Original Research Article

Studies on Heterosis for fruit yield, quality and ToLCV resistant in Tomato *(Solanum lycopersicum* L.)

ABSTRACT

Aims: The current study was designed to investigate the nature and extent of heterosis for marketable fruit output, quality attributes, and resistance to tomato leaf curl virus.

Study design: Statistical Randomized Block Design

Place and Duration of Study: The current study was conducted in Horticulture Research Field at Sam Higginbottom University of Agriculture Technology and Sciences at Prayagraj U.P. India during Rabi, 2016–17.

Methodology: The experimental included three testers and thirteen lines During Rabi, 2016–17, out of these, ten lines (female parents) were crossed with every three testers (male parents). The resulting 30 F1s were assessed for yield, fruit quality, and leaf curl virus resistance. To gather data, five plants from each replication were randomly tagged in each entry and analysis of variance was performed. Heterosis over better parent (BP) was calculated by treating each feature using the approach proposed by Hayes et al. (1955). The studied data were statically analyzed using the Indostat software Hyderabad program.

Results: The standard heterosis for fruit yield ranged from -67.19 to 29.70% Check (Kashi Abhiman). Five crosses *viz.,* Arka Abha x Kashi Aman, Arka Abha x Kashi Vishesh, Pant T-7 x Kashi Vishesh, S-22 x H-88-78-5 and Pant T-7 x Kashi Aman were exhibited sufficient amount of significant and positive heterosis for fruit yield over standard check. The hybrids Azad T-5 x Kashi Aman and Pant T-7 x Kashi Aman exhibited low incidence with negative heterosis for the ToLCV incidence and severity.

Conclusion: Commercialization of hybrid vigor in tomato (*Solanum lycopersium* L.) has gained prominence due to various advantages of hybrids over pure line varieties, including higher marketable fruit output, component characteristics, and resilience to biotic and abiotic stresses. According to data presented in the study it is concluded that hybrid vigour can obtain by crossing of parents having desirable characters in tomato.

***Keywords*:** *Tomato, Heterosis, ToLCV, resistance, Hybrid and Vigour.*

1. INTRODUCTION

Tomato (Solanum l*ycopersium* L.) is a popular vegetable crop in among the vegetables. The major objective of tomato breeding is to be developed high yielding varieties with earliness, desirable/attractive fruit shape, size, colour and free from various diseases (Tomato leaf curl virus).Tomato leaf curl disease

is reported to be widespread in India causing severe yield losses. The disease caused by white fly-transmitted Gemini viruses of economic importance and has become a recent problem on tomato farms in India. Farmers ignorantly use pesticides to control the ToLCV disease but to no avail. The best way to combat this disease is to use plants that are resistant to the disease.

Commercialization of hybrid vigor in tomato (*Solanum lycopersium* L.) has gained prominence due to various advantages of hybrids over pure line varieties, including higher marketable fruit output, component characteristics, and resilience to biotic and abiotic stressors. However, there are studies in the literature about hybrid vigour in tomato and certain cross combinations have been developed and made available to farmers, but more emphasis is needed in the identification and creation of additional acceptable cross combinations. The heterosis discloses the type of gene activity involved, which aids in the selection of proper breeding methodology and parameters for crop development. Taking these facts into account, the current study was designed to investigate the nature and extent of heterosis for marketable fruit output, quality attributes, and resistance to tomato leaf curl virus.

