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Heterosis and inbreeding depression for agro-morphological characters in tomato, *Lycopersicon esculentum* Mill

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ABSTRACT

Line x tester mating design was used to determine heterotic cross combinations in tomato. Heterosis and inbreeding depression in twenty seven crosses from twelve diverse parents and genetic variability studies were carried out during Rabi 2006-2008. The heterobeltiosis and standard heterosis were obtained for fruit yield and its components. Hybrid RCMT-1/DVRT-2, JTP-02-07/DVRT-2 for days to 50 per cent flowering, RCMT-1/DVRT-2 for determinate type of plant habit, Pant T-8/CO-3 and KS-227/CO-3 for fruit set (%), RCMT-1/CO-3 for number of fruits per plant, Pant T-8/DVRT-2 and JTP-02-07/DVRT-2 for average fruit weight (g) and Local-2/DVRT-2 for total fruit yield/plant (kg) were reported promising on the basis of all types of heterosis. However the highest heterobeltiosis was observed in Improved Shalimar/CO-3, Local-2/DVRT-2 and Pant T-8/DVRT-2 and standard heterosis in Local-2/DVRT-2 and Pant T-8/DVRT-2 for total fruit yield per plant. A high degree of heterosis for other traits in desired direction was also observed. The inbreeding depression for fruit yield was found high in fourteen hybrids while only five hybrids viz Local-2/CO-3, KS-229/Cherry Raipur, Imp Shalimar/DVRT-2, Pant T-8/CO-3 and Local-2/DVRT-2 exhibited significant negative inbreeding depression indicating slight improvement in F_2.

Keywords: Tomato; heterosis; inbreeding depression; earliness; agro-morphological characters

INTRODUCTION

Tomato, *Lycopersicon esculentum* Mill is one of the most important solanaceous vegetable crops grown for use as fresh and processing world over due to its wide adaptability range of cultivation under various agro-climatic conditions. It is estimated that only 10 per cent area of vegetables is under the hybrids of which tomato alone covers 36 per cent. There are several species of tomato but the fruits are edible only of two species namely *L esculentum* and *L pimpinellifolium*. Tomato hybrid breeding has played a major role in developing varieties adapted to the new agricultural and processing technologies. An example is the development of cultivars suited for mechanical harvesting which are characterized by a determinate growth habit, concentrated fruit set and firm flesh (Gould 1992). The phenomenon of hybrid vigour in tomato was first observed by Hedrick and Booth (1908) and later on by Wellington (1912). Stuckey (1916) reported that the tomato hybrids were superior to their respective better parent for yield and its components. In the present study objective was to assess the extent of heterosis and inbreeding depression present in F_1 hybrids and F_2 generations respectively.

MATERIAL and METHODS

The experimental material included twelve divergent parents consisting of nine improved lines viz Pant T-7, Pant T-8, JTP-02-09, RCMT-1, RCMT-2, KS-229, KS-227, Improved Shalimar and Local-2 and three testers (improved varieties and wild species) viz DVRT-2, CO-3 and Cherry Raipur. The seeds were sown in nursery with 15 cm line to line spacing during Rabi 2007 at Horticulture Research Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattishgarh. Five week old healthy seedlings were transplanted in the experimental plot at the spacing of 60 cm between rows and 40 cm between plant to plant. A plot size of 4.2 x 3.5 m was kept for each genotype. The genotypes were grown during Rabi 2008 in randomized block design in three replications. The yield and its component traits were recorded from five randomly selected plants of parents, F_1s and F_2s in each replication. Data were analyzed with the line x tester model of genetic analysis (Kempthorne1957) using SPAR I (developed by the Indian Agricultural Statistics Research Institute, New Delhi, India) statistical software.

Analysing heterosis and inbreeding depression

Heterosis for each trait was worked out by utilizing the overall mean of each hybrid over replications for each trait.

Heterobeltiosis: Heterobeltiosis was calculated at the deviation of hybrid from the better parent as follows:

$$\text{Heterobeltiosis (\%)} = \left[\frac{\overline{F_1} - \overline{BP}}{\overline{BP}}\right] \times 100$$

where BP= Average performance of better parent in the respected cross combination

Standard heterosis: It was calculated as the deviation of the hybrid from the check variety in the present study as follows:

$$\text{Standard heterosis (SH)(\%)} = \left[\frac{\overline{F_1} - \overline{CV}}{\overline{CV}}\right] \times 100$$

where SH= Average performance of check variety

Inbreeding depression: It was calculated by using the following formula:

$$\text{ID}\ (\%) = \left[\frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}}\right] \times 100$$

The significance of standard heterosis was carried out by adopting 't' test as suggested by Wynne et al (1970) and heterobeltiosis was tested by 't' test as suggested by Sarawgi and Shrivastava (1988).

