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Heterosis and inbreeding depression to identify superior F_1 hybrids in tomato (*Solanum lycopersicum* L.) for the yield and its contributing traits

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Abstract: Eight parental lines of diverse origin of tomato (*Solanum lycopersicum* L.) were crossed in 8 × 8 diallel mating design excluding reciprocals. The 28 F_1 hybrids along with their parents and one standard check (H-86) were evaluated in a randomized block design with three replications during seasons of *rabi* 2011-12, 2012-13 and 2013-14. In the present study, revealed that heterosis over better parent, mid parent, standard check and inbreeding depression was observed for all the traits under studies. Highly significant heterosis was observed for days to first flowering (-13.49, -13.52 and -12.28%), number of flowers per cluster (17.90, 22.11 and 24.27%), days to first harvest (-8.01, -11.04 and -9.76%), number of fruit per cluster (39.17, 42.71 and 20.71%), fruit diameter (19.93, 31.43 and 13.27%), fruit length (19.29, 22.34 and 13.35%), Average fruit weight (18.88, 19.41 and 7.80%), number of fruits per plant (25.86, 46.69 and 41.87%) and yield per plant (58.61, 75.61 and 56.33%) over the better, mid and standard parents, respectively along with considerable inbreeding depression. Most promising cross Pant T-3 × H-24 showed highly significant positive heterosis over better parent for yield per plant.

Keywords: Heterosis, Hybrids, Inbreeding depression, Tomato, Yield

INTRODUCTION

Tomato (*Solanum lycopersicum* L., 2n = 24) a member of solanaceae family, is grown in almost every corner of the world because of its special nutritive value. Besides, fresh consumption, tomato ranks first among processed vegetables in the world, on global basis, it is planted 4.39 million hectares of with a total production of 150.51 million tones. India is the second largest tomato producer in the world after China, accounting for about 11% of the world tomato production (FAO, 2012). In India, tomato is grown across all agro-ecological zones and occupies an area of about 0.879 mha with an annual production of 18.22 mt, (IHD, 2014). However, yield is a complex character and its direct improvement is difficult. Heterosis breeding provides an efficient means to break the yield barrier in most of crops including tomato. Knowledge of the extent of heterosis for yield and its various component characters is a pre-requisite to bring improvement through heterosis breeding. Heterosis in tomato was first observed by Hedrick and Booth (1968), it is in the form of the greater vigour, faster growth and development, earliness in maturity, increased productivity, higher levels of resistance to biotic and abiotic stresses and increased yield of 20 to 50%. It is further mentioned that exploitation of hybrid vigour in tomato is economical because each fruit contains larger number of seeds as compared to other vegetables. Now a days, farmers of is very much inclined to grow hybrid variety for having high yielding and to get early harvest (short duration) and good quality fruit. But there is lacking of good hybrid. So, development of hybrid variety of tomato is needed to support farmer's interest. It is costly to produce hybrid seeds every year by artificial emasculation and pollination. The study of extent of heterosis in F_1 over better parent provide an indication about the type of gene action and significance of inbreeding depression in F_2 indicates the presence of non additive gene effects (Kumar *et al.,* 2012). Hence, the present studies were undertaken to study the desirable heterosis in yield and its component traits to develop superior F_1 hybrids and to study the inbreeding depression for better understanding of the plant behaviour in hybrid and selfed condition.

MATERIALS AND METHODS

The present study was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.), India. Eight parental lines (Arka Meghali, Pant T-3, Punjab Chhuhara, H-88-78-1, Arka Alok, Azad T-5, H-24 (Hisar Anmol), Sel-7 (Hisar Arun)) of diverse origin of tomato were crossed in 8 × 8 diallel mating design excluding reciprocals to get F_1 seeds during *rabi* 2011-12. All the F_1 seed was sown and at the time of pollination 10 plants were selfed to get F_2 seeds during *rabi* 2012-13. The parents, F_1 hy-

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brids and F_2 population (8 parents, 28 F_1 hybrids and 28 F_2) were field evaluated during *rabi* 2013-14, using randomized complete block design with 3 replications at the spacing of 60 cm × 45 cm. Recommended cultural practices and plant protection measures were followed in all seasons. The observations were recorded on randomly 5 plants in each parent and F_1 and 10 plants in each F_2 population on each replication. The selected pants were tagged and properly leveled before flowering and for recording the nine observations *viz*., days to first flowering, number of flowers per cluster, days to first harvest, number of fruit per cluster, fruit diameter, fruit length, average fruit weight, number of fruits per plant and yield per plant.

