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EXPLOITATION OF HETEROSIS AND INBREEDING DEPRESSION FOR YIELD, HYBRID SEED YIELD, NUTRITIONAL AND PROCESSING QUALITY IMPROVEMENT IN TOMATO (*Solanum lycopersicum* L.) UNDER NORTH INDIAN CONDITIONS

CHANDAN KUMAR AND SURENDRA PRASAD SINGH*
ICAR-Central Arid Zone Research Institute, KVK, Pali - Marwar (Rajasthan) - 306 401, INDIA
*Department of Horticulture, IAS, BHU, Varanasi (U.P.) -221 005, INDIA
e-mail: chandankumarveg.sc@gmail.com

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***Corresponding author**

ABSTRACT

A diallel analysis was carried out to study the heterotic performance in F_1 and F_2 generation of tomato for yield, nutritional and processing quality. The study exposed that significant positive as well as negative heterosis and inbreeding depression was recorded in most of the crosses for all the traits under observation. This experiment comprising a total of 64 treatments (28 F_1 + 28 F_2 + 8 parents) one standard check (H-86) was evaluated in RBD. Promising combination for average fruit weight and number of seeds per fruit was Arka Meghali x Punjab Chhuhara (19.41% and 75.89%, respectively) showing highest significant heterosis. Pant T-3 x H-24 (60.11%) showed highly significant positive heterosis over better parent for yield per plant along with considerable inbreeding depression while, H-88-78-1 x Azad T-5 (31.30%) cross showed promising results for ascorbic acid content and H-24 x Sel-7 cross shows potential hybrid in respect to average heterosis (16.32%) and heterobeltiosis (16.56%) for TSS. Punjab Chhuhara × H-88-78-1 (40.43%) and Punjab Chhuhara × Arka Alok (36.90%) had showed maximum average heterosis and heterobeltiosis for acidity as ACA trait however Arka Alok x Azad T-5 (32.29%) was hopeful hybrid combination for the trait lycopene content.

INTRODUCTION

Tomato (*Lycopersicum esculentum* L.) is one of the most important vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries (Kumar and Singh, 2016a). Exploring natural diversity as a source of novel alleles to improve the productivity, quality and nutritional value of the crop is the base line of any breeding programme. Successful exploitation of heterosis in tomato is economical because each fruit contains larger number of seeds as compared to other vegetables (Kumari and Sharma, 2011). Now a day, farmers of is very much inclined to grow hybrid variety for having high yielding and to get 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 nutrition importance of the tomato indicates there is need to formulate breeding programme and to develop cultivars rich in vitamins, nutrients and oxidants, processing traits with high quality of fruit as well as yield (Dagade, *et al.*, 2015). Total soluble solids (TSS), lycopene content, number of locules per fruit, pericarp thickness and ascorbic acid have been recognized as the most desirable attributes in tomato for contributing towards shelf life besides biochemical changes and processing industry (Shankar, *et al.*, 2014). The increase of 1% TSS in fruits results to increase 20% recovery of processed products (Dagade, *et al.*, 2015). 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 (Meena and Bahadur, 2014). Hence, the present studies were undertaken to study the desirable heterosis in yield, nutritional and processing quality 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, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.), India during *Rabi* season of 2012 and 2013. The soil of experimental field was alluvial type of soil with average fertility level and pH in the range of 6.6 to 7.4. 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 hybrids F_2 population (8 parents, 28 F_1 hybrids and 28 F_2) and one standard check (H-86) was field evaluated during *rabi* 2012-13, using randomized complete block design with 3 replications at the spacing of 60 cm x 45 cm. Recommended cultural practices and plant protection measures were followed in all seasons. The selected pants were tagged and properly labelled before flowering and for recording the nine observations *viz*., average fruit weight (g), number of locules per fruit, pericarp thickness (cm), number of seeds per fruit, yield per plant (Kg.), TSS (°Brix), ascorbic acid (mg/100g FW), acidity as ACA (%) and lycopene content.