$$t\ (\text{heterobeltiosis}) = \left[\frac{\overline{F_1} - \overline{BP}}{\sqrt{\left(\frac{3}{8}\right) \text{Me}}}\right] \times 100$$

$$t\ (\text{standard heterosis}) = \left[\frac{\overline{F_1} - \overline{CV}}{\sqrt{s^2 \left(\frac{1}{2}\right)}}\right] \times 100$$

where $\overline{F_1}$ = Mean of the cross, $\overline{MP}$ = Mid-parental value of the cross, $\overline{BP}$= Better parental value of the cross, $\overline{CV}$ = Check variety value, Me= Estimate of error variance and s^2= Error mean square from ANOVA of particular character

The calculated 't'values were compared with 't' table values at 0.05 and 0.01 per cent probability level with 47 degrees of freedom. When the calculated 't' value was higher than the 't'table value, the heterotic value of concerned F_1 was considered as significant. Standard error of inbreeding depression was calculated as per Shyamal (1992) as under:

$$SE(I) = \sqrt{s^2{}_2 \left(\frac{1}{r} + \frac{1}{10r}\right)}$$

where $S^2{}_2$ = Error variance obtained by using parents

F_1's and F_2's significance of inbreeding depression together was tested by 't' test

$$t = \left[\frac{\overline{F_1} - \overline{F_2}}{SE\ (I)}\right]$$

The 't' value was compared against the table value of 't' at error degree of freedom (ie 218) at P= 0.05.

RESULTS and DISCUSSION

The analysis of variance for individual characters revealed significant difference among genotypes which indicated the presence of high genetic diversity among genotypes, F_1's and F_2's for the respective traits presented in Table 1.

Thus one can proceed for making desirable cross for successful exploitation of heterosis and inbreeding depression. The magnitude of heterosis and inbreeding depression for different characters among hybrid combinations and their F_2 generations are presented in Table 2.

Table 1. Analysis of variance (Parents, F_1 and F_2) for fruit yield and its component characters in tomato, L*ycopersicon esculentum* Mill

Parameter	Mean square		
	Replication	Genotypes	Error
Degrees of freedom	2	65	130
Days to 50% flowering	0.75	173.98**	1.13
Plant height (cm)	1.12	784.74**	1.23
# primary branches/plant	1.84	11.95**	0.39
# flowers/cluster	0.75	30.25**	0.72
# fruits/cluster	0.04	1.99**	0.43
Fruit set (%)	12.40	667.63**	55.85
# fruits/plant	3.68	1109.31**	1.07
Average fruit weight (g)	10.62	1103.68**	5.89
Fruit length (cm)	0.27	4.77**	0.07
Fruit width (cm)	0.11	2.76	0.05
# locules/fruit	0.04	5.36**	0.22
# calyx/fruit	1.21	1.34**	0.12
# seeds/fruit	70.87	6689.92**	84.86
Total fruit yield/plant (kg)	0.02	1.16**	0.05

** Significant at P= 0.01 level

In the present study heterosis was reported over better parent (heterobeltiosis) and over check varieties (standard heterosis) viz Avinash-2 (for fruit yield characters) whereas inbreeding depression was estimated over F_2 generation.

Days to 50 per cent flowering: Early flowering is desirable to achieve more crop per year and in the present investigation the best performing crosses having high negative heterobeltiosis for this character were found highly negative in the hybrids RCMT-1/DVRT-2, JTP-02-07/DVRT-2, Pant T-8/DVRT-2, RCMT-2/DVRT-2 and JTP-02-07/CO-3. The hybrids RCMT-1/CO-3, RCMT-1/DVRT-2, JTP-02-07/DVRT-2, RCMT-2/DVRT-2, JTP-02-07/CO-3, Pant T-8/DVRT-2 and Pant T-8/CO-3 showed negative standard heterosis for days to 50 per cent flowering. Heterosis for early flowering was also reported by Baishya et al (2001). The degree of inbreeding depression for days to 50 per cent flowering was found significant for twenty six hybrids out of twenty seven which showed their suitability for early generation selection.

Plant height (cm): For plant height heterobeltiosis ranged from -30.73 per cent (Imp Shalimar/Cherry Raipur) to 48.68 per cent (RCMT-2/CO-3). Out of twenty seven hybrids, twenty six showed significant heterosis over better parent from which eight hybrids showed significant negative heterobeltiosis for this trait. Highest negative heterobeltiosis was exhibited by hybrid Imp Shalimar/Cherry Raipur followed by RCMT-1/DVRT-2, RCMT-1/CO-3, Imp Shalimar/DVRT-2, Pant T-8/DVRT-2 and KS-229/CO-3 while eighteen hybrids exhibited significant positive heterobeltiosis for plant height.

The standard heterosis for this trait ranged from -37.31 per cent (JTP-02-07/DVRT-2) to 19.84 per cent (Pant T-8/Cherry Raipur). Twenty six hybrids out of twenty seven exhibited significant standard heterosis and eight of them showed significant negative heterosis over check variety for this character. Highest negative significant standard heterosis was reported for JTP-02-07/DVRT-2 followed by JTP-02-07/CO-3, RCMT-1/DVRT-2, RCMT-1/CO-3 and KS-227/CO-3. Remaining eight hybrids showed significant positive standard heterosis for plant height.