Heterosis and inbreeding depression for each trait was worked out by utilizing the overall mean of each hybrid over replications for each trait. Heterosis over better parent (BP) and heterobeltiosis was calculated as per (Fonseca and Patterson, 1968) while standard heterosis (SH) using H-86 variety as standard check was calculated (Meredith and Bridge, 1972). The significance of relative heterosis and 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).

RESULTS AND DISCUSSION

Analysis of variance revealed (Table 1) for genotypes, parents and hybrids were highly significant for all the characters except days to first flowering, indicating the presence of significant variation among the genotypes as well as crosses studied. This emphasized the need of selecting parents for maximization of hybrid vigour with respect to fruit yield and its related traits. Considerable genetic variation for various traits including fruit yield have been reported by many workers (Dagade *et al*., 2015 and Shankar *et al.,* 2014). The improvement in different quantitative and qualitative traits in tomato through heterosis breeding was observed by Tiwari and Lal, (2004), and reported significant heterosis ranging from 23.8% to71.71% for total yield. The mean sum of squares for F_1 and parents *vs*. F_1 generation respective crosses were also found significant for almost traits except days to first flowering and harvesting, which indicated presence of substantial amount of heterosis in all cross combinations. The extent of heterosis and inbreeding depression for different characters is presented in the tables.

Days to first flowering: Perusal of data presented in Table 2 revealed that, out of 28 cross combinations 14 crosses over better parent, 18 crosses over mid-parent and 26 crosses over standard check showed significant negative heterosis for days to first flowering. The crosses *viz.* Arka Alok × H-24, H-88-78-1 × H-24, Pant T-3 × H-24 exhibited significant negative heterobeltiosis to the extent of -13.49, -12.13 and -11.35 per cent, respectively the same crosses also showed -13.52, -12.24 and -11.63 per cent significant negative average heterosis. The cross Arka Alok × H-24 also (-12.28) had maximum standard heterosis.

The magnitude of inbreeding depression ranged between -10.91 (H-88-78-1 × Azad T-5) to 7.66 (H-88-78-1 × Sel-7) per cent. For the development of early fruiting genotypes, negative heterosis is desirable for days to first flowering. Negative heterosis for earliness days to first flowering was also observed by Asati *et al.* (2007), Singh *et al.* (2008), Singh and Sastry (2011), Kumari and Sharma (2011) and Shankar *et al.* (2014) they reported that heterosis over better, mid and standard parent were negative direction which support our finding.

Number of flowers per cluster: Out of 28 cross combinations, 17 crosses over better parent, 19 crosses over mid-parent and 23 crosses over standard check showed heterosis for number of flower per cluster. The crosses Arka Meghali × Sel-7, Arka Meghali × H-88-78-1 and Pant T-3 × H-88-78-1 exhibited significant positive heterobeltiosis to the extent of 17.90, 16.82 and 16.42 per cent respectively. In the order of their merit, the crosses Pant T-3 × H-88-78-1, Punjab Chhuhara × H-24 and Pant T-3 × Sel-7 showed 22.11, 20.09 and 18.34 per cent significant positive average heterosis. The crosses Punjab Chhuhara × H-24, Arka Meghali × Sel-7 and Arka Meghali × H-88-78-1 had maximum standard heterosis (24.27), (21.03) and (19.92) respectively.

The magnitude of inbreeding depression ranged between -3.77 (Arka Meghali × H-24) to 11.97 (H-88-78 -1 × Arka Alok) per cent. Number of flower per cluster

Table 1. Analysis of variance for parents and F_1 fruit yield and related traits in tomato.

Source of variation	d.f.	Days to first flowering	No. of flowers Per cluster	Days to first harvest	No. of fruit per cluster	Fruit dia. (cm)	Fruit length (cm)	Avg. fruit weight (g)	No. of fruits per plant	Yield per plant (Kg.)
REP	2	10.07	0.52	12.83	0.02	0.01	0.10	14.86	3.00	0.01
TRET	35	9.32	2.20**	14.96**	1.19**	0.61**	0.49**	249.11**	124.65**	1.10**
PAR	7	5.02	1.22**	13.45**	0.39	0.79**	0.17	288.86**	151.12**	0.16*
F_1	27	8.21	2.20**	6.87	1.05**	0.42**	0.52**	246.32**	101.98**	0.84**
P V/S F_1	1	69.49	9.01**	244.08	10.74**	4.24**	2.02**	46.13*	551.43**	14.80**
EROR	70	6.62	0.37	4.12	0.24	0.11	0.13	13.98	11.09	0.04
Total	107	7.57	0.97	7.83	0.54	0.27	0.25	90.91	48.08	0.39

*, ** significant at 5% and 1% level, respectively

Table 2. Magnitude of heterosis and inbreeding depression for days to first flowering, number of flowers per cluster and days to first harvest of tomato hybrids.