For estimation of quality traits, ripe fruits were selected randomly. Total soluble solids was estimated by using hand refractometer, ascorbic acid and lycopene content was estimated according to procedure given by Ranganna (1986), titrable acidity will be measure based on the titration of tomato acid mainly citric acid, by an alkaline solution. Heterosis and inbreeding depression for each trait was worked out by utilizing the overall mean of each hybrid over replications for each trait. Significance of heterosis is tested with the help of standard error using't' test. The heterosis of F_1's over the better parent (heterobeltiosis) (Rai, 1979), mid parent (relative heterosis) (Fonseca and Patterson, 1968) and check variety (standard heterosis) (Tysdal *et al.* 1962 and Rai, 1979) were calculated by using the following formula

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F}_1 - \overline{Bp}}{\overline{BP}} \times 100$$

$$\text{Relative Heterosis(\%)} = \frac{\overline{F_1} - MP}{\overline{MP}}$$

$$\text{Standard Heterosis(\%)} = \frac{\overline{F}_1 - \overline{SC}}{\overline{SC}} \times 100$$

Where, F_1 = mean performance of cross, BP = mean performance of better parent and SV = mean performance of standard variety (H-86). Inbreeding depression (ID) from F_1 to F_2 was calculated by the formula, ID (%) = $[(F_1 - F_2) / F_1] \times 100$ where F_2 denotes the mean of F_2 population for a trait. Estimate of inbreeding depression from F_2 over F_1 were calculated in term of percentage. The negative and positive values were considered as per cent as decrease and increase, respectively.

RESULTS AND DISCUSSION

Analysis of variance revealed (Table 1) for, parents, hybrids and parents v/s hybrids were significant for average fruit weight, pericarp thickness, number of seeds per fruit, yield per plant and ascorbic acid, while, parents and parents v/s hybrids were significant for number of locules per fruit and only parents v/s hybrids were significant for TSS and lycopene content characters, which indicated presence of substantial amount of heterosis in all cross combinations. Considerable genetic variation for various traits including yield and quality of fruit has been reported by many workers (Dagade, *et al*., 2015, Meena and Bahadur, 2014 , Shankar, *et al*., 2014 and Kumar and Singh, 2016b).

The extent of heterosis and inbreeding depression for different characters is presented in Table 2 to 4. The maximum significant positive heterosis for average fruit weight was recorded in Arka Meghali x Punjab Chhuhara (18.88 % over better parent and 19.41 % over mid-parent) cross and 6 F_2 populations showed negative (desired) inbreeding depression than their respective F_1s. Pant T-3 x Azad T-5 cross showed highly significant positive for number of locules per fruit Numbers of locules and average fruit weight decide the hybrid seed production, fruit shape and amount of juice increases with an increase in locule number, processing industries favour more loculated fruits. In contrast less number of locules is favoured by farmers and consumers because these fruits will be firm. Similar findings ware also reported Singh *et al.* (2008), Kumar *et al.* (2009), Kumari and Sharma, (2011) and Kumar and Singh, (2016b) by in tomato.

The cross H-88-78-1 x Arka Alok revealed maximum significant positive heterobeltiosis, relative heterosis and standard heterosis (15.97%, 29.58% and -9.80%, respectively) for pericarp thickness. Fruits having high pericarp thickness decide the keeping quality. The number of seeds per fruit (Table 3) was observed highest significant for in the cross Arka Meghali x Punjab Chhuhara. 12 F_2 populations observed negative (desired) inbreeding depression for number of seeds per fruit. Heterosis has been also reported for this trait by Singh *et al.* (2008) and Singh *et al.* (2012).

For yield per plant highest significantly positive heterosis over better, mid and standard parent (Table 3) was recorded in Pant T-3 x H-24 (60.11%), Punjab Chhuhara x Azad T-5 (75.61%) and H-88-78-1 x Azad T-5 (56.33%), respectively crosses. 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 Singh, et al. (2008), Meena and Bahadur, (2014), Kumari and Sharma (2011) and Kumar and Singh, (2016b) .

