Journal of Crop and Weed, 14(3): 61-68 (2018)

Exploitation of heterosis for yield and its attributing traits in tomato (*Solanum lycopersicum* L.)

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Received : 02-08-18 ; Revised : 26-11-18 ; Accepted : 02-12-18

ABSTRACT

Thirty F_1 hybrids of tomato were developed by crossing thirteen parental genotypes(10 lines and 3 testers) in line x tester design for estimation of heterosis for yield and its attributing traits. The hybrids Azad T5 x DT-2, Sel-7 x DT-2 and Punjab Upma x DT-2 were found most promising for yield and its attributing traits. These hybrids exhibited heterosis to the extent of 45.52, 39.80 and 35.01 per cent over better parent and 62.46, 56.08 and 50.76 per cent over standard check.

***Keywords*: Heterosis, tomato, yield and yield attributes**

Tomato universally treated as protective food is being cultivated widely all over the world. India is the second largest tomato producer in the world after china, while it is the world's second most important vegetable crop after potato,it contributes important components in human diet like K, P, Mg and Fe as well as antioxidants such as carotenoids, lycopene and phenolics (Violeta *et al*., 2013). Several breeding techniques have been suggested considering the breeding behavior of crop species. Among all the techniques heterosis breeding is prominent and used in the improvement of tomato. Chaudhary *et al.* (1965) emphasised extensive utilization of heterosis to increase tomato production.

MATERIALS AND METHODS

The experimental materials consisted of 10 lines *viz* Arka Meghali, Punjab Upma, BT-12, Floradade, H-86, H-24, Sel-7, PS-1, Fla-7171and Azad T-5were crossed with three testers *viz* H-88-7-4, DT-2 and Pant T-3 in line x tester fashionto obtain thirty hybrid combinations at the Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The experiment was laid out in Randomized Block Design with three replications. Twenty four plants of each entry (30 F_1, 10 lines, 3 testers and 1 check) were transplanted at a spacing of 60 x 45 cm. The standard cultural practices and dose of fertilizes (150 kg SSP@, 85 kg Urea and 45kg MOP acre^{-1}) were used to raise tomato crop as per the recommendations of the university.Crosses weremade manually using the standardprocedure of hand emasculation and pollination. F_1s were evaluated along withtheir parents for various horticultural traits and compared with standard check.Observations were recorded on days to 50 per cent flowering, plant height, number of primary branches plant^{-1}, number of clusters plant^{-1},number of fruits cluster^{-1}, number of fruits plant^{-1}, fruit length, fruit diameter, average fruit weight and fruit yield plant^{-1}. Statistical analysis was done on the mean values and heterosis was determined as increase or decrease of F_1 hybrids over better parent and commercial hybrid Shaktiman.Heterosis was determined as per method suggested by Wynne *et al*. (1970) and Bitzer *et al*. (1967).

RESULTS AND DISCUSSION

There were significant differences among the parental genotypes with respect to different characters studied including yield plant^{-1}. The mean performance of parents, crosses and check is presented in table 1. The per cent of heterosis estimated over mid parent, better and standard check is given in table 2. With respect to days to 50 per cent flowering the range of mid-parent heterosis varied between -17.85 (Punjab Upma × DT-2) to 2.42 (Azad T-5 × H-88-78-4) per cent. None of the crosses showed significant positive heterosis and twenty crosses showed significant negative heterosis over mid-parent. The range of heterobeltiosis varied between -15.87 (Punjab Upma × DT-2) to 5.77 (BT-12 × DT-2) per cent. One cross showed significant positive heterosis and eleven showed significant negative heterosis over better parent. Heterosis over standard check ranged from -20.82 (Punjab Upma × DT-2) to 4.97 (Azad T-5 × H-88-78-4) per cent. None of the crosses showed significant positive heterosis and eighteen crosses showed significant negative heterosis over standard check.These results are in accordance with the findings of Mahendrakar (2004), Premalakshme *et al.* (2006) and Duhan *et al.* (2005) with respect to earliness in heterotic combinations of tomato.The extent of heterosis for plant height varied from -17.57 (Sel-7 × Pant T-3) to 56.25 (H-86 × Pant T-3) per cent over mid-parent. Twenty five crosses showed significant positive heterosis and three crosses showed significant negative heterosis over mid-parent. The range of

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heterobeltiosis varied between -21.11 (Sel-7 × Pant T-3) to 43.10 (Floradade × Pant T-3) per cent. Twenty four crosses showed significant positive heterosis and four crosses showed significant negative heterosis over better parent. Heterosis over standard check ranged from -11.18 (ArkaMeghali × DT-2) to 76.12 (Floradade × Pant T-3) per cent. Twenty six crosses showed significant positive heterosis and two crosses showed significant negative heterosis over standard check. These results are in conformity with the findings of Sharma and Thakur (2008) and Premalakshme *et al.* (2006).