S. No.	Hybrids	Days to first flowering				Number of flowers per cluster				Days to first harvest			
		BP	MP	St checks	Inb. dep	BP	MP	St checks	Inb. Dep	BP	MP	St checks	Inb. dep
1	Arka Meghali × Pant T-3	-6.54**	-6.90**	-6.54	0.43	8.66**	14.66**	11.55	0.00	-1.41	-1.62	-3.28	-6.66
2	Arka Meghali × Punjab Chhuhara	3.00	2.48	1.95	4.89	9.31**	11.66**	12.21	10.20	-1.00	-2.68	-2.88	-4.22
3	Arka Meghali × H-88-78-1	-4.31*	-4.86**	-4.32	-4.26	16.82**	17.55**	19.92	3.25	-1.37	-1.77	-3.25	-5.06
4	Arka Meghali × Arka Alok	-8.98**	-9.65**	-8.99	-2.01	13.72**	14.18**	17.70	3.09	-6.19**	-9.06**	-7.98	-6.66
5	Arka Meghali × Azad T-5	-7.31**	-7.71**	-7.32	0.04	-4.49**	-0.02	7.66	5.62	-3.99*	-6.34**	-5.81	-8.15
6	Arka Meghali × H-24	-0.24	-0.94	-0.25	-2.00	-4.24**	-1.53	4.02	-3.77	-8.01**	-11.04**	-9.76	-3.77
7	Arka Meghali × Sel-7	4.27**	-0.46	-4.79	0.67	17.90**	18.34**	21.03	1.82	-1.42	-2.16	-4.73	-8.33
8	Pant T-3 × Punjab Chhu-hara	-1.18	-2.06	-2.19	-3.84	10.45**	14.17**	8.60	0.96	1.75	0.25	0.25	-2.18
9	Pant T-3 × H-88-78-1	0.98	0.78	1.75	-4.55	16.42**	22.11**	18.02	9.62	-2.57	-2.75	-4.01	-1.90
10	Pant T-3 × Arka Alok	-3.40	-3.73*	-2.66	-0.95	11.13**	17.71**	15.01	0.19	-2.56	-5.33**	-4.00	-3.93
11	Pant T-3 × Azad T-5	-5.55**	-5.59**	-4.82	-7.47	0.34	10.53**	13.10	2.00	-6.02**	-8.12**	-7.41	-2.47
12	Pant T-3 × H-24	-11.35**	-11.63**	-10.68	-1.04	4.02**	12.69**	13.00	4.86	-4.09*	-7.04**	-5.51	-4.72
13	Pant T-3 × Sel-7	-0.15	-5.06**	-8.82	-2.08	13.61**	19.46**	15.77	4.91	-0.55	-1.51	-3.89	1.56
14	Punjab Chhuhara × H-88-78-1	-0.37	-1.46	-1.39	-3.72	2.81**	4.38**	4.23	8.55	-4.33*	-5.56**	-5.39	0.43
15	Punjab Chhuhara × Arka Alok	0.89	-0.36	-0.15	-8.18	13.73**	16.64**	17.71	7.89	-7.49**	-8.74**	-6.11	-3.54
16	Punjab Chhuhara × Azad T-5	-1.99	-2.92	-3.00	-6.60	4.71**	11.84**	18.02	6.40	-6.82**	-7.53**	-5.44	-2.83
17	Punjab Chhuhara × H-24	-10.26**	-11.35**	-11.18	-4.44	14.40**	20.09**	24.27	1.03	-5.65**	-7.15**	-4.25	-3.55
18	Punjab Chhuhara × Sel-7	-2.51	-6.43**	-10.97	1.72	3.88**	5.73**	5.86	1.11	-0.81	-3.23	-4.14	-1.83
19	H-88-78-1 × Arka Alok	-4.14*	-4.28**	-3.03	-2.13	2.96**	4.02**	6.56	11.97	-3.79*	-6.34**	-4.86	-2.98
20	H-88-78-1 × Azad T-5	-8.51**	-8.64**	-7.72	-10.91	-11.54**	-6.86**	-0.29	10.10	-1.62	-3.64*	-2.71	-1.67
21	H-88-78-1 × H-24	-12.13**	-12.24**	-11.11	-2.61	-9.80**	-6.69**	-2.02	7.18	-7.16**	-9.84**	-8.19	-5.53
22	H-88-78-1 × Sel-7	-2.10	-7.11**	-10.61	7.66	-6.58**	-6.34**	-4.81	2.68	-3.53	-4.64**	-6.77	-4.05
23	Arka Alok × Azad T-5	-4.34*	-4.62**	-3.51	-9.83	-14.68**	-11.04**	-3.83	5.72	-6.68**	-7.24**	-3.84	-1.09
24	Arka Alok × H-24	-13.49**	-13.52**	-12.28	1.59	1.24	3.69**	9.98	9.57	-6.41**	-6.63**	-2.41	-2.38
25	Arka Alok × Sel-7	-0.11	-5.36**	-8.78	3.01	-1.78*	-1.02	1.66	9.95	-2.02	-5.75**	-5.31	-2.44
26	Azad T-5 × H-24	-1.01	-1.27	-0.15	-1.98	-17.87**	-16.35**	-7.43	6.20	-4.59**	-5.39**	-1.70	-1.36
27	Azad T-5 × Sel-7	4.95**	-0.27	-4.17	7.58	-6.09**	-1.35	5.86	2.96	1.01	-2.23	-2.39	-1.24
28	H-24 × Sel-7	-2.18	-7.30**	-10.68	2.68	2.38**	5.66**	11.22	5.00	1.58	-2.52	-1.83	-0.17
	SE	1.75	1.70			0.63	0.56			1.75	1.57		
	CD at 5%	3.71	3.60			1.34	1.19			3.71	3.33		

