Indian J. Hort. 69(4), December 2012: 555-561

Studies on heterosis using heat tomato tolerant lines

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ABSTRACT

Fruit set in tomato is reduced markedly, when average maximum day and night temperatures go above 32°C and 21°C, respectively. In North-Western plains of India, if the tomato crop is transplanted in March, flowering and fruit set period coincides with high day (~37°C) and night temperatures (~25°C), which markedly reduces fruit yield and quality. Therefore, the present study was carried out to identify the heterotic hybrids in tomato, tolerant to heat stress conditions. The 66 F_1 hybrids showed useful heterosis for almost all characters studied. Based on *per se* performance and heterosis estimates under high temperature condition, the best performing cross is LST-36-1 × LST-35-1 ($P_6 \times P_7$) for maximum fruit firmness; LST-37-1 × LST-36-1 ($P_5 \times P_6$) for maximum Endosperm Utilization Efficiency (EUE) and the cross combination, LST-6 × CLN 5915-206 ($P_8 \times P_{11}$) for maximum total fruit yield. The hybrid, $P_8 \times P_{11}$ had fruit yield of 1.17 kg per plant and it showed 193.3 per cent increase over better parent and 291.11 per cent increase over standard check TH-1.

Key words: Tomato, heterosis, endosperm utilization efficiency, diallel cross, heat tolerance.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a member of family Solanaceae, is being extensively grown all over the world for both fresh market and processing. The critical factor in setting of tomato fruits is night temperature, the optimum range being 15° to 21°C. Fruit set is reduced markedly, when average maximum day temperature goes above 32°C and average minimum night temperature goes above 21°C. The genotypes which can set fruit above the critical temperature are called high temperature tolerant cultivars. Besides, high temperature also affects quality of tomato fruits. At temperature above 30°C, red colour is suppressed and temperature above 40°C, lycopene pigment is destroyed and no red colour is developed further resulting in yellow shoulders. High temperature also causes scalding in fruits (Hazra and Som, 8).

In North-Western plains of India, the main season tomato crop is transplanted during end November to early December and fruit availability from this crop is very short, *i.e.*, from mid-April to end-May. Excess production of tomato during this short period of time leads to glut coupled with low prices and this period is followed by a period of scarcity and high prices in market. If the tomato crop is transplanted in March the flowering and fruit setting period coincides with high day (~37°C) and night temperature (~25°C) (Fig. 1.), which markedly reduces fruit yield and quality. Moreover, Gaikwad *et al.* (7) reported that, most of the heat tolerance contributing traits in tomato are governed by the non-additive gene effects, which can be furtherer improved by heterosis breeding. Therefore, the present study was carried out to identify the heterotic hybrids tolerant to heat stress conditions in tomato.

MATERIALS AND METHODS

The experimental material consisted of twelve genetically diverse heat tolerant lines, *viz*., LST-65-2 (P_1), Nagcarlan (P_2), S-12 (P_3), LST-48 (P_4), LST-37-1 (P_5), LST-36-1 (P_6), LST-35-1 (P_7), LST-6 (P_8), LST-17 (P_9), LST-16-1 (P_{10}), CLN 5915-206 (P_{11}) and 2123-E-1 (P_{12}) and 66 F_1 hybrids developed by crossing them in a diallel mating design excluding reciprocals. The experiment was conducted in a randomized complete block design (RBD) with three replications at Department of Vegetable Crops, PAU, Ludhiana. Each replication comprised of two rows with seven plants in each row with spacing of 135 cm × 30 cm. The observations were recorded on five randomly marked plants leaving a border plant at each corner. All the recommended cultural practices and plant protection measures were followed (Mahindra, 9). Cheema *et al.* (2) reported that the genotypes have high endosperm utilization efficiency (EUE) at high temperature will be vigorous and heat tolerant, thus facilitating their identification at early stage. EUE was calculated as the ratio of seedling dry mass gain to seed dry mass loss after ten days since germination had started (Blum and Sinmena, 1), where the seedling dry mass refers to the combined weight of root and shoot and the seed dry mass to the remaining seed weight. Firmness was measured on fruits of