For number of primary branches plant^{-1} the range of heterosis over mid-parent varied between -9.89 (Fla-7171 × Pant T-3) to 48.36 (ArkaMeghali × Pant T-3) per cent. Twenty two crosses showed significant positive heterosis and four crosses showed significant negative heterosis over mid-parent. The magnitude of better parent heterosis was between -20.53 (Punjab Upma × DT-2) to 34.44 (ArkaMeghali × Pant T-3) percent. Fifteen crosses showed significant positive heterosis and six crosses showed significant negative heterosis over better parent. The extent of heterosis over standard check ranged from -23.08 (H-86 × DT-2) to 49.32 (PS-1 × DT-2) per cent. Seventeen crosses showed significant positive heterosis and eight crosses showed significant negative heterosis over standard check. Similar results were reported by Duhan *et al.* (2005), Shalaby (2013) and Solieman *et al.* (2013). For number of clusters plant^{-1} the range of mid-parent heterosis was between -21.75 (ArkaMeghali × DT-2) to 41.82 (BT-12 × H-88-78-4) percent. Twenty crosses showed significant positive heterosis and three croses showed significant negative heterosis over mid-parent. The range of heterobeltiosis varied between -26.59 (Arka Meghali × DT-2) to 36.67 (BT-12 × H-88-78-4) percent. Fourteen crosses showed significant positive heterosis and six crosses showed significant negative heterosis over better parent. Heterosis over standard check ranged from -34.86 (Arka Meghali × DT-2) to 18.09 (H-86 × Pant T-3) per cent. Six crosses showed significant positive heterosis and fourteen crosses showed significant negative heterosis over standard check. Similar results were observed by Shalaby (2013) and Soliemanet *al.* (2013). For number of fruits cluster^{-1}the range of mid-parent heterosis was between -29.74 (H-86 × DT-2) to 52.91 (ArkaMeghali × Pant T-3) percent. Eighteen crosses showed significant positive heterosis and four crosses showed significant negative heterosis over mid-parent. The range of heterobeltiosis varied between -36.96 (Punjab Upma × H-88-78-4) to 44.09 (ArkaMeghali × Pant T-3) per cent. Ten crosses showed significant positive heterosis and ten crosses showed significant negative heterosis over better parent.Heterosis over standard check ranged from -14.70 (H-86 × DT-2) to 59.74 (Arka Meghali × Pant T-3, H-24 × H-88-78-4) per cent. Twenty five crosses showed significant positive heterosis and one cross showed significant negative heterosis over standard check.These results are in accordance with the findings of Sharma and Thakur (2008) and Kumari and Sharma (2011). For number of fruits plant^{-1}the range of heterosis over mid-parent varied between -21.96 (H-86 × DT-2) to 72.34 (Sel-7 × Pant T-3) per cent. Twenty crosses showed significant positive heterosis and five crosses showed significant negative heterosis over mid-parent. The magnitude of better parent heterosis was between -35.43 (PS-1 × Pant T-3) to 60.93 (Sel-7 × Pant T-3) percent. Nineteen crosses showed significant positive heterosis and five crosses showed significant negative heterosis over better parent. The extent of heterosis over standard check ranged from -21.24 (BT-12 × DT-2) to 52.54 (PS-1 × H-88-78-4) per cent. Fifteen crosses showed significant positive heterosis and eight crosses showed significant negative heterosis over standard check. These results are in consonance with the findings of Yashavanta kumar (2008); Kumari and Sharma (2011) and Kumar *et al.* (2012). For fruit length the range of mid-parent heterosis was between -7.29 (Floradade × H-88-78-4) to 34.01 (ArkaMeghali × DT-2) per cent. Twenty two crosses showed significant positive heterosis and one cross showed significant negative heterosis over mid-parent. The range of heterobeltiosis varied between -19.50 (Floradade × H-88-78-4) to 31.22 (Punjab Upma × DT-2) per cent. Fifteen crosses showed significant positive heterosis and five crosses showed significant negative heterosis over better parent. Heterosis over standard check ranged from -18.96 (Floradade × H-88-78-4) to 39.78 (Punjab Upma × DT-2) per cent. Eighteen crosses showed significant positive heterosis and five showed significant negative heterosis over standard check. Islam *et al.* (2012) and Aisyah *et al.* (2016) also reported significant heterosis for fruit length. For fruit diameter the range of heterosis over mid-parent varied between -11.16 (BT-12 × H-88-78-4) to 30.05 (ArkaMeghali × DT-2) per cent. Fourteen crosses showed significant positive heterosis and seven crosses showed significant negative heterosis over mid-parent. The magnitude of better parent heterosis was between -23.93 (BT-12 × H-88-78-4) to 26.64 (Punjab Upma × DT-2) per cent. Six crosses showed significant positive heterosis and thirteen crosses showed significant negative heterosis over better parent. The extent of heterosis over standard check ranged from -24.51 (PS-1 × H-88-78-4) to 38.40 (Fla-7171 × DT-2) per cent. Twelve crosses showed significant positive heterosis and eleven crosses showed significant negative heterosis over standard check.