Table 3. Magnitude of heterosis and inbreeding depression for number of fruit per cluster, fruit diameter and fruit length of tomato hybrids.

S. N.	Hybrids	Number of fruit per cluster				Fruit dia. (cm)				Fruit length (cm)			
		BP	MP	St checks	Inb. dep	BP	MP	St checks	Inb. dep	BP	MP	St checks	Inb. dep
1	Arka Meghali × Pant T-3	23.55**	27.84**	12.91	7.17	-5.26**	-1.20**	-11.11	0.35	0.00	3.45**	0.60	3.33
2	Arka Meghali × Punjab Chhuhara	24.27**	28.10**	20.79	9.78	12.54**	18.49**	-3.09	6.05	15.46**	17.69**	12.68	5.65
3	Arka Meghali × H-88-78-1	18.67**	25.81**	8.45	6.15	-1.31**	3.25**	-6.79	1.32	11.43**	12.23**	4.63	1.28
4	Arka Meghali × Arka Alok	5.36**	7.35**	0.00	6.33	17.06**	31.43**	0.80	4.44	19.29**	22.34**	12.01	2.10
5	Arka Meghali × Azad T-5	20.46**	21.28**	11.58	11.04	1.02**	3.83**	-8.02	5.50	7.86**	10.42**	1.27	4.64
6	Arka Meghali × H-24	-5.14**	-1.68*	-6.75	7.75	0.66*	4.65**	-6.17	13.82	15.71**	20.90**	8.65	3.40
7	Arka Meghali × Sel-7	17.40**	20.46**	13.02	6.27	7.89**	8.66**	-7.10	2.99	18.31**	19.15**	12.68	3.87
8	Pant T-3 × Punjab Chhuhara	-8.20**	-2.18*	-10.76	13.29	0.33	9.91**	-5.86	0.98	1.33**	2.88**	1.95	12.83
9	Pant T-3 × H-88-78-1	39.17**	42.71**	18.64	12.00	2.61**	2.95**	-3.09	6.69	-10.33**	-6.60**	-9.79	7.81
10	Pant T-3 × Arka Alok	13.69**	19.79**	7.91	14.29	0.33	16.86**	-5.86	3.28	-1.33**	4.59**	-0.74	9.80
11	Pant T-3 × Azad T-5	-6.68**	-2.81**	-13.56	13.20	1.32**	2.84**	-4.94	6.17	-6.67**	-1.23**	-6.10	16.79
12	Pant T-3 × H-24	-7.33**	-0.74	-8.90	17.67	8.55**	8.91**	1.85	9.39	-18.33**	-11.87**	-17.84	5.71
13	Pant T-3 × Sel-7	-6.87**	-1.21*	-10.34	9.45	2.96**	8.12**	-3.40	12.46	-5.33**	-2.74**	-4.76	14.44
14	Punjab Chhuhara × H-88-78-1	20.31**	31.24**	16.95	2.09	-10.46**	-1.62**	-15.43	6.20	3.78**	6.53**	1.27	5.96