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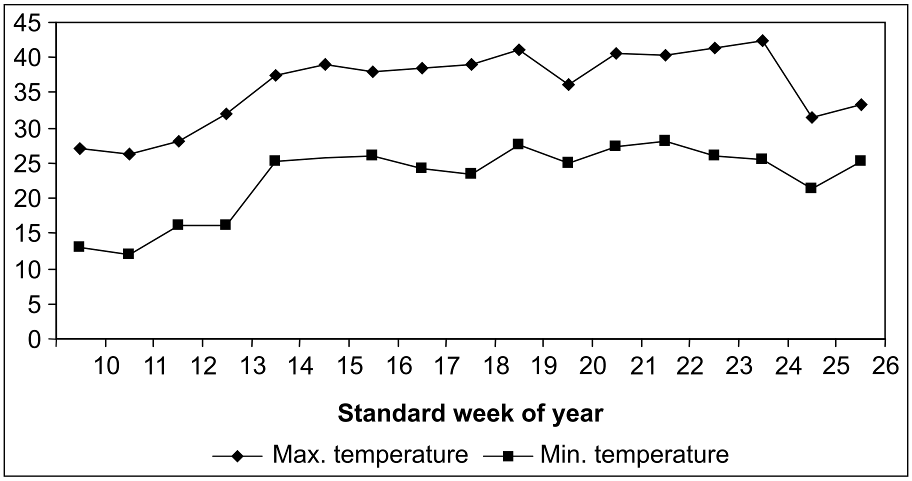

Fig. 1. Weekly maximum and minimum air temperature (°C) recorded during the crop season (March-June, 2006).

comparable maturity by a locally designed non-destructive pressure tester. It expresses deformation of pericarp in millimetres in response to the applied load of 500 g for 10 sec. on stem end of the fruit. The degree of deformation holds inverse relationship with the firmness of the fruit, *i.e.*, the lower the value; the firmer is the fruit (Dhatt and Singh, 4). The data were subjected to statistical analysis by using computer software package SPAR-1 and significance of heterosis over the better parent was tested by using 't-test'. Heterosis over the standard checks was calculated by dividing the deviation between the F_1 and check, by mean performance of check.

RESULTS AND DISSCUSSION

The analysis of variance revealed that mean square due to genotypes were highly significant for all characters studied, indicating sufficient variability among these genotypes (Table 1). The parent P_{12} was earliest to flowering which took 65.33 days to anthesis, while P_2 took the longest duration of 89.67 days (data not shown). Among crosses, $P_2 \times P_8$ took the minimum (61 days) from sowing to anthesis. Out of 66 crosses studied (Table 2a, b, c, d), only four exhibited significant heterosis over their respective better parent, the highest being in $P_5 \times P_{12}$. None of the hybrid showed significant negative heterosis over the standard checks. The findings are in consonance with Sundaram *et al.* (13). For endosperm utilization efficiency, four hybrids ($P_2 \times P_8$, $P_5 \times P_6$, $P_5 \times P_{12}$ and $P_6 \times P_8$) showed significant positive heterosis over the better parent, 24 crosses over the standard check Punjab Upma and twelve over the hybrid check TH-1. The most heterotic hybrid $P_2 \times P_8$ had 58.54 per cent endosperm efficiency and it showed 74.28 per cent increase over better parent. This cross also showed 36.98 and 24.67 per cent increase over standard checks Punjab Upma and TH-1, respectively. These findings were well supported Cheema *et al.* (2). For setting percentage, out of the 66 crosses, only four crosses ($P_5 \times P_7$, $P_6 \times P_7$, $P_6 \times P_{11}$ and $P_7 \times P_8$) exhibited significantly positive heterosis over the respective better parent and only one cross ($P_3 \times P_8$) over the standard check Punjab Upma and fifteen over hybrid check TH-1. The crosses ($P_5 \times P_7$, $P_6 \times P_7$, $P_6 \times P_{11}$ and $P_7 \times P_8$) expressed 31.38, 36.02, 40.88 and 65.88 per cent increase, respectively, over the better parents. A reterobeltotic effects for fruit setting was

Table 1. Analysis of variance for different characters in tomato.

Source of variation	df	Mean sum of square					
		Days to anthesis	Endosperm utilization efficiency (%)	Setting percentage per cluster	Fruit weight (g)	Total fruit yield (kg/ plant)	Fruit firmness
Replication	2	143.27*	12.03	133.59	60.78	0.13*	4.66**
Genotype	79	94.47*	196.39**	242.21*	530.15**	0.16**	2.70**
Error	158	39.03	28.57	114.74	54.37	0.03	0.004

*, ** significant at 5 and 1% levels, respectively.