Table 1: Mean performance of parents and F_1's

Crosses	Days to 50 percent flowering	Plant height (cm)	Number of primary branches plant^{-1}	Number of clusters plant^{-1}	Number of fruits cluster^{-1}	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Total yield plant^{-1} (kg)
Arka Meghali	75.67	96.66	7.10	11.73	3.07	32.82	4.14	4.18	54.85	1.80
Punjab Upma	72.67	110.60	9.44	15.23	3.27	34.96	4.66	4.83	73.52	2.57
BT-12	77.00	106.89	7.83	10.47	3.27	29.87	4.50	4.80	71.99	2.15
Floradade	74.33	108.8	7.10	13.47	3.33	32.59	4.48	4.54	70.27	2.29
H-86	76.00	83.63	6.45	12.98	4.07	44.21	4.12	4.25	55.42	2.45
H-24	75.33	96.85	8.37	11.29	2.87	26.91	4.20	4.31	69.13	1.86
Sel-7	70.33	95.88	7.18	10.80	3.20	28.45	4.18	4.36	62.56	1.78
PS-1	76.67	103.71	9.92	17.10	3.87	54.59	3.04	2.98	30.22	1.65
Fla-7171	75.67	82.55	6.93	10.25	3.47	29.53	4.85	4.98	74.84	2.21
Azad T-5	76.33	96.95	7.90	12.18	3.00	30.30	4.62	4.70	67.99	2.06
Mean of Females	75.00	98.25	7.82	12.55	3.34	34.42	4.28	4.39	63.08	2.08
H-88-78-4	74.67	82.89	7.02	11.29	4.87	43.76	3.30	3.42	41.13	1.80
DT-2	69.33	85.64	6.69	13.39	3.53	36.08	4.74	4.88	74.28	2.68
Pant T-3	70.67	104.91	8.74	13.33	3.47	32.79	5.00	5.06	76.85	2.52
Mean of Males	71.56	91.15	7.48	12.67	3.96	37.54	4.35	4.45	64.09	2.33
Mean of Parents	74.21	96.61	7.74	12.58	3.48	35.14	4.29	4.41	63.31	2.14
ArkaMeghali × H-88-78-4	71.67	116.43	7.34	10.80	4.87	35.44	4.40	4.37	57.00	2.02
ArkaMeghali × DT-2	65.00	78.52	7.86	9.83	4.00	33.86	5.95	5.89	83.29	2.82
ArkaMeghali × Pant T-3	67.33	110.00	11.75	14.10	5.00	40.04	4.68	4.56	64.19	2.57
Punjab Upma × H-88-78-4	69.33	121.54	9.52	15.42	3.07	35.74	4.59	3.96	59.59	2.13
Punjab Upma × DT-2	58.33	116.84	7.50	16.25	3.57	41.83	6.22	6.18	86.50	3.62
Punjab Upma × Pant T-3	62.67	148.35	8.83	14.19	3.27	33.73	5.06	4.83	82.11	2.77
BT-12 × H-88-78-4	71.00	114.79	7.34	15.43	4.47	52.69	4.70	3.65	54.65	2.88
BT-12 × DT-2	73.33	136.79	8.39	12.91	4.33	30.66	5.86	5.47	73.86	2.26
BT-12 × Pant T-3	68.67	127.39	8.76	16.77	3.87	41.99	5.35	4.41	61.62	2.59
Floradade × H-88-78-4	67.67	123.00	8.73	15.02	4.60	54.81	3.62	3.71	57.79	3.17
Floradade × DT-2	61.67	119.04	8.66	15.75	3.73	35.47	6.03	5.84	83.96	2.98
Floradade × Pant T-3	64.67	155.69	9.04	14.12	3.90	44.03	5.03	4.52	63.68	2.80
H-86 × H-88-78-4	70.67	85.92	7.81	16.73	3.87	43.09	4.49	4.03	52.92	2.28
H-86 × DT-2	67.33	106.84	6.21	15.65	2.67	31.33	5.92	5.77	77.24	2.42
H-86 × Pant T-3	68.33	147.30	8.73	17.82	3.60	58.72	5.38	4.96	46.49	2.73
H-24 × H-88-78-4	69.00	118.45	8.93	12.07	5.00	50.52	4.40	4.20	51.73	2.61

Contd...