Table 1 : Analysis of variance (mean sum of squares) for parents, F_1 and parents v/s F_1 of different traits in tomato

Source of variation	d.f	Avg. fruit weight (g)	No of locules per fruit	Pericarp thickness (cm)	Number of seeds per fruit	Yield per plant (Kg.)	TSS (°Brix)	Ascorbic acid (mg /100g FW)	Acidity as ACA (%)	Lyco pene content
REP	2	14.86	0.09	0.01	4.28	0.01	0.15	4.97	0.01	0
TRET	35	249.11**	0.24**	0.01*	612.89**	1.10**	0.4	20.63**	0.04**	0.02
PAR	7	288.86**	0.47**	0.03**	134.81**	0.16*	0.57	40.49**	0.12**	0.01
F_1	27	246.32**	0.11	0.01*	534.37**	0.84**	0.32	15.76**	0.02	0.02
P V/S F_1	1	46.13*	2.29**	0.01*	6079.2**	14.80**	1.47**	13.10**	0	0.04**
EROR	70	13.98	0.07	0	13.25	0.04	0.26	3.33	0.01	0.01
Total	107	90.91	0.13	0.01	209.23	0.39	0.3	9.02	0.02	0.01

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

Table 2 : Magnitude of heterosis and inbreeding depression of average fruit weight, number of locules per fruit and pericarp thickness in 8 x 8 diallel set of tomato.