The range of inbreeding depression for this character was from -14.32 per cent (Imp Shalimar/CO-3) to 25.18 per cent (KS-227/Cherry Raipur). Twenty three out of twenty seven hybrids showed significant inbreeding depression for this trait and thirteen out of them had negative significant inbreeding depression. Highest and significant positive inbreeding depression was reported for the hybrid KS-227/Cherry Raipur. These findings of heterosis are similar to observations of Tiwari and Lal (2004) whereas for inbreeding depression of Pandey and Dixit (2001).

Number of primary branches per plant: Highest positive heterobeltiosis was observed for Local-2/Cherry Raipur, KS-229/CO-3, Pant T-8/DVRT-2, Pant T-8/CO-3, KS-229/DVRT-2 and Local-2/CO-3 whereas the highest positive standard heterosis was exhibited by Imp Shalimar/CO-3 followed by KS-229/CO-3, Imp Shalimar/DVRT-2 and JTP-02-07/Cherry Raipur for number of primary branches per plant. This character is directly correlated to the fruit yield per plant; the hybrids showing high heterosis can be utilized for improvement of yield.

In case of inbreeding depression it was highest for JTP-02-07/Cherry Raipur followed by RCMT-1/Cherry Raipur, KS-229/DVRT-2, RCMT-1/DVRT-2 and RCMT-2/DVRT-2. Eight hybrids out of twenty seven showed significant negative inbreeding depression for this character indicating slight improvement in plant height. Hence desirable segregants can be isolated for further evaluation. These findings are similar to the findings of Tiwari and Lal (2004) whereas for inbreeding depression of Pandey and Dixit (2001).

Number of flowers per cluster: The hybrids Pant T-8/DVRT-2, Imp Shalimar/DVRT-2, JTP-02-07/DVRT-2, RCMT-1/CO-3, RCMT-1/DVRT-2 and Imp Shalimar/CO-3 showed significant positive heterobeltiosis whereas RCMT-1/Cherry Raipur followed by Pant T-8/DVRT-2, RCMT-1/CO-3, JTP-02-07/Cherry Raipur and Imp Shalimar/DVRT-2 showed high significant standard heterosis. However high level of inbreeding depression was expressed by the hybrids like JTP-02-07/ DVRT-2 followed by Pant T-7/Cherry Raipur, JTP-02-07/Cherry Raipur, RCMT-2/DVRT-2 and Pant T-7/DVRT-2 due to presence of recessive genes in F_2. These results of heterosis are in accordance with the findings of Hannan et al (2007) whereas for inbreeding depression Singh and Rai (1990) reported similar findings.

Number of fruits per cluster: Highly significant positive heterobeltiosis was exhibited by only three hybrids viz Pant T-8/DVRT-2, Imp Shalimar/DVRT-2, RCMT-1/CO-3, Pant T-7/CO-3, KS-227/CO-3, Local-2/CO-3 and Pant T-8/ CO-3 whereas Pant T-8/DVRT-2 had highest standard heterosis followed by Imp Shalimar/DVRT-2, RCMT-1/CO-3, RCMT-1/Cherry Raipur, Local-2/CO-3 and Pant T-7/Cherry Raipur that showed significant positive standard heterosis for fruit length.

The high inbreeding depression for fruit length was observed in thirty one hybrids and only six hybrids had sufficient negative inbreeding depression for this character. The hybrids showing high degree of inbreeding depression were Pant T-7/ Cherry Raipur which showed highest depression followed by Pant T-7/CO-3, Pant T-7/DVRT-2, RCMT-1/CO-3, Pant T-8/DVRT-2 and Pant T-8/CO-3 indicating chances for early selection.

These hybrids with high per se performance need not to be the one with high sca effects and vice-versa. Similar results for heterosis were reported by Mohamed and Gaafer (2003).

Fruit set (%): The heterosis over better parent was found positively significant in four hybrids and the top ranking hybrids were Pant T-8/CO-3, KS-227/CO-3, Pant T-7/CO-3 and Pant T-8/DVRT-2. Five hybrids showed significant positive standard heterosis and the top ranking hybrids were Imp Shalimar/Cherry Raipur, Pant T-8/CO-3, KS-227/CO-3, Pant T-7/CO-3 and KS-227/Cherry Raipur. The high level of inbreeding depression was exhibited by twenty three hybrids for fruit set (%) indicating that there was possibility of selection in early generation.

Number of fruits per plant: Highest positive heterobeltiosis was exhibited by the hybrid Imp Shalimar/CO-3 followed by RCMT-1/CO-3, Local-2/DVRT-2, Pant T-7/CO-3, KS-227/CO-3 and Imp Shalimar/DVRT-2. Highest standard heterosis was reported for RCMT-1/ Cherry Raipur followed by Imp Shalimar/ CO-3, Local-2/DVRT-2, RCMT-1/CO-3 and Pant T-7/Cherry Raipur. However twenty one hybrids showed significant positive level of inbreeding depression and the hybrids were Local-2/DVRT-2 followed by JTP-02-07/Cherry Raipur, Pant T-8/ DVRT-2, JTP-02-07/CO-3 and Imp Shalimar/DVRT-2. These findings are in accordance with the reports of Baishya et al (2001) and Tiwari and Lal (2004) for heterosis while Pandey and Dixit (2001) for inbreeding depression.