15	Punjab Chhuhara × Arka Alok	17.00**	18.39**	13.73	6.08	12.35**	20.26**	-12.96	6.38	4.81**	9.52**	2.28	2.30
16	Punjab Chhuhara × Azad T-5	18.42**	21.28**	15.11	5.71	-12.54**	-5.49**	-20.37	2.33	3.44**	7.89**	0.94	4.32
17	Punjab Chhuhara × H-24	18.10**	18.77**	16.10	9.40	-12.58**	-4.52**	-18.52	7.58	7.22**	14.08**	4.63	3.21
18	Punjab Chhuhara × Sel-7	3.89**	4.39**	0.99	1.59	9.09**	14.07**	-7.41	3.00	16.15**	17.57**	13.35	3.85
19	H-88-78-1 × Arka Alok	7.14**	15.61**	1.69	11.10	9.80**	28.24**	3.70	6.85	7.25**	9.23**	-0.74	8.11
20	H-88-78-1 × Azad T-5	7.50**	14.69**	-0.42	1.70	5.23**	7.15**	-0.62	9.94	10.51**	12.34**	2.28	13.11
21	H-88-78-1 × H-24	8.19**	18.62**	6.36	11.95	19.93**	20.72**	13.27	7.34	9.06**	13.16**	0.94	6.31
22	H-88-78-1 × Sel-7	16.20**	26.20**	11.86	5.55	5.23**	10.84**	-0.62	4.35	-1.76**	-0.36	-6.44	7.17
23	Arka Alok × Azad T-5	1.07	2.30**	-4.07	12.90	2.37**	17.74**	-6.79	10.64	-8.24**	-8.07**	-17.84	16.73
24	Arka Alok × H-24	3.45**	5.26**	1.69	3.78	8.61**	26.15**	1.23	8.33	-0.38	1.53**	-11.13	19.62
25	Arka Alok × Sel-7	10.74**	11.52**	6.61	6.99	4.73**	16.84**	-11.11	2.78	-6.34**	-3.27**	-10.80	12.03
26	Azad T-5 × H-24	-3.16**	-0.28	-4.80	25.25	4.97**	6.20**	-2.16	9.15	11.99**	14.34**	0.27	5.69
27	Azad T-5 × Sel-7	2.38**	4.35**	-1.44	13.58	5.76**	9.47**	-3.70	8.33	7.04**	10.34**	1.95	5.92
28	H-24 × Sel-7	17.70**	18.93**	15.71	0.00	7.62**	12.65**	0.31	10.15	-0.70*	4.44**	-5.43	7.80
	SE	0.49	0.43			0.27	0.24			0.27	0.24		
	CD at 5%	1.04	0.91			0.57	0.51			0.57	0.51		

Table 4. Magnitude of heterosis and inbreeding depression for average fruit weight, number of fruits per plant and yield per plant of tomato hybrids.