S. No.	Hybrids	Avg. fruit weight (g)				No of locules per fruit				Pericarp thickness (cm)			
		BP	MP	SV	ID	BP	MP	SV	ID	BP	MP	SV	ID
1	Arka Meghali x Pant T-3	5	9.37**	-13.48	-3.82	-0.53*	1.70**	0.27	-4.06	-8.24**	10.30**	-28.63	-6.42
2	Arka Meghali x Punjab Chhuhara	18.88**	19.41**	-2.04	5.2	0.88**	10.58**	1.68	-1.74	-43.23**	-30.75**	-30.98	-8.49
3	Arka Meghali x H-88-78-1	4.61	7.45*	-13.8	-0.89	1.49**	3.30**	2.3	1.47	6.39**	6.39**	-17.25	1.59
4	Arka Meghali x Arka Alok	13.11**	17.22**	-6.8	4.63	2.41**	9.11**	3.23	2.4	-0.17	11.55**	-22.35	-6.67
5	Arka Meghali x Azad T-5	-11.21**	0.22	-5.23	2.8	2.37**	15.54**	3.18	2.31	-10.91**	-6.29**	-23.14	-2.54
6	Arka Meghali x H-24	0.36	1.73	-15	-2.62	-1.75**	0.90**	-0.97	-4.46	-9.09**	-4.38**	-21.57	-3.33
7	Arka Meghali x Sel-7	5.37	9.78**	-13.17	-1.79	-6.43**	-1.75**	4.24	-1.78	-12.42**	-10.62**	-29.02	-5.5
8	Pant T-3 x Punjab Chhuhara	-5.72	-2.22	-23	1.82	13.76**	22.17**	9.64	4.03	-43.66**	-20.91**	-31.5	0
9	Pant T-3 x H-88-78-1	-6.29	-4.94	-26.87	4.32	10.36**	10.87**	7.34	6.1	-6.22**	12.73**	-27.06	0.9
10	Pant T-3 x Arka Alok	-8.09*	-7.62*	-29.58	2.42	1.15**	5.50**	-2.52	-4.26	13.62**	23.47**	-30.2	9.35
11	Pant T-3 x Azad T-5	-36.42**	-25.66**	-32.15	0.59	18.39**	31.02**	14.1	12.47	-29.09**	-11.28**	-38.82	-7.45
12	Pant T-3 x H-24	-17.43**	-12.87**	-30.07	4.68	5.28**	5.76**	1.46	3.31	-17.42**	3.32**	-28.76	0
13	Pant T-3 x Sel-7	-10.40**	-10.37**	-32.06	1.15	-3.17**	3.83**	7.87	9.02	-30.32**	-14.88**	-43.53	-13.95
14	Punjab Chhuhara x H-88-78-1	4.5	6.87*	-14.65	1.37	3.18**	11.27**	0.35	15.42	-41.29**	-28.39**	-28.63	0
15	Punjab Chhuhara x Arka Alok	3.07	6.36	-15.82	1.97	9.70**	13.09**	-3.01	3.37	-28.39**	-4.86**	-12.94	6.77
16	Punjab Chhuhara x Azad T-5	-20.18**	-9.57**	-14.81	2.15	18.09**	21.98**	-1.86	-5.41	-31.40**	-19.75**	-16.6	9.38
17	Punjab Chhuhara x H-24	1.24	3.08	-14.25	4.27	1.53**	8.56**	-3.05	6.11	-29.03**	-16.98**	-13.73	-5.3
18	Punjab Chhuhara x Sel-7	0.46	4.22	-17.95	3.29	-11.90**	0.91**	-1.86	2.7	-38.71**	-26.45**	-25.49	-7.89
19	H-88-78-1x Arka Alok	8.12*	9.12**	-15.61	2.48	11.73**	17.05**	8.66	7.24	15.97**	29.58**	-9.8	-2.9
20	H-88-78-1 x Azad T-5	-16.56**	-3.61	-10.94	1.8	12.73**	25.25**	9.64	8.06	-20.00**	-15.86**	-30.98	-6.6
21	H-88-78-1 x H-24	-3.28	0.67	-18.09	2.04	8.91**	9.91**	5.92	7.35	-4.55**	0.4	-17.65	6.35
22	H-88-78-1 x Sel-7	11.88**	13.52**	-12.69	4.35	-5.83**	0.55**	4.91	-1.1	-5.16**	-3.21**	-23.14	1.69
23	Arka Alok x Azad T-5	-24.43**	-12.02**	-19.34	-0.63	14.85**	22.18**	1.55	-0.96	1.82**	18.94**	-12.16	1.49
24	Arka Alok x H-24	-3.53	1.3	-18.3	3.28	7.92**	12.07**	3.05	-1.2	-10.00**	5.13**	-22.35	3.36
25	Arka Alok x Sel-7	6.26	6.84*	-18.59	0.31	-1.19**	10.18**	10.08	7.63	-5.16**	7.89**	-23.14	5.08
26	Azad T-5 x H-24	-5.43	5.46	0.94	-3.66	-2.78**	7.14**	-7.16	-7.62	0.91	0.91	-12.94	1.49
27	Azad T-5 x Sel-7	1	18.13**	7.8	0.28	-10.87**	4.95**	-0.71	1.16	-5.45**	-2.50**	-18.43	-2.4
28	H-24 x Sel-7	3.63	9.38**	-12.23	2.56	-2.50**	5.00**	8.62	-0.49	-9.09**	-6.25**	-21.57	-3.33
	SE	3.51	3.12			0.22	0.2			0.54	0.54		
	CD at 5%	7.44	6.61			0.47	0.42			1.28	1.28		

Table 3 : Magnitude of heterosis and inbreeding depression of number of seed per fruit, yield per plant and total soluble solid in 8 x 8 diallel set of tomato.