Average fruit weight (g): Highest positive heterobeltiosis was shown by the hybrid Pant T-8/DVRT-2 followed by JTP-02-07/ DVRT-2 and Local-2/DVRT-2. Highest positive standard heterosis was shown by Pant T-8/DVRT-2 followed by JTP-02-07/ DVRT-2, Local-2/DVRT-2, KS-229/ DVRT-2, RCMT-2/DVRT-2, Pant T-7/ DVRT-2, KS-227/DVRT-2, Imp Shalimar /DVRT-2 and Pant T-8/CO-3. Similar results were observed by Baishya et al (2001) and Joshi and Thakur (2004).

The high inbreeding depression was observed in thirteen hybrids which might be due to presence of dominance and additive X additive type of epistasis. Only three hybrids exhibited significant negative inbreeding depression for fruit weight (g) that could be further exploited by its improvement. Similar results were also suggested by Pandey and Dixit (2001).

Fruit length (cm): Highest significant standard heterosis was exhibited by twenty four hybrids and the top ranking among them were Local-2/DVRT-2, KS-229/ DVRT-2, Imp Shalimar/DVRT-2, Local-2/CO-3, RCMT-2/DVRT-2, JTP-02-07/ DVRT-2, Pant T-8/DVRT-2, RCMT-1/ DVRT-2 and KS-227/DVRT-2. The high level of inbreeding depression was shown by eighteen hybrids, the highest being in KS-229/Cherry Raipur, KS-227/CO-3, KS-227/Cherry Raipur, RCMT-1/Cherry Raipur, JTP-02-07/DVRT-2 and KS-229/ CO-3. Thus selection in early generation is possible in these hybrids. Joshi et al (2005b) reported similar findings for heterosis and Pandey and Dixit (2001) for inbreeding depression.

Fruit width (cm): The highest heterosis over better parent was exhibited by only one hybrid RCMT-1/DVRT-2. The standard heterosis was observed positively significant in eighteen hybrids. Local-2/ DVRT-2 followed by Local-2/CO-3, JTP-02-07/DVRT-2, KS-229/CO-3, KS-227/ CO-3, Pant T-7/DVRT-2 and KS-229/ DVRT-2 were found promising while the extent of inbreeding depression was found high in eighteen hybrids. Highest inbreeding depression was shown by RCMT-2/CO-3 followed by JTP-02-07/DVRT-2, Imp Shalimar/DVRT-2 and RCMT-1/CO-3. Pandey and Dixit (2001) reported similar findings for inbreeding depression.

Number of locules per fruit: The highest heterosis over better parent was exhibited by RCMT-1/CO-3, RCMT-2/DVRT-2, KS-227/CO-3, KS-229/DVRT-2 and RCMT-2/Cherry T. The standard heterosis

Table 2. Heterosis (over mid-parent, better parent and check variety) inbreeding depression for fruit yield and component characters

