.

Plant height

In case of plant height at last harvest, though 18 cross combinations out of 28 provided positive heterosis over better parent, among them, only 4 crosses showed significant positive heterosis (Table 3). The heterobeltiotic effects ranged from -21.19 % to 36.72 %. Maximum significant positive heterosis was evident in the cross P_2 x P_5 (36.72 %) followed by that in P_1 x P_7 (26.79 %). Heterosis in relation to plant height under high temperature was also manifested by Fageria *et al.* (2001).

Table 3. Percent heterosis over better parent for fruit length, fruit diameter, branches/ plant, plant height, seeds/ fruit, 1000-seed weight, TSS (%), and shelf life.

Cross combinations	Fruit length (cm)	Fruit diameter (cm)	Branches/ plant	Plant height (cm)	Seeds/ fruit	1000-seed wt (g)	TSS (%)	Shelf life (days)
P_1 xP_2	7.63**	5.18**	-11.39**	3.52	-8.55**	12.80**	10.25**	-11.82**
P_3	1.35**	-4.04**	5.61**	7.05	-1.10	7.12**	2.39**	6.56**
P_4	4.50**	0.34**	-22.80**	-4.28	65.50**	6.52**	1.36**	5.32**
P_5	1.23**	-1.35**	6.09**	10.61	67.56**	3.78**	4.60**	-12.07**
P_6	8.35**	5.28**	4.59**	-1.17	53.08**	9.96**	6.82**	7.00**
P_7	6.76**	-18.82**	17.13**	26.79**	-63.53**	-11.74**	8.21**	-3.44**
P_8	-4.49**	-1.31**	-32.25**	-21.19	29.29**	-6.60**	4.41**	-12.32**
P_2 x P_3	-0.95**	1.03**	20.03**	4.71	3.40*	19.38**	-2.53**	-2.65**
P_4	3.60**	7.76**	4.59**	4.13	13.80**	14.88**	5.68**	10.35**
P_5	0.88**	1.66**	4.92**	36.72**	32.65**	1.82**	-3.79**	-2.65**
P_6	5.10**	7.72**	9.35**	17.61*	-0.02	3.46**	-2.21**	14.40**
P_7	5.75**	-26.63**	10.49**	11.69	-68.54**	-8.30**	7.62**	-3.69**
P_8	-5.94**	-4.56**	-30.32**	-3.52	-6.36**	9.34**	8.24**	3.60**
P_3 x P_4	5.86**	8.78**	16.00**	2.52	-34.38**	14.30**	-3.45**	2.32**
P_5	-5.78**	0.23**	11.74**	6.54	36.97**	0.30**	2.23**	-2.64**
P_6	3.58**	7.15**	4.09**	8.07	66.17**	35.29**	4.02**	22.78**

Table 3. Cont'd.

P_7	3.25**	-20.57**	29.37**	8.02	-36.30**	2.21**	6.54**	2.86**
P_8	-3.05**	-2.58**	-29.70**	-10.15	-48.08**	18.75**	-12.51**	-2.91**
P_4 x P_5	1.58**	13.09**	1.61*	0.95	19.49**	-10.33**	-3.38**	2.53**
P_6	14.12**	9.35**	5.10**	8.14	68.41**	14.29**	11.49**	22.29**
P_7	5.07**	-19.99**	8.95**	7.63	-58.06**	-16.53**	3.66**	-2.35**
P_8	3.75**	3.15**	-46.59**	-20.51*	-59.24**	4.17**	-8.32**	-3.47**
P_5 x P_6	-3.45**	21.22**	14.75**	3.95	44.76**	-23.40**	4.80**	-0.89
P_7	-3.65**	-9.41**	22.66**	19.32*	-26.17**	0.91**	-17.11**	0.02
P_8	-7.58**	-18.43**	-34.94**	-17.78*	117.55**	-3.04**	2.30**	-12.13**
P_6 x P_7	13.92**	0.16	2.24**	-4.78	39.05**	12.65**	2.20**	0.29
P_8	-3.78**	-4.80**	-25.12**	-5.37	21.33**	-7.64**	-11.87**	-3.40**
P_7 x P_8	-7.30**	-29.13**	-21.38**	-22.92**	6.81**	-11.46**	-8.53**	2.50**
SE	0.09	0.08	0.73	8.21	2.02	0.06	0.09	0.48
CD (5%)	0.18	0.17	1.48	16.69	4.11	0.13	0.19	0.97
CD (1%)	0.24	0.23	1.99	22.42	5.52	0.17	0.26	1.30

* Significant at 5% level of probability, ** Significant at 1% level of probability

Seeds per fruit

Significant positive heterosis were manifested by 16 crosses varying from 3.40 to 117.55 % (Table 3). The highest heterotic value was achieved by the hybrid P_5 x P_8 (117.55%) followed by the crosses P_4 x P_6 (68.41%), P_1 x P_5 (67.56%), and P_1 x P_4 (65.50%) and the lowest positive heterosis was provided by the hybrid P_2 x P_3 (3.40%) . El-Ahmadi and Stevens (1979b) and Ahmad (2002) reported higher degree of heterosis for this trait.