2. MATERIALS AND METHODS

The current study was conducted at Sam Higginbottom University of Agriculture Technology and Sciences at Prayagraj's Horticulture Research Field. The experimental included three testers (Kashi Aman and Kashi Vishesh) and thirteen lines (H-88-78-5, Arka Abha, Arka Vikash, S-22, Hisar Lalit, Azad T-5, Azad T-6, Pant T-5, Pant T-7, and Kashi Sharad) during the Rabi season of the year 2016–17. Out of these, ten lines (female parents) were crossed with every three testers (male parents). The resulting 30 F1s were assessed for yield, fruit quality, and leaf curl virus resistance. In a randomized block design that was duplicated three times, all 43 entries including 13 parents, 30 F1s, and one commercial hybrid (Kashi Abhiman) were sowed in the rainy season of 2017. Each entry was grown in two rows, with ten plants in each row, using a 60 cm between rows and 45 cm within rows spacing. To gather data, five plants were chosen at random and labeled for each entry. To produce a healthier yield, cultural procedures were uniformly applied to all treatments. There were no insecticides applied to lure the whiteflies virus vector to the area. To gather data, five plants from each replication were randomly tagged in each entry. In accordance with the procedures outlined by Panse and Sukhatme (1967), an analysis of variance was performed. Heterosis over better parent (BP) was calculated by treating each feature using the approach proposed by Hayes et al. (1955). The breeding value of the plant material was determined by examining heterosis data for the complete trait of the F_1 under consideration. The studied data were statically analyzed using the Indostat software Hyderabad program.

3. RESULTS AND DISCUSSION

Increased yield, which in turn depends on the contribution of multiple component features, is the typical manifestation of heterosis. To determine the value of a cross, heterosis manifestation in all of the desirable characteristics has been studied. Any trait for which the majority of crossings show significant

heterosis over better parents indicates non-additive gene activity is involved in the genetic control of that trait. The mean performance of the 10 lines and three testers utilized as parents in the current investigation (Table 1&2). Numerous hybrids in this experiment displayed quite significant heterosis in the intended direction for the various traits (Table 3&4) and character wise described below.

3.1. Days to First Flowering

Range of mean values of parents, F_1 hybrids and heterosis (%) over mid, better and commercial check is given in table 3 & 4. Days to 50% flowering mean value range from 31.67 (Arka Abha) to 46.00 (Kashi Sharad) for parents and 36.33 (Check) to 51.67 (Azad T-5 x Kashi Vishesh) for F1 hybrids. Range of heterosis percentage for Days to 50% flowering varied from 2.43 to 35.45 for MP 0.00 to 30.00 for BP and 12.29 to 43.12 for CC. The hybrids Azad T-6 x H-88-78-5 (35.45), Azad T-6 x H-88-78-5(30.70) and S-22 x Kashi Vishesh (43.12) were showed significant heterosis percent over mid parent, better parent and standard check, respectively (Table 3&4).there in no parnt shows the significant heterosis in negative direction. However, the hybrid Azad T-6 x H-88-78-5 take minimum days to 50% flowering.

3.2. Number of Fruits per Plant

The minimum parental mean value for No. of fruits/ plant produced by check (46.58) whereas, the maximum in S-22 (71.93) for parent and 30.67 (Angoorlata x H-88-78-5) to 69.64 (S-22 x H-88-78-5) for F1 hybrid. For number of fruits/plant heterosis ranged from -40.89% (Azad T-6 x Kashi Aman) to 22.34% (Azad T-6 x H-88-78-5), -47.19% (Azad T-6 x Kashi Aman) to 15.18% (Azad T-6 x H-88-78-5) and -33.33% (Angoorlata x H-88-78-5) to 51.39% (S-22 x H-88-78-5) over mid parent, better parent and SC, correspondingly. One hybrid has demonstrated considerable positive heterosis over the mid parent, and seven hybrids have demonstrated significant positive heterosis over the mid parent These findings are supported by Yadav et al. (2013) and Kumari (2010).