Table 1 Contd...

Crosses	Days to 50 percent flowering	Plant height (cm)	Number of primary branches $plant^{-1}$	Number of clusters $plant^{-1}$	Number of fruits $cluster^{-1}$	Number of fruits $plant^{-1}$	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Total yield $plant^{-1}$ (kg)
H-24 × DT-2	64.67	89.58	8.47	12.78	4.33	48.87	5.57	4.98	69.98	3.42
H-24 × Pant T-3	68.00	116.82	10.53	12.46	3.20	36.78	5.71	4.26	61.17	2.25
Sel-7 × H-88-78-4	66.33	123.93	7.63	11.58	4.00	40.40	4.14	4.09	56.93	2.30
Sel-7 × DT-2	59.67	119.67	7.38	12.86	4.90	54.86	5.35	5.04	68.28	3.75
Sel-7 × Pant T-3	66.00	82.76	7.38	14.07	3.87	52.77	4.96	4.26	52.39	2.76
PS-1 × H-88-78-4	76.67	111.14	11.03	17.58	4.20	59.38	3.62	3.43	40.48	2.40
PS-1 × DT-2	69.67	125.63	12.05	16.34	4.07	54.84	4.22	4.88	48.14	2.64
PS-1 × Pant T-3	72.00	100.13	11.29	15.46	3.73	35.25	4.97	4.01	55.32	1.95
Fla-7171 × H-88-78-4	76.33	100.98	8.83	13.83	4.57	43.69	4.52	3.86	51.73	2.26
Fla-7171 × DT-2	65.67	108.96	7.74	10.49	4.20	39.65	5.82	6.28	83.81	3.32
Fla-7171 × Pant T-3	70.67	121.30	7.06	14.13	3.10	40.65	5.30	4.70	65.25	2.65
Azad T-5 × H-88-78-4	77.33	103.19	8.87	15.84	3.90	51.21	4.09	4.07	55.46	2.84
Azad T-5 × DT-2	67.67	99.14	10.12	15.33	3.87	49.41	4.96	6.01	78.91	3.90
Azad T-5 × Pant T-3	69.33	117.71	9.11	15.89	3.53	50.81	4.79	4.88	65.95	3.35
Mean of crosses	68.22	114.93	8.76	14.38	3.98	44.08	4.99	4.70	66.68	2.75
General Mean	70.03	109.39	8.46	13.84	3.83	41.38	4.78	4.61	66.57	2.56
Range	58.33-77.33	78.52-155.69	6.21-12.05	9.83-17.82	2.67-5.00	30.66-59.38	3.62-6.22	3.43-6.28	40.48-86.50	1.95-3.90
First standard check (KashiAmrit)	73.67	93.40	8.07	15.09	3.13	38.93	4.45	4.54	61.65	2.40
Second standard check (Shaktiman)	72.33	107.33	9.11	13.23	3.87	42.36	4.92	5.02	70.35	2.98

Table 2: Estimates of heterosis and inbreeding depression for plant height and number of primary branches plant^{-1} (percent)