Table 2a. Mean performance and per cent heterosis of F_1 hybrids over better parent and standard checks.

Hybrid	Days to anthesis				Endosperm utilization efficiency (%)				Setting percentage per cluster			
	Mean	Heterosis (%)			Mean	Heterosis (%)			Mean	Heterosis (%)		
		BP	PU	TH1		BP	PU	TH1		BP	PU	TH1
$P_1 \times P_2$	67.00	-9.05	-3.83	-4.74	55.48	-17.68	29.83*	18.16	55.88	1.45	13.85	51.64*
$P_1 \times P_3$	70.33	-4.52	0.96	0.00	52.68	-8.32	23.28*	12.20	56.58	2.71	15.27	53.54*
$P_1 \times P_4$	80.33	16.42	15.31	14.22	49.37	-14.08	15.54*	5.1	50.75	12.10	3.40	37.72
$P_1 \times P_5$	76.67	-0.10	10.05	9.00	61.56	7.13	44.06*	31.12*	45.98	20.28	-6.32	24.78
$P_1 \times P_6$	75.67	2.71	8.61	7.58	62.28	8.38	45.73*	32.64*	55.34	0.46	12.75	50.18*
$P_1 \times P_7$	75.67	7.08	8.61	7.58	48.57	-15.48	13.66	3.44	44.98	41.56	-8.35	22.07
$P_1 \times P_8$	67.67	-7.73	-2.87	-3.79	51.83	54.33	21.29*	10.39	46.97	-28.7	-4.31	27.45
$P_1 \times P_9$	82.67	12.22	18.66	17.54	55.15	15.44	29.05*	17.45	61.61	8.06	25.51	67.18*
$P_1 \times P_{10}$	76.00	-7.31	9.09	8.06	58.13	1.17	36.04*	23.81*	44.81	14.84	-8.71	21.60
$P_1 \times P_{11}$	76.00	-4.60	9.09	8.06	54.63	-5.08	27.84*	16.35	57.78	4.89	17.71	56.79*
$P_1 \times P_{12}$	68.67	-6.79	-1.44	-2.37	57.73	0.46	35.09*	22.95*	56.08	1.81	14.26	52.19*
$P_2 \times P_3$	74.00	-5.13	6.22	5.21	48.12	-28.61	12.61	2.48	49.40	9.54	0.65	34.06
$P_2 \times P_4$	75.00	-16.35*	7.66	6.64	56.12	1.99	31.32*	19.52	46.63	3.0	-5.00	26.54
$P_2 \times P_5$	73.67	-13.67	5.74	4.74	47.15	-30.04	10.34	0.43	51.90	35.78	5.75	40.85
$P_2 \times P_6$	74.33	-0.89	6.70	5.69	50.66	-24.84	18.54	7.89	39.43	39.76	-19.67	7.00
$P_2 \times P_7$	70.00	-0.94	0.48	-0.47	48.22	-28.46	12.84	2.70	33.23	4.57	-32.30	-9.82
$P_2 \times P_8$	61.00	-16.82*	-12.44	-13.2	58.54	74.28*	36.98*	24.67*	46.76	128.1	-4.74	26.88
$P_2 \times P_9$	75.33	-8.50	8.13	7.11	54.26	13.59	26.97*	15.56	47.76	133.0	-2.70	29.61
$P_2 \times P_{10}$	73.00	-10.97	4.78	3.79	47.39	15.97	10.89	0.92	39.77	1.92	-18.97	7.92
$P_2 \times P_{11}$	78.67	-1.26	12.92	11.85	44.16	-34.49	3.33	-5.96	37.51	83.00	-23.58	1.79
$P_2 \times P_{12}$	78.33	-12.64	12.44	11.37	37.50	-44.36	-12.25	-20.13	37.54	2.13	-23.52	1.86
$P_3 \times P_4$	72.67	-6.84	4.31	3.32	48.63	-11.61	13.81	3.58	50.37	11.27	2.62	36.69
$P_3 \times P_5$	80.67	-5.47	15.79	14.69	46.99	-14.32	9.97	0.09	36.77	-18.5	-25.09	-0.23
$P_3 \times P_6$	81.33	8.44	16.75	15.64	41.97	-23.58	-1.79	-10.61	37.89	34.30	-22.80	2.82
$P_3 \times P_7$	77.33	-0.85	11.00	9.95	51.10	-9.68	19.57	8.82	48.79	8.09	-0.60	32.39
$P_3 \times P_8$	70.33	-4.09	0.96	0.00	40.53	20.66	-5.16	-13.69	70.66	7.22	43.95*	91.74*
$P_3 \times P_9$	79.33	-3.64	13.88	12.80	37.53	-31.57	-12.18	-20.07	50.31	11.46	2.49	36.52
$P_3 \times P_{10}$	82.67	5.98	18.66	17.54	50.85	24.45	18.99	8.30	56.72	25.66	15.55	53.91*
$P_3 \times P_{11}$	74.67	-4.27	7.18	6.16	44.29	-23.04	3.65	-5.67	54.63	10.91	11.31	48.26*
$P_3 \times P_{12}$	69.33	-11.11	-0.48	-1.42	46.34	-30.49	8.43	-1.31	47.75	5.81	-2.71	29.59
$P_4 \times P_5$	77.00	-9.77	10.53	9.48	49.61	-9.83	16.09	5.66	44.91	17.47	-8.51	21.86*
$P_4 \times P_6$	67.33	-2.42	-3.35	-4.27	46.01	-16.38	7.67	-2.01	38.50	36.44	-21.57	4.47
$P_4 \times P_7$	75.33	9.18	8.13	7.11	45.65	-19.30	6.83	-2.77	25.72	-43.2	-47.59	-30.19
$P_4 \times P_8$	71.33	-2.73	2.39	1.42	42.59	26.82	-0.33	-9.29	56.39	24.55	14.88	53.02*
$P_4 \times P_9$	86.67	25.60	24.40	23.22	45.82	-16.72	7.22	-2.42	51.78	14.80	5.49	40.52
$P_4 \times P_{10}$	67.33	-2.42	-3.35	-4.27	40.83	-25.78	-4.45	-13.03	46.35	2.39	-5.57	25.78
$P_4 \times P_{11}$	69.00	-13.39	-0.96	-1.90	42.42	-26.30	-0.74	-9.66	56.48	14.68	15.08	53.28*
$P_4 \times P_{12}$	71.67	9.69	2.87	1.90	51.11	-23.33	19.60	8.85	51.06	12.79	4.03	38.56