3.3. Fruit Weight (g)

The parental mean for Fruit weight varied from 40.40 (S-22) to 56.65 (Arka Vikas) and 33.40 (Azad T-6 x Kashi Aman) to 72.17 (Azad T-5 x Kashi Aman) for F1 hybrid. The range of heterosis over MP, BP and SC for fruit weight ranged from -35.25% (Pant T-7 x H-88-78-5) to 53.95% (Azad T-5 x Kashi Aman), -37.75% (Pant T-7 x H-88-78-5) to 42.06% (Arka Abha x Kashi Aman and -55.70% (Azad T-6 x Kashi Aman) to -4.29% (Arka Abha x Kashi Aman) correspondingly. Among the hybrids, 6 and 2 crosses shows the positive heterosis over the MP and BP, accordingly. Angoorlata x H-88-78-5 was the best hybrid for this charter. Similar trend also reported by Mali and Patel (2014), and Sekhar et al. (2010)

3.4. Fruit Yield (kg/plant)

Fruit yield/ plant mean value range from 2.32-3.68 for parent and 1.12-4.44 for F1 hybrid. The highest fruit yield kg per plant was recorded by Pant T-7 (3.68 kg), followed by Kashi Vishesh (3.57 kg) and Hisar Lalit (3.30 kg). This was due to the higher average fruit weight, greater number of fruits per plant, correspondingly. Seven hybrids had notable positive heterosis compared to baseline heterosis (Check). From -60.42% (Azad T-6 x Kashi Aman) to 42.82% (Arka Abha x Kashi Aman), the fruit yield (Kg) per plant fluctuated. -67.19% (Angoorlata x H-88-78-5) to 29.70% (Pant T-7 x Kashi Aman) and -60.78%

(Azad T-6 x Kashi Aman) to 42.41% (Arka Abha x Kashi Aman) over MP, BP and SC, respectively. Singh et al. (2012), Chauhan et al. (2014), Mali and Patel (2014), and Sekhar et al. (2010) all reported very identical results. One hybrid has demonstrated considerable positive heterosis over the better parent, and four hybrids have demonstrated significant positive heterosis over the mid parent. Best F1 hybrid for Fruit yield/ plant was Pant T-7 x H-88-78-5 whereas Best three parents werePant T-7 (3.68), Kashi Vishesh(3.57), Hisar Lalit (3.30).\

3.5. Ascorbic Acid (mg/100g)

Ascorbic acid mean value range from 13.38 (S-22) to 16.03 (Pant T-7) for parents and the crosses mean ranged from 12.00 (Pant T-5 x H-88-78-5) to 17.00 (Pant T-7 x Kashi Aman) for F1 hybrid. The range of heterosis i.e. MP, BP and SC for ascorbic acid ranged from -14.80 (Pant T-5 x Kashi Aman) to 19.76 (Angoorlata x H-88-78-5), -19.92 (Azad T-6 x H-88-5) to 13.61 (Arka Vikash x H-88-78-5) and -20.88 (Pant T-5 x H-88-78-5) to 7.69 (Angoorlata x H-88-78-5) respectively. &, # and 2 crosses were showed positive heterosis over MP, BP and SC, respectively. The hybrids was better than others in respect of Ascorbic acid. Pant T-5 x Kashi Aman and Azad T-5 x Kashi Aman

Chattopadhyay (2012) produced findings that were comparable.

3.6. Lycopene (mg/100g)

The parental mean value for Lycopene ranged from 2.47 (Azad T-6) to 4.01 (Pant T-7) and the crosses mean varied from 1.91 (Azad T-6 x Kashi Vishesh) to 4.43 (Pant T-7 x Kashi Vishesh).In terms of lycopene heterosis, the values varied from -36.44 (Azad T-6 x Kashi Vishesh) to 20.65 (Pant T-7 x Kashi Aman), -46.04 (Azad T-6 x Kashi Vishesh) to 18.28 (Angoorlata x H-88-78-5), and -5.68 (Pant T-7 x Kashi Aman) to 59 .40 (Azad T-6 x Kashi Vishesh), respectively. No hybrid exhibited significant heterosis except two that showed significant heterosis over mid parent. The hybrid Hisar Lalit x Kashi Vishesh was performed better than others.