Crosses	Days to 50 percent flowering			Plant height (cm)			No.of primary branches plant^{-1}			No. of clusters plant^{-1}		
	MPH	MPH	BPH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
ArkaMeghali × H-88-78-4	-4.66	-4.02	-2.71	29.69**	20.45**	31.71**	4.05	3.45	-8.99**	-6.18*	-7.93*	-28.43**
ArkaMeghali × DT-2	-10.35**	-6.25*	-11.77**	-13.86**	-18.77**	-11.18**	13.98**	10.70**	-2.61	-21.75**	-26.59**	-34.86**
ArkaMeghali × Pant T-3	-7.98**	-4.73	-8.61**	9.14**	13.80**	24.43**	48.36**	34.44**	45.60**	12.53**	5.78	-6.56*
Punjab Upma × H-88-78-4	-5.89	-4.60	-5.89	25.63**	9.89**	37.49**	15.69**	0.85	17.97**	16.29**	1.25	2.19
Punjab Upma × DT-2	-17.85**	-15.87**	-20.82**	19.08**	5.64*	32.17**	-6.99**	-20.53**	-7.04*	13.52**	6.68**	7.67**
Punjab Upma × Pant T-3	-12.56**	-11.32**	-14.93**	37.67**	34.13**	67.82**	-2.83	-6.43*	9.45**	-0.62	-6.82**	-5.95
BT-12 × H-88-78-4	-6.38*	-4.91	-3.62	20.97**	7.39**	29.85**	-1.07	-6.20*	-8.99**	41.82**	36.67**	2.25
BT-12 × DT-2	0.23	5.77*	-0.46	42.10**	27.97**	54.74**	15.49**	7.09*	3.91	8.20**	-3.61	-14.44**
BT-12 × Pant T-3	-7.00*	-2.83	-6.79*	20.29**	19.18**	44.11**	5.77	0.27	8.59**	40.92**	25.81**	11.13**
Floradade × H-88-78-4	-9.17**	-8.96**	-8.14**	28.33**	13.05**	39.14**	23.67**	22.96**	8.18**	21.32**	11.51**	-0.46
Floradade × DT-2	-14.15**	-11.05**	-16.29**	22.44**	9.41**	34.66**	25.59**	21.97**	7.31*	17.23**	16.90**	4.35
Floradade × Pant T-3	-10.80**	-8.49**	-12.22**	45.70**	43.10**	76.12**	14.13**	3.42	12.00**	5.37**	4.83*	-6.43*
H-86 × H-88-78-4	-6.19*	-5.36	-4.07	3.19	2.74	-2.81	15.97**	11.28**	-3.23	37.87**	28.89**	10.87**
H-86 × DT-2	-7.34*	-2.88	-8.61**	26.24**	24.75**	20.86**	-5.53*	-7.23*	-23.08**	18.67**	16.88**	3.71
H-86 × Pant T-3	-6.83*	-3.31	-7.25*	56.25**	40.41**	66.63**	14.94**	-0.11	8.18**	35.46**	33.68**	18.09**
H-24 × H-88-78-4	-8.00**	-7.59*	-6.34*	31.80**	22.30**	33.99**	16.06**	6.69*	10.66**	6.91**	6.91**	-20.01**
H-24 × DT-2	-10.59**	-6.72*	-12.22**	-1.82	-7.51**	1.33	12.47**	1.19	4.96	3.55	-4.56	-15.31**
H-24 × Pant T-3	-6.85*	-3.78	-7.70*	15.80**	11.35**	32.15**	23.09**	20.48**	30.48**	1.24	-6.50*	-17.41**
Sel-7 × H-88-78-4	-8.51**	-5.69*	-9.96**	38.65**	29.26**	40.19**	7.48*	6.27*	-5.45	4.84	2.57	-23.26**
Sel-7 × DT-2	-14.55**	-13.93**	-19.00**	31.85**	24.81**	35.37**	6.41*	2.79	-8.55**	6.30**	-3.96	-14.78**
Sel-7 × Pant T-3	-6.38*	-6.16*	-10.41**	-17.57**	-21.11**	-6.38*	-7.29**	-15.56**	-8.55**	16.62**	5.55	-6.76*
PS-1 × H-88-78-4	1.32	2.68	4.07	19.12**	7.16**	25.72**	30.24**	11.19**	36.68**	23.85**	2.81	16.50**
PS-1 × DT-2	-4.56	0.49	-5.43	32.70**	21.14**	42.12**	45.08**	21.47**	49.32**	7.17**	-4.44	8.28**
PS-1 × Pant T-3	-2.27	1.88	-2.27	-4.01*	-4.56*	13.27**	21.01**	13.81**	39.90**	1.61	-9.59**	2.45
Fla-7171 × H-88-78-4	1.54	2.22	3.61	22.07**	21.82**	14.23**	26.66**	25.86**	9.45**	28.41**	22.50**	-8.35**
Fla-7171 × DT-2	-9.42**	-5.28	-10.86**	29.57**	27.23**	23.26**	13.70**	11.75**	-4.04	-11.26**	-21.65**	-30.48**
Fla-7171 × Pant T-3	-3.42	0.00	-4.07	29.41**	15.62**	37.22**	-9.89**	-19.22**	-12.52**	19.85**	6.00*	-6.36*
Azad T-5 × H-88-78-4	2.42	3.56	4.97	14.76**	6.44*	16.73**	18.91**	12.27**	9.90**	34.98**	30.05**	4.97
Azad T-5 × DT-2	-7.09*	-2.39	-8.14**	8.59**	2.26	12.15**	38.75**	28.14**	25.44**	19.92**	14.53**	1.62
Azad T-5 × Pant T-3	-5.67	-1.90	-5.89	16.63**	12.20**	33.16**	9.51**	4.25	12.90**	24.56**	19.18**	5.28
S.E. Diff	0.75	0.92	0.92	1.63	1.80	1.80	0.32	0.38	0.38	0.62	0.76	0.76
CD 95 %	1.50	1.84	1.84	3.26	3.60	3.60	0.64	0.75	0.75	1.23	1.52	1.52