Hybrid	Days to 50% flowering			Plant height (cm)			# primary branches/plant			# flowers/cluster		
	HB	SH	ID	HB	SH	ID	HB	SH	ID	HB	SH	ID
Pant T-7/DVRT-2	5.22*	-4.54*	-8.34*	6.71*	-10.57*	-0.53	-4.91*	-13.69*	-2.50*	3.66	38.85*	47.93*
Pant T -7/CO-3	5.45*	-7.52*	0.16	16.65*	-13.51*	-3.52*	-2.98	-3.08*	3.97*	-26.78*	11.89*	32.09*
Pant T -7/Cherry Raipur	60.13*	2.70*	33.29*	22.16*	19.84*	-12.67*	-40.09*	-1.38	-2.18*	-35.16*	46.20*	55.57*
Pant T-8/DVRT-2	-4.20*	-13.09*	8.14*	-3.45*	-18.02*	5.18*	12.80*	2.38*	0.08	35.41*	81.37*	45.27*
Pant T -8/CO-3	0.29*	-12.04*	5.67*	1.23*	-24.94*	-5.73*	7.92*	6.85*	3.53*	-36.89*	-3.55	22.49*
Pant T -8/Cherry Raipur	65.49*	6.14*	1.92*	0.30*	10.24*	3.86*	-44.86*	-9.23*	7.63*	-39.51*	36.40*	29.92*
JTP-02-07/DVRT-2	-7.11*	-15.72*	-11.15*	1.51*	-37.31*	-3.25*	5.25*	-4.46*	-0.64	19.58*	60.17*	57.92*
JTP-02-07/CO-3	-2.99*	-14.92*	-19.38*	0.02	-36.34*	-1.52	-5.75*	-6.69*	6.84*	-12.35*	33.95*	25.89*
JTP-02-07/Cherry Raipur	49.82*	-3.91*	8.23*	43.51*	-8.65*	2.27*	-34.25*	8.23*	21.82*	-21.03*	78.06*	55.26*
RCMT-1/DVRT-2	-12.12*	-21.68*	7.40*	-16.37*	-36.14*	-5.35*	-4.49*	-9.85*	-7.51*	10.98*	48.65*	29.10*
RCMT-1/CO-3	-0.11*	-21.97*	-13.36*	-10.52*	-33.66*	-7.08*	-8.16*	-9.08*	2.71*	17.81*	78.92*	43.84*
RCMT-1/Cherry Raipur	35.43*	-13.14*	8.18*	13.81*	-13.09*	0.06	-39.58*	-0.54	-12.92*	-17.78*	85.42*	44.48*
RCMT-2 /DVRT-2	-5.84*	-14.57*	-6.67*	-0.72*	-19.44*	6.05*	2.12	-7.31*	-3.73*	0.00	33.95*	53.34*
RCMT-2/CO-3	21.02*	6.14*	-1.11*	48.68*	10.24*	2.63*	-8.31*	-9.23*	-0.85	-10.74*	36.40*	46.99*
RCMT-2/Cherry Raipur	44.04*	-7.61*	1.80*	10.17*	-10.60*	2.71*	-40.93*	-1.38	4.06*	-40.92*	33.21*	31.92*
KS-229/DVRT-2	1.19	-8.19*	5.12*	1.75*	-17.24*	-10.49*	7.37*	-2.54*	-11.29*	-10.98*	19.24*	46.56*
KS-229 /CO-3	5.07*	-7.85*	-11.82*	-1.89*	-27.26*	-6.76*	14.68*	13.54*	11.25*	-10.74*	36.40*	47.89*
KS-229/Cherry Raipur	67.08*	7.16*	2.22*	25.96*	2.46*	-4.92*	-0.38*	1.54*	-13.64*	-40.60*	33.95*	18.57*
KS-227/DVRT-2	6.29*	-3.56*	1.35*	1.56*	-24.72*	4.61*	1.89	-0.69	20.22*	-1.58	52.82*	13.39*
KS-227/CO-3	7.92*	-5.35*	3.72*	5.14*	-29.49*	-5.89*	1.01	0.00	14.62*	-29.53*	11.15*	-54.36*
KS-227/Cherry Raipur	62.88*	4.47*	10.46*	10.02*	0.10	25.18*	-43.59*	-7.15*	13.01*	-55.81*	-0.37	-116.48*
Imp.Shalimar/DVRT-2	6.28*	-3.57*	-5.47*	-5.23*	8.88*	2.16*	-9.53*	13.23*	-2.58*	23.79*	65.81*	9.09*
Imp.Shalimar/CO-3	6.58*	-6.53*	-2.08*	3.89*	-8.69*	-14.32*	-2.08*	22.54*	10.23*	5.85*	61.76*	-7.58*
Imp.Shalimar/Cherry Raipur	61.55*	3.61*	7.66*	-30.73*	13.91*	-9.47*	-35.51*	6.15*	6.52*	-67.39*	-26.47*	-213.33*
Local-2/DVRT-2	10.82*	0.55*	-3.67*	-1.18*	-12.17*	0.90	-5.42*	-14.15*	3.23*	-8.83*	43.01*	-9.68*
Local-2/CO-3	17.85*	3.36*	-3.44*	14.82*	-16.46*	-6.46*	6.68*	5.62*	8.23*	2.11	60.17*	-20.89*
Local-2/Cherry Raipur	74.57*	11.96*	0.08*	1.05*	5.61*	-5.78*	34.58*	7.69*	6.43*	-48.53*	16.05*	-16.16*