Table 2b. Mean performance and per cent heterosis of F_1 hybrids over better parent and standard checks.

Hybrid	Days to anthesis				Endosperm utilization efficiency (%)				Setting percentage per cluster			
	Mean	Heterosis (%)			Mean	Heterosis (%)			Mean	Heterosis (%)		
		BP	PU	TH1		BP	PU	TH1		BP	PU	TH1
$P_5 \times P_6$	81.00	-5.08	16.27	15.17	67.33	22.61*	57.57*	43.40*	43.57	13.99	-11.23	18.25
$P_5 \times P_7$	82.67	-3.13	18.66	17.54	57.46	1.58	34.47*	22.38*	50.22	31.38*	2.32	36.29
$P_5 \times P_8$	69.00	-5.91	-0.96	-1.90	57.72	6.48	35.07*	22.93*	42.56	11.34	-13.28	15.5
$P_5 \times P_9$	83.33	-2.34	19.62	18.48	63.47	17.08	48.52*	35.17*	37.60	-34.04	-23.39	2.04
$P_5 \times P_{10}$	82.67	-3.13	18.66	17.54	54.57	0.67	27.71*	16.23	31.85	-18.38	-35.12	-13.58
$P_5 \times P_{11}$	77.67	-2.51	11.48	10.43	51.07	-11.26	19.52	8.77	46.71	22.19	-4.84	26.76
$P_5 \times P_{12}$	69.67	-18.3*	0.00	-0.95	66.11	21.96*	54.70*	40.80*	46.39	21.34	-5.49	25.88
$P_6 \times P_7$	85.00	20.28	22.01	20.85	46.46	-17.87	8.72	-1.05	43.22	36.02*	-11.94	17.30
$P_6 \times P_8$	78.67	7.27	12.92	11.85	54.76	63.04*	28.14*	16.63	44.82	58.85	-8.69	21.62
$P_6 \times P_9$	75.67	-8.10	8.61	7.58	38.91	-29.15	-8.95	-17.13	43.54	54.34	-11.29	18.16
$P_6 \times P_{10}$	85.00	13.33	22.01	20.85	47.61	16.52	11.41	1.40	35.61	26.22	-27.44	-3.36
$P_6 \times P_{11}$	79.00	-0.84	13.40	12.32	40.38	-29.83	-5.50	-13.99	39.75	40.88*	-19.02	7.86
$P_6 \times P_{12}$	74.67	-0.44	7.18	6.16	47.79	-28.32	11.83	1.77	42.42	15.41	-13.58	15.11
$P_7 \times P_8$	72.67	-0.91	4.31	3.32	42.86	27.61	0.30	-8.72	52.71	65.88*	7.40	43.05
$P_7 \times P_9$	74.67	-9.31	7.18	6.16	44.81	-20.78	4.87	-4.56	58.02	1.77	18.21	57.45*
$P_7 \times P_{10}$	82.00	16.03	17.70	16.59	62.58	10.63	46.45*	33.29*	42.08	7.84	-14.27	14.19
$P_7 \times P_{11}$	76.00	-4.60	9.09	8.06	52.01	-8.05	21.72	10.78	37.88	19.19	-22.83	2.79
$P_7 \times P_{12}$	70.67	8.16	1.44	0.47	46.15	-30.77	8.00	-1.71	37.27	1.40	-24.07	1.13
$P_8 \times P_9$	73.33	-10.93	5.26	4.27	29.63	-37.97	-30.66	-36.89	47.90	-27.31	-2.41	29.99
$P_8 \times P_{10}$	73.67	-10.16	5.74	4.74	35.57	5.91	-16.76	-24.24	47.21	20.99	-3.82	28.11
$P_8 \times P_{11}$	71.00	-3.18	1.91	0.95	59.26	2.95	38.67*	26.20*	51.51	4.57	4.94	39.77
$P_8 \times P_{12}$	67.67	-7.73	-2.87	-3.79	39.96	18.98	-6.49	-14.89	46.97	27.80	-4.31	27.46
$P_9 \times P_{10}$	80.67	-1.63	15.79	14.69	54.71	14.53	28.03*	16.53	45.56	16.75	-7.19	23.63
$P_9 \times P_{11}$	74.67	-6.28	7.18	6.16	46.07	-19.96	7.80	-1.89	58.87	3.26	19.94	59.76*
$P_9 \times P_{12}$	75.33	-8.50	8.13	7.11	42.13	-36.80	-1.40	-10.27	58.76	3.08	19.72	59.47*
$P_{10} \times P_{11}$	74.33	-6.69	6.70	5.69	41.09	0.55	-3.85	-12.49	38.49	-21.85	-21.58	4.45
$P_{10} \times P_{12}$	68.33	-16.6*	-1.91	-2.84	41.15	0.70	-3.71	-12.37	37.75	2.71	-23.09	2.44
$P_{11} \times P_{12}$	71.33	-10.46	2.39	1.42	48.17	-27.75	12.71*	2.58	47.80	30.06	-2.61	29.72
CD (5%)		15.61				38.37				32.64		

BP = Better parent, PU = Punjab Upma, * significant at 5% level.

also reported by Raijadhav *et al.* (12), Patgaonkar *et al.* (11), and Natrajan (10). Fruit firmness is important characteristic, determines transportation and storage quality of tomato fruits. Out of the 66 crosses studied, 49 crosses exhibited significant negative heterosis over the respective better parents and fifty seven hybrids showed significant negative heterosis over standard check TH-1. The range of the significant negative heterosis over the better parent varied from -1.58 ($P_3 \times P_5$) to - 83.96 per cent ($P_8 \times P_{12}$). The hybrid $P_6 \times P_7$ showed more firmness, and expressed 67.31 per cent more firmness over better parent.

Average fruit weight directly contributed towards total yield and has key role in acceptance of produce by the consumer. The range of the significant positive heterosis over the better parent was from 26.28 ($P_9 \times P_{12}$) to 94.79 per cent ($P_4 \times P_{11}$). The hybrid $P_3 \times P_{10}$ had maximum fruit weight of 89.22 g and it showed

Table 2c. Mean performance and per cent heterosis of F_1 hybrids over better parent and standard checks.