MPH = Mid parent heterosis, BPH = Better parent heterosis, SH = Standard heterosis over check

**Significant at p= 0.05, ** Significant at p= 0.01*

Table 3: Estimates of heterosisover mid parent (MPH), better parent (BPH) and standard check (SH) for different yield attributing trades in tomato

Crosses	Number of fruits cluster^{-1}			Number of fruits plant^{-1}			Fruit length (cm)			Fruit diameter (cm)		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
ArkaMeghali × H-88-78-4	22.67**	0.00	55.59**	-7.44*	-19.01**	-8.96*	18.32**	6.32	-1.09	14.95**	4.50	-3.79
ArkaMeghali × DT-2	21.21**	13.31**	27.80**	-1.72	-6.16	-13.03**	34.01**	25.53**	33.71**	30.05**	20.72**	29.76**
ArkaMeghali × Pant T-3	52.91**	44.09**	59.74**	22.05**	22.01**	2.85	2.44	-6.37*	5.20	-1.33	-9.91**	0.41
Punjab Upma × H-88-78-4	-24.57**	-36.96**	-1.92	-9.19**	-18.32**	-8.18*	15.38**	-1.46	3.19	-3.88	-17.91**	-12.67**
Punjab Upma × DT-2	5.00	1.13	14.06**	17.76**	15.94**	7.45	32.34**	31.22**	39.78**	27.29**	26.64**	36.12**
Punjab Upma × Pant T-3	-2.97	-5.76	4.47	-0.43	-3.52	-13.36**	4.81	1.25	13.76**	-2.38	-4.60	6.33
BT-12 × H-88-78-4	9.83**	-8.21*	42.81**	43.12**	20.39**	35.34**	20.62**	4.53	5.71	-11.16**	-23.93**	-19.58**
BT-12 × DT-2	27.35**	22.66**	38.34**	-7.02*	-15.02**	-21.24**	26.79**	23.58**	31.63**	12.93**	12.00**	20.39**
BT-12 × Pant T-3	14.84**	11.53**	23.64**	34.04**	28.07**	7.87*	12.71	7.07*	20.31**	-10.49**	-12.79**	-2.80
Floradade × H-88-78-4	12.20**	-5.54	46.96**	43.57**	25.24**	40.78**	-7.29*	-19.50**	-18.96**	-6.85*	-18.34**	-18.34**
Floradade × DT-2	8.75*	5.67	19.17**	3.32	-1.69	-8.88*	30.71**	27.12**	35.41**	23.89**	19.57**	28.53**
Floradade × Pant T-3	14.71**	12.39**	24.60**	34.68**	34.28**	13.10**	6.09	0.58	13.01**	-5.73	-10.58**	-0.33
H-86 × H-88-78-4	-13.42**	-20.53**	23.64**	-2.04	-2.54	10.68*	21.06**	9.01**	0.93	5.14	-5.13	-11.19**
H-86 × DT-2	-29.74**	-34.40**	-14.70**	-21.96**	-29.13**	-19.52**	33.74**	25.00**	33.14**	26.35**	18.20**	27.05**
H-86 × Pant T-3	-4.51	-11.55*	15.02**	52.51**	32.82**	50.83**	17.89**	7.52*	20.81**	6.59*	-1.94	9.29**
H-24 × H-88-78-4	29.20**	2.67	59.74**	42.97**	15.43**	29.77**	17.38**	4.80	-1.09	8.67*	-2.55	-7.49*
H-24 × DT-2	35.31**	22.66**	38.34**	55.17**	35.45**	25.54**	24.53**	17.43**	25.09**	8.47*	2.13	9.78**
H-24 × Pant T-3	0.95	-7.78*	2.24	23.23**	12.18**	-5.52	24.17**	14.24**	28.36**	-9.16**	-15.89**	-6.26*
Sel-7 × H-88-78-4	-0.87	-17.86**	27.80**	11.90**	-7.69*	3.78	10.80**	-0.86	-6.88*	5.09	-6.24*	-9.96**
Sel-7 × DT-2	45.62**	38.81**	56.55**	70.03**	54.82**	40.92**	20.04**	12.95**	20.31**	9.09**	3.28	11.01**
Sel-7 × Pant T-3	16.04**	11.53**	23.64**	72.34**	60.93**	35.56**	8.10*	-0.77	11.50**	-9.64**	-15.89**	-6.26
PS-1 × H-88-78-4	-3.89	-13.76**	34.19**	20.76**	8.78*	52.54**	14.12**	9.62**	-18.71**	7.10*	0.21	-24.51**
PS-1 × DT-2	10.00**	5.17	30.03**	20.97**	0.46	40.87**	8.54*	-10.92**	-5.11	24.25**	0.07	7.56*
PS-1 × Pant T-3	1.63	-3.62	19.17**	-19.32**	-35.43**	-9.45**	23.70**	-0.54	11.75**	-0.26	-20.76**	-11.68**
Fla-7171 × H-88-78-4	9.59*	-6.16	46.01**	19.23**	-0.16	12.23**	11.04*	-6.71*	1.68	-8.00*	-22.41**	-14.89**
Fla-7171 × DT-2	20.00**	18.98**	34.19**	20.86**	9.89*	1.84	21.46**	20.08**	30.88**	27.45**	26.17**	38.40**
Fla-7171 × Pant T-3	-10.66*	-10.66*	-0.96	30.46**	23.97**	4.42	7.57*	9.23**	19.05**	-6.29*	-7.04*	3.61
Azad T-5 × H-88-78-4	-0.89	-19.92**	24.60**	38.30**	17.02**	31.55**	3.23	-11.52**	-8.13*	0.14	-13.50**	-10.45**
Azad T-5 × DT-2	18.53**	9.63*	23.64**	48.88**	36.95**	26.93**	6.02	4.68	11.50**	25.56**	23.25**	32.48**
Azad T-5 × Pant T-3	9.12*	1.73	12.78**	61.08**	54.96**	30.52**	-0.34	-4.13	7.72*	0.07	-3.49	7.56*
S.E. Diff	0.24	0.29	0.29	1.25	1.32	1.32	0.21	0.24	0.24	0.19	0.22	0.22
CD 95 %	0.48	0.58	0.58	2.50	1.63	1.63	0.42	0.48	0.48	0.38	0.44	0.44