3.7. Total Soluble Solid (^{o}Brix)

The parents' TSS mean values vary from 3.83 (Hisar Lalit) to 5.80 (Pant T-7) while the F1 hybrids Angoorlata x Kashi Vishesh and Arka Abha x Kashi Vishesh have TSS mean values of 3.17 and 6.20, respectively. As opposed to this, the TSS heterosis values over MP BP and SC were -35.33 (S-22 x Kashi Aman) to 43.08 (Arka Abha x Kashi Vishesh), -35.37 (Angoorlata x Kashi Aman) to 34.78 (Arka Abha x Kashi Vishesh), and -37.91 (Angoorlata x Kashi Aman) to 5. In regards to MP, BP, and SC, 9, 6, and 3 hybrids, respectively, showed considerable heterosis. the hybrid Angoorlata x Kashi Aman showed good for Lycopene concert. Yadav et al. (2013) and Mali and Patel (2014) published findings that were connected.

3.8. Acidity (%)

The parental mean value for Acidity (%) range from 0.48 (Angoorlata) to 1.35 (Pant T-7) and the crosses mean ranged from 0.18 (Pant T-7x Kashi Aman) to 1.40 (Arka Abha x H-88-78-5). The heterosis for acidity varied between -73.98 (Arka Abha x H-88-78-5) to 20.51 (Kashi Sharad x Kashi Vishesh), -79.70 to 20.41 (Kashi Sharad x Kashi Vishesh), and -63.78 to 185.61 (Pant T-7 x Kashi Aman). Thirteen

hybrid showed significant positive heterosis over SC. The hybrid Angoorlata x Kashi Aman was better perform in respect of acidity.The result are supporting to Gaikwad and Chema. (2009).

3.9. Leaf Curl Incidence (%)

Leaf curl incidence mean value range from 26.11 (Kashi Vishesh) to 50.00 (Arka Vikas and Azad T-6) for parents and 16.11-50.00 for F1 hybrid ToLCV incidence negative heterosis will be desirable. For ToLCV incidence heterosis ranged from -55.57 (Azad T-5 x Kashi Aman) to 58.88 (Kashi Sharad x Kashi Vishesh) over mid parent. In respect of ToLCV incidence The heterosis over MP, BP and SC ranged from -62.51 (Azad T-5 x Kashi Aman) to 41.66 (Kashi Sharad x Kashi Vishesh) and -43.15 (Pant T-7 x Kashi Aman) to 76.48 (Hisar Lalit x Kashi Vishesh) respectively. Three and ten hybrid showed significant negative heterosis which is desirable for ToLCV incidence over MP and BP. The crosses developed using ToLCV resistant variety Kashi Aman showed low percent of ToLCV incidence. The hybrids Azad T-5 x Kashi Aman and Pant T-7 x Kashi Aman exhibited low incidence with negative heterosis.

3.10. Leaf Curl Severity (%)

Leaf curl severity mean value range from 17.22-28.33 for parents and 9.44 (Pant T-7 x Kashi Aman) to 27.77 (Hisar Lali x Kashi Vishesh). Heterosis for ToLCV severity ranged from -58.55 (Pant T-7 x Kashi Aman) to 50.00 (S-22 x H-88-78-5), -66.68 (Pant T-7 x Kashi Aman) to 36.84 (Arka Abha x Kashi Vishesh) and -67.32 (Pant T-7 x Kashi Aman) to 21.15(S-22 x H-88-78-5). The desirable negative significant for ToLCV severity was exhibited by 3, 8 and 20 hybrids over MP, BP and SC, respectively. Pant T-7 x Kashi Vishesh, Azad T-6 x Kashi Vishesh and Pant T-7 x Kashi Aman were showed resistant to ToLCV with significant negative heterosis.