S. No.	Hybrids	Number of seed per fruit				Yield per plant (Kg.)				TSS (°Brix)			
		BP	MP	SV	ID	BP	MP	SV	ID	BP	MP	SV	ID
1	Arka Meghali x Pant T-3	-6.83	1.77	-4.33	3.11	-5.69**	0	-4.18	3.55	-4.93**	4.80**	3.9	2.78
2	Arka Meghali x Punjab Chhuhara	74.09**	75.89**	48.55	-1.05	51.94**	75.52**	54.37	0.84	-13.01**	-9.15**	3.9	2.1
3	Arka Meghali x H-88-78-1	36.00**	41.78**	26.36	-0.21	46.37**	47.08**	48.71	-5.94	4.11**	10.84**	13.78	1.58
4	Arka Meghali x Arka Alok	26.15**	29.42**	7.64	3.27	15.74**	22.64**	17.59	1.05	-7.29**	-0.54**	1.33	-0.85
5	Arka Meghali x Azad T-5	23.91**	33.53**	23.53	0.93	46.37**	53.52**	48.71	-2.75	7.64**	13.31**	17.64	2.79
6	Arka Meghali x H-24	2.95	10.29**	1.34	-5.33	11.62**	19.90**	13.41	1.08	-5.71**	1.73**	3.04	-4.47
7	Arka Meghali x Sel-7	35.61**	44.63**	32.2	-0.24	43.70**	49.59**	46	-1.58	4.11**	12.55**	13.78	5.01
8	Pant T-3 x Punjab Chhuhara	-4.68	5.09	-2.13	-0.57	27.19**	39.37**	14.51	8.81	-15.88**	-3.60**	0.47	-0.23
9	Pant T-3 x H-88-78-1	14.95**	20.69**	18.03	0.43	6.97**	12.90**	7.63	5.94	10.45**	14.64**	6.05	0.29
10	Pant T-3 x Arka Alok	-5.51	5.64	-2.98	-1.72	17.33**	17.41**	5.78	-1.05	4.88**	8.00**	-0.94	-1.26
11	Pant T-3 x Azad T-5	-3.48	-2.06	-0.9	-3.05	13.89**	15.19**	4.92	1.41	-1.79**	3.13**	-3.4	-5.41
12	Pant T-3 x H-24	19.50**	22.02**	22.7	1.74	60.11**	62.33**	44.16	1.03	5.86**	8.35**	-1.25	-1.58
13	Pant T-3 x Sel-7	-0.32	2.27	2.35	5.17	13.93**	16.14**	6.64	7.5	8.61**	10.94**	0.9	3.71
14	Punjab Chhuhara x H-88-78-1	56.55**	64.83**	45.45	-0.32	50.61**	73.28**	51.54	4.94	-17.06**	-8.04**	-0.94	9.45
15	Punjab Chhuhara x Arka Alok	45.75**	48.02**	21.81	1.79	18.14**	29.54**	6.52	1.73	2.09**	14.01**	21.94	9.15
16	Punjab Chhuhara x Azad T-5	19.24**	29.73**	18.88	2.09	58.61**	75.61**	46.13	0.45	-2.94**	6.45**	15.93	9.15
17	Punjab Chhuhara x H-24	0.13	8.30**	-1.43	-2.58	52.53**	65.05**	33.58	6.94	-1.86**	10.20**	17.21	5.79
18	Punjab Chhuhara x Sel-7	9.86*	18.29**	7.1	1.5	19.19**	32.89**	11.56	2.43	0.65	13.24**	20.22	10.45
19	H-88-78-1x Arka Alok	4.23	11.36**	-3.16	-0.72	10.15**	16.18**	10.82	0.78	15.37**	16.31**	10.77	1.76
20	H-88-78-1 x Azad T-5	45.02**	50.13**	44.58	1.5	55.38**	62.22**	56.33	4.07	0.4	1.61**	-1.25	-3.08
21	H-88-78-1 x H-24	-3.83	-1.06	-5.34	0.99	18.70**	26.93**	19.43	4.53	5.08**	6.60**	0.9	-1.7
22	H-88-78-1 x Sel-7	22.04**	24.98**	18.98	1.58	36.55**	41.48**	37.39	4.32	1.30**	2.98**	-2.73	-3.13
23	Arka Alok x Azad T-5	4.47	15.27**	4.15	0.57	13.75**	14.98**	4.8	5.52	2.26**	4.33**	0.59	1.09
24	Arka Alok x H-24	7.25*	17.67**	5.57	-1.18	20.33**	22.08**	8.49	4.65	10.00**	10.69**	3.9	2.03
25	Arka Alok x Sel-7	26.93**	38.65**	23.75	3.56	16.56**	18.74**	9.1	0	11.03**	11.96**	4.88	-4.17
26	Azad T-5 x H-24	6.64	7.31*	6.31	0.57	7.61**	10.34**	-0.86	12.28	2.58**	5.30**	0.9	-0.15
27	Azad T-5 x Sel-7	41.13**	42.71**	40.7	-1.25	46.39**	47.55**	37.02	4.18	-0.91*	1.92**	-2.54	-0.48
28	H-24 x Sel-7	19.30**	19.88**	17.44	2.91	44.28**	49.08**	35.06	12.5	16.32**	16.56**	8.51	1.8
	SE	3.31	2.94			0.18	0.15			0.42	0.36		
	CD at 5%	**7.02**	**6.23**			**0.38**	**0.32**			**0.89**	**0.76**		