Table 2 contd…

Hybrid	# fruits/cluster			Fruit set (%)			# fruits/plant			Average fruit weight (g)		
	HB	SH	ID	HB	SH	ID	HB	SH	ID	HB	SH	ID
Pant T-7/DVRT-2	4.58	8.41*	30.86*	-8.96*	-22.86*	-33.76	-19.27*	-12.87*	6.17*	-11.81*	13.74*	1.60*
Pant T -7/CO-3	19.93*	24.31*	42.65*	29.82*	10.00*	15.46	9.90*	9.66*	2.85*	-15.12*	-18.69*	-15.60*
Pant T -7/Cherry Raipur	-55.55*	31.63*	45.83*	-29.25*	-9.89*	-19.14	-79.89*	16.29*	-4.07*	-46.27*	-48.47*	-14.34*
Pant T-8/DVRT-2	62.25*	68.19*	25.00*	11.55*	-7.89*	-36.90	-2.98*	4.70*	12.39*	14.55*	47.74*	2.59
Pant T -8/CO-3	11.64*	15.72*	22.59*	42.78*	17.90*	-1.20	-20.49*	-16.54*	4.74*	-8.75*	3.54*	-1.27
Pant T -8/Cherry Raipur	-65.86*	1.10	-17.54*	-43.06*	-27.48*	-70.61	-86.52*	-22.05*	7.51*	-39.59*	-31.45*	9.80
JTP-02-07/DVRT-2	-22.68*	8.41*	19.06*	-43.81*	-31.88*	-90.51*	-7.75*	-0.45	6.56*	7.66*	38.86*	1.56
JTP-02-07/CO-3	-22.68*	8.41*	-1.18	-34.08*	-20.08*	-40.91	-0.22*	-0.45	11.41*	-12.08*	-4.40*	13.02*
JTP-02-07/Cherry Raipur	-62.53*	10.97*	4.45	-52.45*	-39.44*	-119.67*	-83.97*	-7.31*	15.28*	-52.60*	-48.46*	-11.42
RCMT-1/DVRT-2	-16.31*	-6.22*	0.58	-50.25*	-37.70*	-44.23	-43.54*	-39.07*	-7.77*	-22.19*	0.35	4.18
RCMT-1/CO-3	40.29*	57.22*	26.74*	-29.86*	-12.17*	-28.65	20.22*	19.95*	6.36*	-9.37*	-15.82*	5.78
RCMT-1/Cherry Raipur	-49.38*	49.91*	19.51*	-36.62*	-19.28*	-45.34	-78.52*	24.24*	-0.78	-50.57*	-54.09*	6.79
RCMT-2 /DVRT-2	-35.12*	-18.28*	21.70*	-37.61*	-36.62*	-60.63	-14.11*	-7.31*	-3.47*	-8.68*	17.77*	5.50
RCMT-2/CO-3	-19.74*	1.10	18.63*	-28.61*	-27.48*	-56.17	-21.87*	-22.05*	7.51*	-38.85*	-31.45*	2.50
RCMT-2/Cherry Raipur	-67.34*	-3.29*	-11.53*	-44.31*	-29.07*	-65.55	-85.06*	-13.32*	-0.26	-35.46*	-27.64*	8.80
KS-229/DVRT-2	-15.34*	-12.25*	8.33*	-6.76*	-27.64*	-75.36	-8.14*	-0.87	-0.32	-0.98*	27.71*	0.09
KS-229 /CO-3	-21.16*	-18.28*	-2.91	-19.22*	-39.71*	-100.47*	-9.25*	-9.46*	4.73*	-9.77*	3.74*	4.27
KS-229/Cherry Raipur	-69.13*	-8.59*	-26.00	-47.65*	-33.33*	-60.12	-84.71*	-11.59*	-30.69*	-44.61*	-36.31*	0.98
KS-227/DVRT-2	9.34	13.35*	1.61	-12.88*	-26.19*	-14.43	-22.46*	-16.32*	10.77*	-12.25*	13.17*	66.36*
KS-227/CO-3	19.29*	24.31*	-1.47	31.68*	11.57*	33.88	7.97*	7.72*	-8.46*	-0.55	-15.57*	38.86*
KS-227/Cherry Raipur	-64.19*	6.03*	-15.52*	-16.44*	6.42*	46.05	-81.60*	6.44*	7.47*	-47.14*	-55.13*	-17.04*
Imp.Shalimar/DVRT-2	58.73*	64.53*	4.44*	-18.69*	-1.43*	-5.86	3.99*	12.23*	11.39*	-13.49*	11.57*	49.02*
Imp.Shalimar /CO-3	-14.11*	-10.97*	-19.10*	-55.43*	-45.96*	-14.60	22.81*	22.53*	-0.87	-2.97*	1.94*	53.34*
Imp.Shalimar/Cherry Raipur	-69.94*	-10.97*	-109.45*	-5.53*	20.32*	32.96	-89.65*	-40.14*	0.00	-45.58*	-42.83*	42.95*
Local-2/DVRT-2	-18.55*	-3.66*	-36.62*	-18.26*	-32.12*	-23.63	12.14*	21.02*	16.49*	4.19*	34.38*	56.04*
Local-2/CO-3	13.29*	34.00*	-5.05*	-0.04	-16.98*	12.81	-12.28*	-9.66*	-0.82	-35.11*	-18.69*	38.93*
Local-2/Cherry Raipur	-64.19*	6.03*	-29.31*	-28.88*	-9.42*	-18.65	-87.76*	-29.19*	-34.55*	-37.40*	-21.56*	53.38*