4. CONCLUSION

The following hybrids Azad T-6 x H-88-78-5, Angoorlata x H-88-78-5, Angoorlata x H-88-78-5, Pant T-7 x H-88-78-5, Angoorlata x Kashi Aman, Hisar Lalit x Kashi Aman, Pant T-5 x Kashi Aman, Hisar Lalit x Kashi Vishesh, Pant T-7 x Kashi Aman and Pant T-7 x Kashi Vishesh were found superior than others for the character Days to 50% flowering, Fruit weight, No. of fruits/ plant, Fruit yield/ plant, TSS, Acidity, Ascorbic acid, Lycopene, Leaf curl incidence and ,Leaf curl severity, respectively. According to data presented in the study it is concluded that hybrid vigour can obtain by crossing of parents having desirable characters in tomato.

Table 1: Mean Performance for ten different characters of Parents in tomato.

Parents	Days to 50% Flowering	Fruit Weight (g)	Fruits / Plant	Fruit Yield/Plant (kg)	TSS (^{0}brix)	Acidity (%)	Ascorbic Acid (mg/100g)	Lycopene (mg/100g)	Leaf Curl Incidence (%)	Leaf Curl Severity (%)
Arka Vikas	39.33	56.37	51.03	2.87	4.10	0.80	14.08	3.37	50.00	18.99
Pant T-7	38.33	56.65	64.62	3.68	5.80	1.35	16.03	4.01	36.11	28.33
Azad T-6	35.33	53.17	52.75	2.91	4.97	0.72	15.82	2.47	50.00	26.66
S-22	37.33	40.40	71.93	2.88	5.10	0.89	13.38	3.70	38.89	27.22
Arka Abha	31.67	43.22	65.12	2.84	4.07	0.60	14.56	2.83	41.66	21.11
Kashi Sharad	46.00	46.33	53.85	2.43	4.97	0.83	15.57	3.83	33.33	22.77
Hisar Lalit	43.00	51.42	57.09	3.30	3.83	0.85	15.15	2.97	44.44	23.88
Azad T-5	36.00	51.05	50.65	2.68	5.57	1.05	12.71	3.30	44.44	18.88
Angoorlata	37.67	48.48	50.83	2.32	4.73	0.48	13.80	2.82	41.66	18.88
Pant T-5	39.00	50.37	58.52	2.93	5.53	0.80	14.23	3.68	38.89	28.33
Kashi Aman	40.67	42.71	67.03	2.85	4.90	1.34	14.72	3.33	30.55	17.22
Kashi Vishesh	42.67	50.97	68.13	3.57	4.60	0.83	13.73	3.53	26.11	20.00
H-88-78-5	38.00	52.28	46.58	2.43	4.40	0.76	13.48	3.10	33.33	19.44
(Check) Kashi Abhiman	36.33	75.40	46.00	3.42	5.10	0.49	15.17	4.70	28.33	28.88
Mean	**44.10**	**53.81**	**53.91**	**2.92**	**4.69**	**0.74**	**14.48**	**3.39**	**32.26**	**20.15**
C.V.	**7.56**	**19.71**	**15.34**	**18.04**	**7.03**	**21.40**	**7.15**	**16.84**	**31.77**	**26.88**
S.E.	**1.93**	**6.12**	**4.78**	**0.30**	**0.19**	**0.09**	**0.60**	**0.33**	**5.92**	**3.13**

Table 2: Mean Performance for different characters of crosses/ hybrids in tomato .