Hybrid	Fruit weight (g)				Total fruit yield (kg/plant)				Fruit firmness			
	Mean	Heterosis (%)			Mean	Heterosis (%)			Mean	Heterosis (%)		
		BP	PU	TH1		BP	PU	TH1		BP	PU	TH1
$P_1 \times P_2$	50.00	22.73	-7.72	8.70	1.04	215.2*	92.6*	246.6*	1.78	-23.89*	81.02	3.89
$P_1 \times P_3$	46.89	15.09	-13.47	1.93	0.63	34.04	16.67	110.0*	0.41	-67.28*	-58.3*	-76.07*
$P_1 \times P_4$	49.79	22.22	-8.10	8.25	0.58	6.06	8.02	94.44	1.29	-2.26*	31.19	-24.71*
$P_1 \times P_5$	60.67	30.0*	11.97	31.88*	0.30	29.76	-44.4	0.00	0.46	-58.00*	-53.2*	-73.15*
$P_1 \times P_6$	37.84	-7.13	-30.17	-17.75	0.66	98.98*	21.60	118.89*	0.62	-8.78*	-36.9*	-63.81*
$P_1 \times P_7$	68.29	36.59*	26.04*	48.46*	0.69	108.0*	27.16	128.89*	0.60	-48.13*	-38.9*	-64.98*
$P_1 \times P_8$	30.94	-24.34	-42.89	-32.73	0.99	200*	83.3*	230.0*	1.52	-30.86*	54.58	-11.28*
$P_1 \times P_9$	38.50	-19.42	-28.94	-16.30	0.26	13.04	-51.8	-13.33	1.70	33.24	72.88	-0.78
$P_1 \times P_{10}$	45.00	10.46	-16.95	-2.17	0.25	-54.04	-54.3	-17.78	1.76	11.18	78.98	2.72
$P_1 \times P_{11}$	35.83	59.71	-33.87	-22.10	0.39	19.19	-27.2	31.11	2.80	80.59	184.75	63.42
$P_1 \times P_{12}$	40.15	-1.75	-25.90	-12.72	0.61	21.33	12.35	102.22*	0.96	-27.20*	-2.37	-43.97*
$P_2 \times P_3$	47.67	19.71	-12.03	3.62	0.52	11.34	-3.09	74.44	1.18	-6.33*	20.00	-31.13*
$P_2 \times P_4$	48.33	-25.64	-10.80	5.07	0.16	-11.51	-70.9	-47.78	4.40	37.16	347.46	156.81
$P_2 \times P_5$	55.56	19.05	2.53	20.78	0.41	73.24	-24.1	36.67	1.51	-35.42*	53.56	-11.87*
$P_2 \times P_6$	64.45	61.11*	18.94	40.10*	0.51	78.82	-6.17	68.89	1.27	-45.66*	29.15	-25.88*
$P_2 \times P_7$	66.89	2.90	23.45*	45.41*	0.52	14.71	-3.70	73.33	0.65	-43.84*	-33.9*	-62.06*
$P_2 \times P_8$	36.58	-43.12	-32.48	-20.47	0.72	193.2*	33.95	141.11*	1.18	-46.29*	20.00	-31.13*
$P_2 \times P_9$	45.22	-30.0	-16.54	-1.70	0.34	46.37	-37.6	12.22	0.80	-32.11*	-18.6*	-53.31*