S. N.	Hybrids	Avg. fruit weight (g)				No. of fruits per plant				Yield per plant (Kg.)			
		BP	MP	St checks	Inb. dep	BP	MP	St checks	Inb. Dep	BP	MP	St checks	Inb. dep
1	Arka Meghali × Pant T-3	5.00	9.37**	-13.48	-3.82	17.54**	18.10**	7.11	7.12	-5.69**	0.00	-4.18	3.55
2	Arka Meghali × Punjab Chhuhara	18.88**	19.41**	-2.04	5.20	5.16*	10.47**	-5.09	-5.05	51.94**	75.52**	54.37	0.84
3	Arka Meghali × H-88-78-1	4.61	7.45*	-13.80	-0.89	5.89*	10.82**	-4.43	-4.59	46.37**	47.08**	48.71	-5.94
4	Arka Meghali × Arka Alok	13.11**	17.22**	-6.80	4.63	-3.36	3.53	0.61	-3.38	15.74**	22.64**	17.59	1.05
5	Arka Meghali × Azad T-5	-11.21**	0.22	-5.23	2.80	3.98	22.24**	-6.15	-5.44	46.37**	53.52**	48.71	-2.75
6	Arka Meghali × H-24	0.36	1.73	-15.00	-2.62	8.81**	8.87**	-1.80	3.75	11.62**	19.90**	13.41	1.08
7	Arka Meghali × Sel-7	5.37	9.78**	-13.17	-1.79	-26.78**	-14.61**	-7.57	0.45	43.70**	49.59**	46.00	-1.58
8	Pant T-3 × Punjab Chhuhara	-5.72	-2.22	-23.00	1.82	25.86**	32.82**	14.68	7.52	27.19**	39.37**	14.51	8.81
9	Pant T-3 × H-88-78-1	-6.29	-4.94	-26.87	4.32	18.66**	24.76**	8.13	2.47	6.97**	12.90**	7.63	5.94
10	Pant T-3 × Arka Alok	-8.09*	-7.62*	-29.58	2.42	5.76*	12.80**	10.11	-3.87	17.33**	17.41**	5.78	-1.05
11	Pant T-3 × Azad T-5	-36.42**	-25.66**	-32.15	0.59	24.29**	46.69**	13.26	0.88	13.89**	15.19**	4.92	1.41
12	Pant T-3 × H-24	-17.43**	-12.87**	-30.07	4.68	23.26**	23.92**	12.32	-4.05	60.11**	62.33**	44.16	1.03
13	Pant T-3 × Sel-7	-10.40**	-10.37**	-32.06	1.15	11.55**	29.57**	40.82	6.47	13.93**	16.14**	6.64	7.50
14	Punjab Chhuhara × H-88-78-1	4.50	6.87*	-14.65	1.37	19.72**	20.19**	-1.57	3.43	50.61**	73.28**	51.54	4.94
15	Punjab Chhuhara × Arka Alok	3.07	6.36	-15.82	1.97	-11.01**	-0.21	-7.35	-0.28	18.14**	29.54**	6.52	1.73
16	Punjab Chhuhara × Azad T-5	-20.18**	-9.57**	-14.81	2.15	15.15**	29.68**	-6.06	-1.74	58.61**	75.61**	46.13	0.45
17	Punjab Chhuhara × H-24	1.24	3.08	-14.25	4.27	20.02**	26.01**	8.20	2.98	52.53**	65.05**	33.58	6.94
18	Punjab Chhuhara × Sel-7	0.46	4.22	-17.95	3.29	6.33**	29.18**	34.23	-0.65	19.19**	32.89**	11.56	2.43
19	H-88-78-1 × Arka Alok	8.12*	9.12**	-15.61	2.48	-7.54**	3.32	-3.74	-1.57	10.15**	16.18**	10.82	0.78
20	H-88-78-1 × Azad T-5	-16.56**	-3.61	-10.94	1.80	21.32**	37.10**	-0.25	2.53	55.38**	62.22**	56.33	4.07
21	H-88-78-1 × H-24	-3.28	0.67	-18.09	2.04	18.40**	23.84**	6.74	2.55	18.70**	26.93**	19.43	4.53
22	H-88-78-1 × Sel-7	11.88**	13.52**	-12.69	4.35	0.17	21.32**	26.45	0.03	36.55**	41.48**	37.39	4.32
23	Arka Alok × Azad T-5	-24.43**	-12.02**	-19.34	-0.63	-4.44	18.86**	-0.51	6.05	13.75**	14.98**	4.80	5.52
24	Arka Alok × H-24	-3.53	1.30	-18.30	3.28	-6.59**	0.13	-2.74	1.53	20.33**	22.08**	8.49	4.65
25	Arka Alok × Sel-7	6.26	6.84*	-18.59	0.31	-22.23**	-14.76**	-1.82	-0.24	16.56**	18.74**	9.10	0.00
26	Azad T-5 × H-24	-5.43	5.46	0.94	-3.66	-10.16**	5.56*	-19.01	15.61	7.61**	10.34**	-0.86	12.28
27	Azad T-5 × Sel-7	1.00	18.13**	7.80	0.28	-29.89**	-6.60*	-11.49	3.99	46.39**	47.55**	37.02	4.18
28	H-24 × Sel-7	3.63	9.38**	-12.23	2.56	11.75**	30.38**	41.07	10.52	44.28**	49.08**	35.06	12.50
	SE	3.51	3.12			2.38	2.16			0.18	0.15		
	CD at 5%	7.44	6.61			5.05	4.58			0.38	0.32		

directly affected the total fruit yield per plant, so this character is very important for fruit yield. These findings are in agreement with finding of Shankar *et al.* (2014), they recorded cross LE-53 × Arka Alok had (25.66%) highest standard heterosis for number of flowers per cluster which was similar to our result.