Table 2 contd…

Hybrid	Fruit length (cm)			Fruit width (cm)			# locules/fruit		
	HB	SH	HB	HB	HB	ID	HB	SH	ID
Pant T-7/DVRT-2	-11.13	19.85*	1.41*	-17.18*	31.70*	6.65*	-43.34*	-25.80*	-9.27*
Pant T -7/CO-3	-14.75	7.75*	6.97*	-19.65*	7.47*	-3.60*	-2.50	24.57*	3.35*
Pant T -7/Cherry Raipur	-33.00*	-34.14*	-9.93*	-27.36*	-2.84*	10.88*	-6.61	-9.83*	-3.54
RCMT-1/DVRT-2	-9.11	23.24*	1.96*	22.85*	22.68*	14.50*	-1.12	29.48*	39.28*
RCMT-1/CO-3	-2.55*	0.97	-14.39*	-11.46	15.46*	14.51*	32.11*	-13.27*	-44.48*
RCMT-1/Cherry Raipur	-52.32*	-35.35*	14.98*	-36.89*	-36.08*	-58.06*	-41.34*	-44.23*	-124.67*
RCMT-2 /DVRT-2	-5.21	27.85*	8.52*	-31.12*	9.54*	3.06*	25.14*	63.88*	26.54*
RCMT-2/CO-3	-4.95*	-26.63*	11.55*	-10.73	20.10*	45.06*	-37.50*	-19.66*	-16.21*
RCMT-2/Cherry Raipur	-44.47*	-35.59*	23.68*	-19.77*	-11.08*	-64.35*	20.48*	-13.27*	-16.15*
KS-229/DVRT-2	1.83	48.43*	2.28*	-19.61*	27.84*	9.48*	21.38*	58.97*	-0.46
KS-229 /CO-3	-33.72*	-3.39*	11.78*	-1.90	32.73*	-6.60*	-7.69	17.94*	-8.33*
KS-229/Cherry Raipur	-44.35*	-18.89*	22.09*	-18.28*	10.57*	-1.40*	-47.07*	-24.57*	-4.23
KS-227/DVRT-2	-9.33	22.28*	9.31*	-21.39*	25.00*	2.89*	-2.44	27.76*	9.62*
KS-227/CO-3	-26.05*	-6.54*	18.65*	1.86	31.96*	3.71*	21.73*	55.53*	5.21*
KS-227/Cherry Raipur	-42.29*	-31.96*	18.15*	-40.99*	-26.55*	-75.09*	-39.79*	-42.75*	-11.59*
Imp.Shalimar/DVRT-2	8.44	46.25*	-14.74*	-43.11*	-9.54*	19.09*	-11.26*	16.22*	6.98*
Imp.Shalimar /CO-3	-6.32	18.40*	-13.09*	-6.13	22.42*	13.89*	-20.58*	1.47	7.99*
Imp.Shalimar/Cherry Raipur	-44.77*	-36.08*	6.06*	-41.88*	-31.70*	12.08*	-3.31	-6.63*	21.05*
Local-2/DVRT-2	11.67	50.61*	-0.64	-6.16	49.23*	5.01*	-27.73*	119.41*	9.29*
Local-2/CO-3	14.37	44.55*	3.35*	11.86	45.88*	-1.77*	-19.88*	0.00	-10.57*
Local-2/Cherry Raipur	-20.12*	0.00	-1.21	-31.69*	-14.43*	-2.41*	-38.93*	-23.10*	-24.60*

Table 2 contd…

Hybrid	# calyx/fruit			# seeds/fruit			Total fruit yield/plant (kg)		
	HB	SH	ID	HB	SH	ID	HB	SH	ID
Pant T-7/DVRT-2	9.76	13.88*	-0.49	-45.25*	75.56*	-63.50*	-36.46*	-30.98*	2.84*
Pant T -7/CO-3	1.59	8.07*	7.99*	-26.04*	118.63*	6.20	-10.82	-32.16*	5.78*
Pant T -7/Cherry Raipur	0.00	-4.88*	1.38	70.55*	21.98*	4.71	-36.56	-53.73*	9.32*
Pant T-8/DVRT-2	-19.26*	10.13*	-20.95*	-55.84*	37.92*	4.51	9.39	18.82*	3.63*
Pant T -8/CO-3	-1.93	33.77*	14.45*	-11.89*	122.63*	8.21	-31.43*	-34.12*	-2.38*
Pant T -8/Cherry Raipur	-16.51*	13.88*	-13.67*	84.27*	27.54*	4.70	-58.37*	-60.00*	-1.96
JTP-02-07/DVRT-2	0.00	28.89*	-9.17*	-62.87*	29.10*	10.00	-21.66	-14.90*	3.69*
JTP-02-07/CO-3	-11.64*	13.88*	-13.67*	-41.91*	72.16*	3.26	-4.63	-27.45*	0.54
JTP-02-07/Cherry Raipur	-21.69*	0.94	8.92*	101.33	34.46*	8.78	-50.27*	-63.92*	-3.26
RCMT-1/DVRT-2	-13.49*	-3.75*	-7.21*	13.06*	103.70*	5.87	-28.89*	-22.75*	0.51
RCMT-1/CO-3	-11.63	-1.69	-1.15	16.87*	108.79*	2.48	0	-23.92*	-1.55
RCMT-1/Cherry Raipur	-6.24	4.32*	11.87*	23.90*	3.05*	1.94	-31.68	-56.86*	-1.82
RCMT-2 /DVRT-2	-9.58	-6.19*	2.00*	48.28*	74.88*	3.82	-23.46	-16.86*	-0.47
RCMT-2/CO-3	7.05	13.88*	2.80*	-9.22*	27.54*	0.44	-49.50*	-60.00*	-1.96
RCMT-2/Cherry Raipur	12.88	10.13*	4.60*	16.38*	0.00	-0.22	-38.86*	-49.41*	3.10*
KS-229/DVRT-2	-13.82*	8.82*	3.45*	7.14*	88.11*	3.62	-10.47	-2.75*	3.63*
KS-229 /CO-3	-15.89	6.19*	-2.47*	-66.49*	38.18*	-9.62	-14.22	-29.02*	-0.55
KS-229/Cherry Raipur	-8.17	15.95*	-0.32	-6.19*	-9.16*	-36.42	-46.92*	-56.08*	-7.14*
KS-227/DVRT-2	-9.88	2.63*	-6.03*	-7.49*	109.47*	-8.18	-32.49*	-26.67*	6.42*
KS-227/CO-3	0.00	13.88*	7.74*	-36.68*	60.03*	-2.66	9.28	-29.80*	5.59*
KS-227/Cherry Raipur	-14.33*	-2.44*	-7.69*	70.73*	22.05*	-6.07	-40.37	-62.35*	-2.08
Imp.Shalimar/DVRT-2	19.89*	28.89*	28.68*	2.94*	64.57*	-1.48	-8.66	-0.78	-7.11*
Imp.Shalimar /CO-3	3.49	11.26*	7.25*	-49.71*	7.40*	-13.84	21.13	-7.84*	0.00
Imp.Shalimar/Cherry T	-34.90*	-30.02*	-98.39*	78.75*	25.30*	7.53	-58.38*	-73.73*	5.97*
Local-2/DVRT-2	-8.03	13.88*	-5.44*	21.70*	75.22	-7.79	16.97	27.06*	-1.23*
Local-2/CO-3	1.97	26.27*	10.85*	-12.68*	40.62	-4.95	-41.29*	-43.14*	-17.24*
Local-2/Cherry Raipur	-22.27*	-3.75*	-7.21*	95.63*	32.15	-7.05	-56.28*	-57.65*	1.85