$P_2 \times P_{10}$	32.70	-50.29	-39.64	-28.91	0.30	44.44	-43.8	1.11	1.10	-2.65*	11.86	-35.80*
$P_2 \times P_{11}$	62.92	180.4	16.13	36.79*	0.65	62.50	20.37	116.67*	0.70	-37.38*	-28.8*	-59.14*
$P_2 \times P_{12}$	52.63	28.78	-2.87	14.41	0.72	44.0	33.33	140.00*	0.72	-69.13*	-26.7*	-57.98*
$P_3 \times P_4$	54.24	4.08	0.10	17.91	0.61	10.91	12.96	103.33*	1.16	-7.92*	17.97	-32.30*
$P_3 \times P_5$	56.20	20.43	3.73	22.18	0.45	88.73	-17.3	48.89	1.24	-1.58*	26.10	-27.63*
$P_3 \times P_6$	34.52	-13.69	-36.28	-24.95	0.31	8.24	-43.2	2.22	1.08	-14.25*	9.8	-36.96*
$P_3 \times P_7$	45.77	14.95	-15.52	-0.49	0.40	-15.60	-26.5	32.22	1.10	-5.16*	11.86	-35.80*
$P_3 \times P_8$	33.26	-18.69	-38.62	-27.70	0.82	75.18*	52.47	174.44*	1.22	-3.17*	24.07	-28.79*
$P_3 \times P_9$	40.00	0.45	-26.18	-13.04	0.29	27.54	-45.6	-2.22	1.10	-6.76*	11.86	-35.80*
$P_3 \times P_{10}$	89.22	35.61*	64.66*	93.96*	0.71	32.92	32.10	137.78*	0.96	-15.0*	-2.37	-43.97*
$P_3 \times P_{11}$	45.20	13.50	-16.59	-1.75	0.55	17.02	1.85	83.33	1.30	80.79	32.20	-24.12*
$P_3 \times P_{12}$	43.35	6.08	-19.99	-5.76	0.99	97.33*	82.7*	228.8*	0.95	-24.54*	-3.39	-44.55*
$P_4 \times P_5$	62.49	19.92	15.33	35.85*	0.47	97.18	-13.6	55.56	1.02	-7.25*	3.73	-40.47*
$P_4 \times P_6$	69.39	33.15*	28.06*	50.84*	0.71	29.70	32.10	137.78*	1.16	-2.16*	17.97	-32.30*
$P_4 \times P_7$	54.63	4.84	0.83	18.77	0.44	-20.61	-19.1	45.56	1.00	-13.75*	1.69	-41.63*
$P_4 \times P_8$	33.42	-35.86	-38.31	-27.34	0.34	39.19	-36.4	14.44	1.32	-10.78*	34.24	-22.96*
$P_4 \times P_9$	55.00	5.55	1.51	19.57	0.13	-76.36	-75.9	-56.67	1.56	39.78	58.64	-8.95*
$P_4 \times P_{10}$	43.00	-34.64	-20.64	-6.52	0.64	16.96	19.14	114.44*	0.89	-21.17*	-9.49*	-48.05*
$P_4 \times P_{11}$	43.70	94.79*	-19.34	-4.99	0.66	20.00	22.22	120.00*	0.63	-43.62*	-35.9*	-63.23*
$P_4 \times P_{12}$	67.88	30.26*	25.27*	47.56*	0.39	-23.03	-27.7	30.00	0.63	-57.30*	-35.9*	-63.23*