S.N	Parents/ hybrids	Days to 50% Flowering	Fruit Weight (g)	No. of Fruits/ Plant	Fruit Yield /Plant (kg)	TSS (^{0}brix)
1	Arka Vikash x Kashi Aman	45.33	52.38	61.42	3.12	5.37
2	Arka Vikash x Kashi Vishesh	45.33	55.70	49.82	2.84	5.33
3	Arka Vikash x H-88-78-5	45.67	42.47	56.52	2.46	5.67
4	Pant T-7 x Kashi Aman	48.33	68.40	65.27	4.44	4.43
5	Pant T-7 x Kashi Vishesh	47.00	62.03	67.64	4.01	4.77
6	Pant T-7 x H-88-78-5	46.33	35.27	51.31	1.79	4.10
7	Azad T-6 x Kashi Aman	48.00	33.40	35.40	1.14	4.17
8	Azad T-6 x Kashi Vishesh	45.33	48.73	47.71	2.31	4.00
9	Azad T-6 x H-88-78-5	49.67	,41.97	60.76	2.50	5.33
10	S-22 x Kashi Aman	41.67	57.93	59.29	3.44	3.23
11	S-22 x Kashi Vishesh	52.00	50.90	42.51	2.17	3.87
12	S-22 x H-88-78-5	46.67	51.40	69.64	3.57	3.83
13	Arka Abha x Kashi Aman	42.67	61.40	67.41	4.06	5.83
14	Arka Abha x Kashi Vishesh	42.67	62.10	66.42	4.03	6.20
15	Arka Abha x H-88-78-5	46.67	51.07	54.50	2.76	4.00
16	Kashi Shar x Kashi Aman	50.00	55.63	39.51	2.20	4.30
17	Kashi Shar x Kashi Vishesh	51.67	58.00	55.81	3.22	3.90
18	Kashi Shar x H-88-78-5	49.33	49.10	43.76	2.21	5.03
19	Hisar Lali x Kashi Aman	50.00	58.54	43.11	2.50	4.13
20	Hisar Lali x Kashi Vishesh	49.33	59.25	42.53	2.55	5.07
21	Hisar Lali x H-88-78-5	46.67	51.32	35.85	1.84	5.03
22	Azad T-5 x Kashi Aman	45.00	72.17	51.31	3.41	5.03
23	Azad T-5 x Kashi Vishesh	51.67	63.39	37.93	2.55	4.90
24	Azad T-5 x H-88-78-5	47.33	50.85	46.96	2.42	5.27
25	Angoorlata x Kashi Aman	46.00	61.33	46.80	2.87	3.17
26	Angoorlata x Kashi Vishesh	46.67	54.67	57.23	3.10	5.30
27	Angoorlata x H-88-78-5	44.27	36.73	30.67	1.12	5.13
28	Pant T-5 x Kashi Aman	40.80	66.92	46.48	3.01	3.87
29	Pant T-5 x Kashi Vishesh	47.60	56.58	41.19	2.27	3.77
30	Pant T-5 x H-88-78-5	44.40	49.17	47.32	2.21	4.87
31	Kashi Abhiman (SC)	36.33	75.40	46.00	3.42	5.10
	Mean	**44.10**	**53.81**	**53.91**	**2.92**	**4.69**
	C.V.	**7.56**	**19.71**	**15.34**	**18.04**	**7.03**
	S.E.	**1.93**	**6.12**	**4.78**	**0.30**	**0.19**

Table 3: Mean Performance for different characters of crosses/ hybrids in tomato Cont.