*Significant at P= 0.01 level, HB = Hetero beltiosis, SH = Standard heterosis, ID = Inbreeding depression was observed positively significant in twenty four hybrids, some Local-2/DVRT-2, RCMT-2/DVRT-2, KS-229/DVRT-2, KS-227/CO-3, RCMT-1/DVRT-2, KS-227/DVRT-2, Pant T-7/CO-3 and KS-229/CO-3 were found promising. The extent of inbreeding was found high in twelve hybrids. Highest inbreeding depression was shown by RCMT-1/DVRT-2 followed by RCMT-2/DVRT-2, Imp Shalimar/Cherry Raipur, KS-227/DVRT-2 and Local-2/DVRT-2. Similar results for heterosis were obtained by Joshi et al (2005a) and Sharma et al (2006).

Number of calyces per fruit: The heterobeltiosis of this trait was found highest in Imp Shalimar/DVRT-2. Pant T-8/CO-3, JTP-02-07/DVRT-2, Imp Shalimar/DVRT-2, Local-2/CO-3, Local-2/DVRT-2, RCMT-2/CO-3 and JTP-02-07/CO-3 hybrids exhibited significantly positive standard heterosis for this character.

The inbreeding depression for this trait was observed highly positive in eleven hybrids. The top ranking hybrid was Imp Shalimar/DVRT-2 followed by Pant T-8/CO-3, RCMT-1/Cherry Raipur, Local-2/CO-3 and JTP-02-07/Cherry Raipur while eleven hybrids showed negative inbreeding depression which indicated slight improvement in F_2 generation.

Number of seeds per fruit: Highest negative heterobeltiosis was shown by the hybrid KS-227/CO-3 followed by JTP-02-07/DVRT-2, Pant T-8/DVRT-2, Imp Shalimar/CO-3, Pant T-7/DVRT-2 and JTP-02-07/CO-3. Highest negative standard heterosis was shown by only KS-229/Cherry Raipur. Most of the hybrids showed negative relative heterosis, heterobeltiosis and standard heterosis.

The high inbreeding depression was observed in twenty six hybrids which may be due to presence of dominance and additive x additive epistasis. Only one hybrid exhibited significant negative inbreeding depression for this trait indicating the possibilities of selection for traits with less number of seeds.

Total fruit yield per plant (kg): Four hybrids showed significant positive heterobeltiosis. The hybrids showing highest heterobeltiosis were Imp Shalimar/CO-3 followed by Local-2/DVRT-2, Pant T-8/DVRT-2 and KS-227/CO-3. Highest positive standard heterosis was shown by Local-2/DVRT-2 and Pant T-8/DVRT-2.

The inbreeding depression for this character was found high in fourteen hybrids. The hybrid showing higher inbreeding depression was Pant T-7/Cherry Raipur followed by KS-227/DVRT-2, KS-227/CO-3, Imp Shalimar/Cherry Raipur and Pant T-7/CO-3 while only five hybrids exhibited significant negative inbreeding depression viz Local-2/CO-3, KS-229/Cherry Raipur, Imp Shalimar/DVRT-2, Pant T-8/CO-3 and Local-2/DVRT-2 indicating slight improvement in F_2. Similar reports for heterosis were suggested by Bhatt et al (2001), Pandey and Dixit (2001), Mohamed and Gaafer (2003), Joshi and Thakur (2004) and Hannan et al (2007). The results of inbreeding depression are in accordance with the results of Pandey and Dixit (2001) and Singh et al (2009). Hence utilization of superior cross combination may be advantageous for exploitation of hybrid vigor for perusing the better plant type of respective autogamous crop ie tomato.

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