MPH = Mid parent heterosis, BPH = Better parent heterosis, SH = Standard heterosis over check

*Significant at p= 0.05, ** Significant at p= 0.01

Table 4: Estimates of heterosisover mid parent (MPH), better parent (BPH) and standard check (SH) for different yield attributing trades in tomato

Crosses	Average fruit weight (g)			Total yield plant^{-1} (kg)		
	MPH	BPH	SH	MPH	BPH	SH
ArkaMeghali × H-88-78-4	18.77**	3.91	-7.55*	12.22**	12.22**	-15.83**
ArkaMeghali × DT-2	29.00**	12.13**	35.10**	25.89**	5.22	17.50**
ArkaMeghali × Pant T-3	-2.53	-16.48**	4.12	18.98**	1.98	7.08*
Punjab Upma × H-88-78-4	3.95	-18.95**	-3.34	-2.52	-17.12**	-11.25**
Punjab Upma × DT-2	17.05**	16.45**	40.31**	37.84**	35.01**	50.76**
Punjab Upma × Pant T-3	9.21**	6.84*	33.19**	8.82**	7.76**	15.40**
BT-12 × H-88-78-4	-3.37	-24.08**	-11.35**	45.82**	33.95**	19.98**
BT-12 × DT-2	0.99	-0.57	19.81**	-6.28*	-15.55**	-5.64
BT-12 × Pant T-3	-17.20**	-19.82**	-0.05	10.92**	2.78	7.82*
Floradade × H-88-78-4	3.75	-17.76**	-6.26	54.85**	38.28**	31.97**
Floradade × DT-2	16.17**	13.03**	36.19**	19.79**	11.07**	24.10**
Floradade × Pant T-3	-13.43**	-17.14**	3.29	16.42**	11.11**	16.82**
H-86 × H-88-78-4	9.62**	-4.52	-14.17**	7.29*	-6.94*	-5.00
H-86 × DT-2	19.11**	3.99	25.29**	-5.65*	-9.70**	0.83
H-86 × Pant T-3	-29.70**	-39.50**	-24.58**	9.86**	8.33**	13.75**
H-24 × H-88-78-4	-6.17*	-25.17**	-16.09**	42.81**	40.50**	8.89**
H-24 × DT-2	-2.41	-5.79	13.51**	50.66**	27.61**	42.50**
H-24 × Pant T-3	-16.19**	-20.40**	-0.78	2.74	-10.71**	-6.25*
Sel-7 × H-88-78-4	9.81**	-9.00**	-7.66*	28.49**	27.78**	-4.17
Sel-7 × DT-2	-0.21	-8.08*	10.76**	68.01**	39.80**	56.08**
Sel-7 × Pant T-3	-24.84**	-31.83**	-15.02**	28.53**	9.66**	15.20**
PS-1 × H-88-78-4	13.47**	-1.58	-34.34**	39.32**	33.52**	0.16
PS-1 × DT-2	-7.87**	-35.19**	-21.91**	21.94**	-1.49	10.00**
PS-1 × Pant T-3	3.33	-28.02**	-10.27**	-6.48*	-22.62**	-18.75**
Fla-7171 × H-88-78-4	-10.79**	-30.88**	-16.09**	12.72**	2.26	-5.83
Fla-7171 × DT-2	12.41**	11.99**	35.94**	35.92**	24.01**	38.45**
Fla-7171 × Pant T-3	-13.97**	-15.09**	5.84*	12.19**	5.29	10.52**
Azad T-5 × H-88-78-4	1.65	-18.43**	-10.04**	47.15**	37.86**	18.34**
Azad T-5 × DT-2	10.93**	6.23*	28.00**	64.56**	45.52**	62.46**
Azad T-5 × Pant T-3	-8.93**	-14.18**	6.97**	46.29**	32.94**	39.63**
S.E. Diff	1.57	1.62	1.62	0.24	0.27	0.27
CD 95 %	3.04	3.24	3.24	0.48	0.54	0.54

MPH = Mid parent heterosis, BPH = Better parent heterosis, SH = Standard heterosis over check