S.N	Parents/ hybrids	Acidity (%)	Ascorbic Acid (mg/100g)	Lycopene (mg/100g)	Leaf Curl Incidence (%)	Leaf Curl Severity (%)
1	Arka Vikash x Kashi Aman	1.07	13.33	3.67	30.00	16.11
2	Arka Vikash x Kashi Vishesh	0.76	13.67	3.20	28.89	15.55
3	Arka Vikash x H-88-78-5	0.49	16.00	2.87	27.78	16.11
4	Pant T-7 x Kashi Aman	1.40	17.00	4.43	16.11	9.44
5	Pant T-7 x Kashi Vishesh	0.57	17.27	4.14	16.66	11.11
6	Pant T-7 x H-88-78-5	1.21	13.17	2.64	33.33	33.88
7	Azad T-6 x Kashi Aman	0.90	15.83	2.48	44.44	20.55
8	Azad T-6 x Kashi Vishesh	0.76	14.93	1.91	28.89	14.44
9	Azad T-6 x H-88-78-5	0.84	12.67	3.24	36.11	27.77
10	S-22 x Kashi Aman	0.51	14.33	3.33	25.55	17.77
11	S-22 x Kashi Vishesh	0.48	15.00	3.13	29.44	20.55
12	S-22 x H-88-78-5	0.68	12.67	2.87	36.11	34.99
13	Arka Abha x Kashi Aman	1.13	14.47	3.43	23.33	26.66
14	Arka Abha x Kashi Vishesh	0.32	15.03	3.33	31.66	28.88
15	Arka Abha x H-88-78-5	0.18	15.00	2.23	36.11	16.11
16	Kashi Shar x Kashi Aman	0.82	14.13	3.92	28.88	19.44
17	Kashi Shar x Kashi Vishesh	1.00	15.03	3.53	47.22	13.33
18	Kashi Shar x H-88-78-5	0.83	13.37	3.95	20.55	17.22
19	Hisar Lali x Kashi Aman	0.40	14.03	3.19	38.89	17.77
20	Hisar Lali x Kashi Vishesh	0.86	14.82	2.48	50.00	22.33
21	Hisar Lali x H-88-78-5	0.51	13.33	3.37	20.55	20.55
22	Azad T-5 x Kashi Aman	0.44	14.80	3.30	16.66	15.55
23	Azad T-5 x Kashi Vishesh	0.53	15.33	2.92	36.11	21.66
24	Azad T-5 x H-88-78-5	0.66	14.33	3.08	33.33	18.33
25	Angoorlata x Kashi Aman	0.54	15.83	3.71	23.89	16.11
26	Angoorlata x Kashi Vishesh	0.45	15.67	4.15	30.55	13.88
27	Angoorlata x H-88-78-5	0.30	16.33	3.67	26.66	13.33
28	Pant T-5 x Kashi Aman	0.58	12.33	3.72	27.77	15.55
29	Pant T-5 x Kashi Vishesh	0.84	14.33	3.59	31.66	18.89
30	Pant T-5 x H-88-78-5	0.83	12.00	3.95	23.33	19.44
31	Kashi Abhiman (SC)	0.49	15.17	4.70	28.33	28.88
	Mean	**0.74**	**14.48**	**3.39**	**32.26**	**20.15**
	C.V.	**21.40**	**7.15**	**16.84**	**31.77**	**26.88**
	S.E.	**0.09**	**0.60**	**0.33**	**5.92**	**3.13**

Table 4: Range of Heterosis over mid parent, better parent and standard check for different characters in tomato.

Sl. No.	Characters	Range of mean values		Range of heterosis(%) over			No. of hybrids showing significant heterosis over check					
		Parent	Hybrids (F_1)	MP	BP	Check	MP		BP		Check	
							+	-	+	-	+	-
1.	**Days to 50% flowering**			2.43 to 35.45	0.00 to 30.00	12.29 to 43.12	7	0	14	0	28	0
2	**Fruit weight**			-35.25 to 53.95	-37.75 to 42.06	-55.70 to -4.29	6	1	2	2	0	18
3	**No. of fruits/ plant**	46.58-71.93		-40.89 to 22.34	-47.19 to 15.18	-33.33 to 51.39	0	12	0	14	7	1
4	**Fruit yield/ plant**	2.32-3.68	1.12-4.44	-60.42 to 42.82	-60.78 to 42.41	-67.19 to 29.70	4	8	1	9	1	16
5	**TSS**	3.83-5.80	3.17-6.20	-35.33 to 43.08	-35.37 to 34.78	-37.91 to 5.23	9	12	6	16	3	13
6	**Acidity**	0.48-1.35	0.18-1.40	-73.98 to 20.51	-79.70 to 20.41	-63.68 to 185.61	0	15	0	18	13	1
7	**Ascorbic acid**	13.38-16.03	12.00-17.00	-14.80 to 19.76	-19.92 to 13.61	-20.88 to 7.69	7	4	3	5	2	8
8	**Lycopene**	2.47-4.01	1.91-4.43	-36.44 to 20.65	-46.04 to 18.28	-5.68 to -59.40	2	3	0	4	0	24
9	**Leaf curl incidence**	26.11-50.00	16.11-50.00	-55.57 to 58.88	-62.51 to 41.66	-43.15 to 76.48	2	3	0	10	2	0
10	**Leaf curl severity**	17.22-28.33	9.44-27.77	-58.55 to 50.00	-66.68 to 36.84	-67.32 to 21.15	3	4	0	8	0	20