Among the 28 crosses, the cross H-24 x Sel-7 had maximum heterosis over better parent (16.32%) and mid parent (16.56%), While hybrid Punjab Chhuhara x Arka Alok (21.94%) showed maximum over standard check for TSS content. The ascorbic acid and acidity as ACA (Titrable acidity) content top positive significant heterosis noticed in crosses H-88-78-1 x Azad T-5

Table 4 : Magnitude of heterosis and inbreeding depression of ascorbic acid, acidity as ACA and lycopene content in 8 x 8 diallel set of tomato.

S. No.	Hybrids	Ascorbic acid (mg/100g FW)				Acidity as ACA (%)				Lycopene content			
		BP	MP	SV	ID	BP	MP	SV	ID	BP	MP	SV	ID
1	Arka Meghali x Pant T-3	-20.22**	-6.02**	-8.84	3.49	-45.16**	-26.95**	-24.9	-2.67	-2.08**	-1.14**	8.12	11.54
2	Arka Meghali x Punjab Chhuhara	2.68	10.31**	-4.98	2.6	11.93**	12.92**	-23.13	1.04	-10.28**	-7.85**	-0.94	10.5
3	Arka Meghali x H-88-78-1	15.15**	16.57**	-5.89	-1.62	-6.26**	1.76**	-23.57	-4.74	-10.85**	-3.18**	-1.56	11.02
4	Arka Meghali x Arka Alok	-20.07**	-7.59**	-12.67	-0.47	23.51**	25.34**	-15.18	-2.83	-14.25**	-7.43**	-5.31	9.25
5	Arka Meghali x Azad T-5	1.68	10.10**	-4.27	4.74	-12.62**	3.44**	-12.97	8.29	-11.89**	-6.97**	-2.71	14.1
6	Arka Meghali x H-24	-11.51**	-2.97*	-14.35	-0.26	-18.10**	-7.65**	-27.31	0.55	-16.79**	-12.85**	-8.13	14.48
7	Arka Meghali x Sel-7	-18.31**	-3.40*	-5.78	2.73	-4.37**	-1.13**	-29.72	2.86	-9.72**	-4.87**	-0.31	5.86
8	Pant T-3 x Punjab Chhuhara	-1.92	8.38**	12.07	3.78	-27.86**	-3.34**	-1.2	-0.81	-4.23**	-2.54**	3.75	10.8
9	Pant T-3 x H-88-78-1	-1.58	14.76**	12.46	-0.22	-35.31**	-18.90**	-11.41	-23.08	15.38**	24.22**	25	20
10	Pant T-3 x Arka Alok	-1.43	0.78	12.64	0.5	-33.49**	-10.53**	-8.92	-7.93	7.69**	15.23**	16.67	12.1
11	Pant T-3 x Azad T-5	-10.65**	-2.03	2.09	6.48	-24.63**	-12.73**	3.21	6.61	-0.48**	4.12**	7.81	11.54
12	Pant T-3 x H-24	-4.17*	3.77*	9.5	4.89	-29.79**	-14.80**	-3.86	-7.53	-6.25**	-2.69**	1.56	6.12
13	Pant T-3 x Sel-7	-4.50*	-4.05**	10.15	2.34	-22.11**	1.37**	6.67	8.27	-3.37**	0.90**	4.69	8.73
14	Punjab Chhuhara x H-88-78-1	4.30*	10.77**	-3.48	6.17	28.33**	40.43**	4.62	10.73	-13.35**	-8.23**	-9.38	2.29