Table 2d. Mean performance and per cent heterosis of F_1 hybrids over better parent and standard checks.

Hybrid	Fruit weight (g)				Total fruit yield (kg/plant)				Fruit firmness			
	Mean	Heterosis (%)			Mean	Heterosis (%)			Mean	Heterosis (%)		
		BP	PU	TH1		BP	PU	TH1		BP	PU	TH1
$P_5 \times P_6$	51.37	10.08	-5.19	11.68	0.31	9.41	-42.59	3.33	1.18	9.08	20.00	-31.13*
$P_5 \times P_7$	56.67	13.33	4.58	23.19	0.56	24.26	4.32	87.78	0.24	-77.94*	-75.6*	-85.99*
$P_5 \times P_8$	39.05	-16.33	-27.93	-15.11	0.86	306.7*	59.26	186.67*	1.36	-38.12*	38.31	-20.62*
$P_5 \times P_9$	76.67	60.5*	41.49*	66.67*	0.26	11.27	-51.23	-12.22	0.58	-47.13*	-41.0*	-66.15*
$P_5 \times P_{10}$	65.00	39.3*	19.96	41.30*	0.37	56.34	-31.48	23.33	0.90	-18.13*	-8.47*	-47.47*
$P_5 \times P_{11}$	61.67	32.14*	13.81	34.06*	0.55	37.50	1.85	83.33	1.49	7.04	51.53	-13.04*
$P_5 \times P_{12}$	42.08	2.98	-22.33	-8.51	0.77	54.00	42.59	156.67*	0.64	-41.69*	-34.9*	-62.65*
$P_6 \times P_7$	43.83	9.58	-19.10	-4.71	0.36	27.06	-33.33	20.00	0.22	-67.31*	-77.6*	-87.16*
$P_6 \times P_8$	44.14	7.93	-18.53	-4.04	0.61	115.3	12.96	103.33*	1.87	-14.98*	90.17	9.14
$P_6 \times P_9$	80.00	67.4*	47.65*	73.91*	0.34	18.82	-37.65	12.22	1.50	6.18	52.54	-12.45*
$P_6 \times P_{10}$	49.33	23.33	-8.95	7.25	0.33	115.29*	-39.51	8.89	1.20	7.7	22.0	-29.96*
$P_6 \times P_{11}$	57.33	42.3*	5.81	24.64	0.29	3.53	-45.68	-2.22	5.70	4.6	479.66	232.68
$P_6 \times P_{12}$	45.20	10.60	-16.58	-1.74	0.62	23.99	14.81	106.67*	1.60	-67.69*	62.71	-6.61*
$P_7 \times P_8$	44.30	8.31	-18.24	-3.70	0.77	69.12*	41.98	155.56*	1.84	-16.33*	87.12	7.39
$P_7 \times P_9$	60.55	21.11	11.76	31.64*	0.60	31.62	10.49	98.89*	0.59	-48.99*	-40.0*	-65.56*
$P_7 \times P_{10}$	74.00	12.47	36.57*	60.87*	0.49	7.35	-9.88	62.22	1.28	20.63	30.17	-25.29*
$P_7 \times P_{11}$	63.22	26.44*	16.68	37.0*	0.55	22.06	2.47	84.44	0.92	-17.80*	-6.44*	-46.30*
$P_7 \times P_{12}$	51.00	2.00	-5.88	10.87	0.34	-32.00	-37.04	13.33	1.15	-0.008	16.95	-32.88*
$P_8 \times P_9$	33.75	-29.36	-37.71	-26.63	0.63	155.4*	16.67	110.00*	1.17	-0.008	18.98	-31.71*
$P_8 \times P_{10}$	39.94	-39.30	-26.29	-13.18	1.16	118.0*	116.6*	290.0*	1.61	-26.78*	63.73	-6.03*
$P_8 \times P_{11}$	41.78	2.14	-22.90	-9.18	1.17	193.3*	117.2*	291.1*	0.61	-45.40*	-37.9*	-64.40*