1000-seed weight

Highly significant positive heterosis regarding 1000-seed weight was observed by 19 hybrids indicating seed quality can be improved through hybridization (Table 3). This result is in accordance with the findings of Subburamu *et al.* (1999).

Total soluble solids

Out of 28 crosses, positive highly significant heterosis regarding total soluble solids was found in 18 hybrids. The highest positive heterosis (11.49 %) was observed by the cross P_4 x P_6 (11.49%) followed by that in $P_1 \times P_2$ (10.25 %) and the lowest positive heterosis was recorded in the cross $P_1 \times P_4$ (1.36%) (Table 3). This result is in accordance with the findings of Bhatt *et al.* (1999).

Shelf life

Shelf life is one of the most important physical attributes for tomato as increased shelf life prevents the post harvest loss with a significant manner. Here, about 50% cross combinations exhibited positive high significant heterosis with a few exceptions (Table 3). High heterosis in terms of shelf life was also revealed by Premalakshmi (2002).

Locules per fruit

Only five cross combinations out of 28 showed significant positive heterobeltiosis (Table 4). Negative heterosis was also demonstrated in most of the cross combinations by Taslim (2006). Kurian and Peter (2001) also identified heterotic hybrids for locule number in tomato.

Fruit firmness

Appreciable positive heterosis ranging from 4.61 % to 33.33 % was recorded by several hybrids over the best parental lines for this character (Table 4). Premalakshmi (2002) mentioned high heterosis over better parents with other qualitative characters.

Fruit flesh thickness

Highly significant heterosis was manifested by majority of the cross combinations towards positive heterosis over better parental lines (Table 4). The 12 hybrids exhibited more than 10 % heterosis indicating improvement on fruit quality like flesh thickness is possible with a significant manner through heterosis breeding. Positive heterosis in relation to flesh thickness was also observed by the several workers such as Dhaliwal *et al.* (1999), Sharma *et al.* (2001) and Makesh *et al.* (2002).

Table 4. Percent heterosis over better parent in summer season for locules per fruit, fruit firmness and flesh thickness.

Cross combinations	Locules/fruit	Fruit firmness	Flesh thickness (mm)
P_1 x P_2	-20.01**	15.98**	0.60**
P_3	-18.41**	33.33**	-13.38**
P_4	-30.07**	23.10**	3.20**
P_5	-46.81**	5.86**	-6.09**
P_6	-14.57**	14.27**	9.24**
P_7	37.88**	19.26**	0.82**
P_8	-22.38**	15.99**	-6.31**
P_2 x P_3	27.83**	-1.54**	6.91**
P_4	-2.37**	-3.84**	12.86**
P_5	-36.57**	-20.43**	7.05**
P_6	7.33**	-8.40**	36.23**
P_7	-57.07**	8.29**	49.81**
P_8	29.17**	-7.39**	19.69**
P_3 x P_4	-2.51**	-16.83**	9.55**
P_5	-41.00**	-14.29**	5.76**
P_6	-20.33**	-14.67**	21.52**
P_7	-19.51**	11.70**	21.00**
P_8	0.00	-35.62**	13.07**
P_4 x P_5	-43.36**	-4.29**	13.02**
P_6	-33.33**	-4.67**	-12.07**
P_7	-39.75**	6.60**	-23.52**
P_8	-16.32**	0.00	-39.48**
P_5 x P_6	-12.09**	-13.20**	16.06**
P_7	-4.55**	4.61**	23.80**
P_8	-55.40**	-33.33**	-4.51**
P_6 x P_7	5.96**	13.47**	-1.96**
P_8	-11.00**	-1.73**	65.25**
P_7 x P_8	-52.39**	-15.73**	88.75**
SE	0.13	0.06	0.15
CD (5%)	0.27	0.13	0.31
CD (1%)	0.37	0.17	0.42

* Significant at 5% level of probability, ** Significant at 1% level of probability.

Based upon the above results and discussion, it is clear that appreciable heterosis towards desirable direction were manifested by all the characters studied. In addition, it can be concluded that the improvement of yield and yield contributing characters including qualitative attributes in tomato can be accomplished through heterosis breeding. The presence of high heterosis indicated genetic diversity within the parental lines. Therefore, the hybrids those are capable enough to express better yield potential with acceptable qualitative performances as compared to the existing varieties could be used for commercial utilization.

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