**Significant at p= 0.05, ** Significant at p= 0.01*

Similar results were reported by Islam *et al.* (2012) and Aisyah *et al.* (2016). For average fruit weight the range of heterosis over mid-parent varied between -29.70 (H-86 × Pant T-3) to 29.00 (ArkaMeghali × DT-2) per cent. Eleven crosses showed significant positive heterosis and nine crosses showed significant negative heterosis over mid-parent. The magnitude of better parent heterosis was between -39.50 (H-86 × Pant T-3) to 16.45 (Punjab Upma × DT-2) per cent.

Six crosses showed significant positive heterosis and eighteen crosses showed significant negative heterosis over better parent. The extent of heterosis over standard check ranged from -34.34 (PS-1 × H-88-78-4) to 40.31 (Punjab Upma × DT-2) per cent. Twelve crosses showed significant positive heterosis and twelve crosses showed significant negative heterosis over standard check. These results are in conformity with the findings of Kurian (2001) Prashanth (2004) and Yashavantakumar (2008). Extent of heterosis for fruit yield plant^{-1} over md-parent ranged from -6.48 (PS-1 × Pant T-3) to 68.01 (Sel-7 × DT-2) percent. Twenty five crosses showed significant positive heterosis and three crosses showed significant negative heterosis over mid-parent.The range of heterobeltiosis varied between -22.62 (PS-1 × Pant T-3) to 45.52 (Azad T-5 × DT-2) per cent. Eighteen crosses showed significant positive heterosis and six crosses showed significant negative heterosis over better parent.Heterosis over standard check ranged from -18.75 (PS-1 × Pant T-3) to 62.46 (Azad T-5 × DT-2) per cent. Twenty crosses showed significant positive heterosis and four crosses showed significant negative heterosis over standard check. These results are in accordance with the findings of Sharma and Thakur (2008), Kumari and

Sharma (2011), Singh and Asati (2011), Chauhan *et al.* (2014), Aisyah *et al.* (2016) and Savale *et al*. (2017).

The crosses Azad T-5 × DT-2, Sel-7 × DT-2 and Punjab Upma × DT-2 exhibited highest significant positive heterosis over standard check and thus they were found to be best heterotic combinations. The high yielding cross Azad T-5 × DT-2 expressed 62.46 per cent heterosis for yield plant^{-1} over standard check can be recommended for commercial exploitation.

ACKNOWLEDGEMENT

Experimental materials and assistance provided by Institute of Agricultural Sciences, Banaras Hindu University, Varanasi for conducting the research is duly acknowledged.

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