Days to first harvest: Early harvesting was desirable and preferable over late harvesting, data presented in Table 2 revealed that the magnitude of heterosis for days to first harvest ranged from -8.01 to 1.75 (over better parent), -11.04 to 0.25 (mid-parent) and -9.76 to 0.25 (standard check) per cent. Out of 28 crosses 14 exhibited significant heterobeltiosis in desired (negative) direction and 18 expressed significantly negative average heterosis. The highest magnitude of heterobeltiosis, average heterosis and standard heterosis was observed in the cross Arka Meghali × H-24.

Inbreeding depression ranged between -8.33 (Arka Meghali × Sel-7) to 1.56 (Pant T-3 × Sel-7) per cent. Most of the F_2 populations produced earlier harvesting than their corresponding F_1s for this trait. Earliness is required in such crops for realizing the potential economic yield in as less time as possible, which is an important consideration for a tomato grower. Negative heterosis was also reported by Asati *et al.* (2007) and Singh *et al*. (2008) where it ranged up to -12.40 per cent for days to first picking.

Number of fruit per cluster: Significant heterobeltiosis of number of fruit per cluster (Table 3) ranged from -8.20 (Pant T-3 × Punjab Chhuhara) to 39.17 per cent (Pant T-3 × H-88-78-1), varied heterosis from -2.81 (Pant T-3 × Azad T-5) to 42.71 per cent (Pant T-3 × H-88-78-1) and -13.56 (Pant T-3 × Azad T-5) to 20.79 (Arka Meghali × Punjab Chhuhara) per cent over standard check. Inbreeding depression ranged between 0.00 (H-24 × Sel-7) to 25.25 (Azad T-5 × H-24) which was positive and highly significant in this trait.

Number of fruits per cluster indicated the per cent fruit set. Twenty one hybrids showed significant positive heterobeltiosis. While twenty two crosses showed positive average heterosis. This result is on line with Shankar *et al.* (2014) and Kumari and Sharma (2011) for relative heterosis, heterobeltiosis and standard heterosis.

Fruit diameter (cm): Perusal of data revealed that heterobeltiosis, heterosis and standard heterosis for fruit diameter ranged from -12.58 (Punjab Chhuhara × H-24) to 19.93 (H-88-78-1 × H-24) per cent, -5.49 (Punjab Chhuhara × Azad T-5) to 31.43 (Arka Meghali × Arka Alok) per cent and -20.37 (Punjab Chhuhara × Azad T-5) to 13.27 (H-88-78-1 × H-24), respectively (Table 7). Out of 28 cross combinations, 21crosses over better parent, 24 crosses over mid-parent and 6 crosses over standard check H-86 exhibited significantly positive heterosis. Among the 28 crosses, the cross H-88-78-1 × H-24 has highest positive significant heterosis of 13.27 per cent over standard check (H -86) followed by H-88-78-1 × Arka Alok (3.70%). Inbreeding depression ranged between 0.35 (Arka Meghali × Pant T-3) to 13.82 (Arka Meghali × H-24) per cent.

All F_2 populations showed positive inbreeding depression than their corresponding F_1s. Fruit diameter is an important fruit quality parameter. Most promising hybrid was Arka Meghali × Arka Alok which exhibited highest significant positive heterosis for fruit diameter. The results of heterosis for fruit diameter are in close agreement with the findings of Asati *et al.* (2007), Shankar *et al.* (2014) and Dagade *et al.* (2015). They showed significant heterosis in F_1 and high inbreeding depression in F_2 generation revealing presence of non additive gene.

Fruit length (cm): The maximum positive heterosis over better parent, mid-parent and standard checks for fruit length (Table 3) was recorded in Arka Meghali × Arka Alok (19.29%), Arka Meghali × Arka Alok (22.34%) and Punjab Chhuhara × Sel-7 (13.35%) the maximum negative heterosis over better parent (-18.33), mid-parent (-11.87) and standard checks (-17.84) was recorded in Pant T-3 × H-24. All F_2 populations showed positive inbreeding depression than their corresponding F_1s means reduction in fruit length in F_2 generation. The lowest inbreeding depression observed in cross Arka Meghali × H-88-78-1 (1.28%) while highest in cross Arka Alok × H-24 (19.62%). For fruit length most promising hybrid was Arka Meghali × Arka Alok, which exhibited highest significant positive heterosis.