$P_8 \times P_{12}$	33.59	-17.81	-38.01	-26.99	1.08	116.0*	100.00*	260.0*	0.35	-83.96*	-64.4*	-79.57*
$P_9 \times P_{10}$	86.94	32.2*	60.46*	89.01*	0.50	115.9*	-8.02	65.56	0.68	-39.70*	-30.8*	-60.31*
$P_9 \times P_{11}$	57.90	21.19	6.86	25.87	0.82	105.0*	51.85	173.33*	4.53	6.35	360.68	164.40
$P_9 \times P_{12}$	60.33	26.28*	11.35	31.16*	0.44	91.30*	-18.52	46.67	1.17	-0.008	18.98	-31.71*
$P_{10} \times P_{11}$	72.59	10.33	33.97*	57.80*	0.65	21.12	20.37	116.67*	0.83	-25.81*	-15.6*	-51.56*
$P_{10} \times P_{12}$	46.74	14.38	-13.73	1.62	0.79	46.58	45.68	162.22*	0.98	-13.23*	-0.34	-42.80*
$P_{11} \times P_{12}$	41.87	2.46	-22.72	-8.97	0.42	5.83	-21.60	41.11	1.10	-0.02	11.86	-35.80*
CD (5%)		164.97				0.032				0.015		

BP = Better parent, PU = Punjab Upma, * Significant at 5% level.

35.61 per cent increase over better parent and 64.66 and 93.96 per cent increase over its standard checks Punjab Upma and TH-1, respectively. For average fruit weight, among the 66 crosses, 15 crosses showed positive significant heterosis over better parent, 10 over Punjab Upma and 19 hybrids over Th-1. The results are in accordance with Cheema *et al.* (3), and Patgaonkar *et al.* (11). Total fruit yield per plant is one of the most important traits, which deserve highest consideration in any breeding programme. In present studies, fifteen hybrids exhibited significantly positive heterosis over the respective better parent, six over standard check Punjab Upma and twenty nine hybrids over TH-1. The magnitude of heterobeltotic effects varied from 69.12 ($P_7 \times P_8$) to 306.7 ($P_5 \times P_8$) per cent. The cross combination $P_8 \times P_{11}$ had maximum fruit yield of 1.17 kg per plant and it showed 193.3 per cent increase over better parent and 291.11

per cent increase over standard check TH-1. These results are in close conformity with those of Cheema *et al.* (3), Dod *et al.* (5), and Gaikwad *et al.* (6). Thus, the crosses, which exhibited significant heterosis can be consider superior combinations among the 66 crosses studied for heat tolerance and can be utilized for commercial exploitation and determining the strategies for future heat stress tolerant tomato varieties/hybrids development.

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Received : December, 2009; Revised : January, 2012; Accepted : July, 2012