15	Punjab Chhuhara x Arka Alok	-12.72**	-5.49**	-4.64	1.85	36.90**	37.72**	-7.63	6.96	-11.35**	-6.71**	-7.29	13.45
16	Punjab Chhuhara x Azad T-5	-3.25*	-2.41	-8.91	2.59	-17.74**	-1.92**	-18.07	-0.49	4.58**	7.58**	9.37	9.51
17	Punjab Chhuhara x H-24	-0.23	2.01	-3.43	1.78	-7.69**	4.88**	-18.07	-4.41	0.20*	2.24**	4.79	15.48
18	Punjab Chhuhara x Sel-7	-15.24**	-5.94**	-2.23	7.58	11.48**	16.24**	-18.07	-8.82	-3.88**	-1.33**	0.52	8.68
19	H-88-78-1x Arka Alok	-6.18**	7.34**	2.51	-3.03	8.37**	19.24**	-11.65	2.71	27.21**	28.06**	19.79	13.19
20	H-88-78-1 x Azad T-5	22.64**	31.30**	15.46	2.83	-23.71**	-16.10**	-24.02	-3.68	16.67**	20.22**	15.21	9.03
21	H-88-78-1 x H-24	15.76**	25.52**	12.04	2.76	0.36*	4.62**	-10.92	-7.21	3.73**	7.76**	4.17	-1.2
22	H-88-78-1 x Sel-7	-7.32**	8.49**	6.9	0.02	-4.68**	0.26*	-22.29	8.25	11.87**	15.51**	10.94	12.41
23	Arka Alok x Azad T-5	-11.24**	-4.64**	-3.02	3.37	-18.95**	-2.90**	-19.28	4.98	29.22**	32.29**	27.6	16.61
24	Arka Alok x H-24	-4.59**	1.19	4.25	5.07	-6.02**	7.34**	-16.59	3.85	14.32**	17.99**	14.79	14.13
25	Arka Alok x Sel-7	-11.23**	-8.83**	2.39	1.05	13.33**	18.85**	-16.71	-3.38	11.34**	14.22**	10.42	12.45
26	Azad T-5 x H-24	-1.58	-0.22	-4.74	1.3	-12.90**	-7.89**	-13.25	-7.87	9.96**	10.88**	10.42	7.55
27	Azad T-5 x Sel-7	-11.34**	-2.37	2.26	4.6	-1.21**	13.69**	-1.61	2.86	4.52**	4.74**	3.65	4.42
28	H-24 x Sel-7	-1.11	7.53**	14.06	5.76	1.36**	10.89**	-10.04	5.36	19.81**	20.56**	20.31	8.62
	SE	1.53	1.31		0.08	0.06			0.06	0.06			
	CD at 5%	3.24	2.78		0.17	0.13			0.13	0.13			

and Punjab Chhuhara x H-88-78-1, respectively. For lycopene content trait, Arka Alok x Azad T-5 showed highest magnitude of heterosis, so that this cross is most promising for this trait. Highly significant positive heterosis for vitamin C, TSS and lycopene content was also recognized by Dagade *et al*. (2015), Singh *et al*. (2008), Kumar *et al*. (2009) and Kumari and Sharma (2011) .Heterosis breeding may be one of the most prominent approaches for quality improvement, as most of the quality characters are governed by non-additive gene action.

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