Fruit length is a vital character influencing fruit quality. Fruits with more length and diameter are preferable both for consumption and for processing purpose. Significant heterosis and both direction inbreeding depression for fruit length was also reported by Kurian *et al.* (2001) and Dagade *et al.* (2015).

Average fruit wt. (Kg.): Perusal of data presented in Table 4 revealed that heterobeltiosis, mid-heterosis and standard heterosis for average fruit weight ranged from -36.42 (Pant T-3 × Azad T-5) to 18.88 (Arka Meghali × Punjab Chhuhara) per cent, -25.66 (Pant T-3 × Azad T-5) to 19.41 (Arka Meghali × Punjab Chhuhara) and -32.15 (Pant T-3 × Azad T-5) to 7.80 (Azad T-5 × Sel-7) per cent, respectively. The maximum positive heterosis over better parent and mid-parent for average fruit weight was recorded in Arka Meghali × Punjab Chhuhara. Some of the hybrids exhibited positive heterobeltiosis, but they were not significant. Six F_2 populations showed negative (desired) inbreeding depression for average fruit weight than their respective F_1s.

Average fruit weight directly affects the total fruit yield, so this character is very important so far fruit yield is concerned. Shankar *et al.* (2014), Singh and Sastry (2011) and Kumari and Sharma (2011) also reported positive heterosis up to 10 to 40 per cent for average fruit weight in tomato. High average fruit weight is of prime importance in breeding high yielding cultivars.

Number of fruits per plant: Heterobeltiosis, mid-parent and standard heterosis for number of fruits per plant is presented in Table 4 and these values ranged from -29.89 (Azad T-5 × Sel-7) to 25.86 (Pant T-3 × Punjab Chhuhara) per cent, -14.76 (Arka Alok × Sel-7) to 46.69 (Pant T-3 × Azad T-5) per cent and -19.01 (Azad T-5 × H-24) to 41.07 (H-24 × Sel-7), respectively. Among 28 cross combinations, 17 crosses over better parent, 19 crosses over mid-parent and 13 crosses over standard check (H-86) exhibited positively significant heterosis for this trait in desirable direction. Inbreeding depression ranged between -5.44 (Arka Meghali × Azad T-5) to 15.61 (Azad T-5 × H-24) per cent. Eleven F_2 populations produced negative and highly significant inbreeding depression were recorded in this trait.

Number of fruits directly affects the total fruit yield per plant, so this character is very important for fruit yield. These findings are in close agreement with Asati *et al.* (2007), Kumari and Sharma (2011), and Singh and Sastry (2011).

Yield per plant (Kg.): Yield is a complex quantitative character which depends on yield contributing characters. The data on per cent heterosis revealed that the crosses exhibited yield (Table 4), out of 28 cross combinations Pant T-3 × H-24 had highest positive significant heterosis of 60.11 per cent over better parent followed by Punjab Chhuhara × Azad T-5 (58.61%) and H-88-78-1 × Azad T-5 (55.38%). The cross Punjab Chhuhara × Azad T-5 (75.61%) showed highest significant positive heterosis over mid parent followed by Arka Meghali × Punjab Chhuhara (75.52%) and Punjab Chhuhara × H-88-78-1 (73.28%). Similarly, hybrids H-88-78-1 × Azad T-5, Arka Meghali × Punjab Chhuhara and Punjab Chhuhara × H-88-78-1 showed 56.33, 54.37 and 51.54 per cent over standard check respectively. Inbreeding depression ranged between -5.94 (Arka Meghali × H-88-78-1) to 12.50 (H-24 × Sel -7) per cent. Among 28 crosses, 4 F_2 populations exhibited negative inbreeding depression which was desirable for fruit yield per plant.

The observed heterosis for fruit yield may be due to genetic diversity of the parent used in hybrid combinations, increase in fruit size, weight and number of fruits. These findings are in close agreement with the findings of Asati *et al.* (2007), Singh *et al.* (2008), Kurian *et al.* (2001) and Kumari and Sharma (2011).

It can be concluded from the results that none of the cross combinations was heterotic for all characters simultaneously. In this study promising hybrid Pant T-3 × Punjab Chhuhara produced the highest number of fruits per plant while Pant T-3 × H-24 produced highest total yield per plant. High heterosis for yield appears to be the consequence of heterosis of these yield attributing traits viz number of flowers per cluster, number of fruits per cluster, average fruit weight and number of fruit per plant.

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