Table 5: Heterosis (%) of top three hybrids over better parent and commercial check for 10 characters in tomato

traits	Days to 50% flowering	Fruit weight	No. of fruits/ plant	Fruit yield/ plant	TSS	Acidity	Ascorbic acid	Lycopene	Leaf curl incidence	Leaf curl severity
1. Top three parent with their mean value										
P1	Arka abha (31.67)	Pant T-7 (56.65)	S-22 (71.93)	Pant T-7 (3.68)	Pant T-7 (5.80)	Pant T-7 (1.35)	Pant T-7 (16.03)	Pant T-7 (4.01)	Kashi Vishesh (26.11)	Angoorlata (18.88)
P2	Azad T-6 (35.33)	Arka Vikash (56.37)	Kashi Vishesh (68.13)	Kashi Vishesh (3.57)	Azad T-5 (5.57)	Kashi Aman (1.34)	Azad T-6 (15.82)	Kashi Sharad (3.83)	Kashi Aman (30.55)	Azad T-5 (18.88)
P3	Azad T-5 (36.00)	Azad T-6 (53.17)	Kashi Aman (67.03)	Hisar Lalit (3.30)	Pant T-5 (5.53)	Azad T-5 (1.05)	Kashi Sharad (15.57)	Kashi Vishesh (3.53)	H-88-78-5 (33.33)	Arka Vikash (18.99)
2. Top three F1s with heterosis Percentage										
BP	Azad T-6 x H-88-78-5 (30.70)	Pant T-7 x H-88-78-5 (-37.75)	Azad T-6 x Kashi Aman (-47.19)	Azad T-6 x Kashi Aman (-60.42)	S-22 x Kashi Aman (-36.60)	Arka Abha x H-88-78-5 (-76.70)	Azad T-6 x H-88-78-5 (-19.92)	Azad T-6 x Kashi Vishesh (-46.04)	Azad T-5 x Kashi Aman (-62.51)	Pant T-7 x Kashi Aman (-66.68)
	Azad T-5 x H-88-78-5 (24.6)	Azad T-6 x Kashi Aman (-37.18)	Azad T-5 x Kashi Vishesh (-44.32)	Angoorlata x H-88-78-5 (-53.84)	Angoorlata x Kashi Aman (-35.37)	Hisar Lalit x Kashi Aman (-69.92)	Pant T-7 x H-88-78-5 (-17.88)	Pant T-7 x H-88-78-5(-34.16)	Pant T-7 x Kashi Aman (-55.40)	Pant T-7 x Kashi Vishesh (-60.80)
	S-22 x H-88-78-5 (22.81)	Angoorlata x H-88-78-5 (-29.74)	Kashi Sharad x Kashi Aman (-41.05)	Pant T-7 x H-88-78-5 (-51.45)	Pant T-5 x Kashi Vishesh (-31.93)	Azad T-5 x Kashi Aman (-67.02)	Pant T-5 x Kashi Aman (-16.19)	Hisar Lalit x Kashi Vishesh (-29.91)	Pant T-7 x Kashi Vishesh (-53.85)	Azad T-6 x Kashi Vishesh (-45.84)
SC	S-22 x Kashi Vishesh (43.12)	Azad T-6 x Kashi Aman (-55.70)	Angoorlata x H-88-78-5 (-33.33)	Angoorlata x H-88-78-5 (-67.19)	Angoorlata x Kashi Aman (-37.91)	Arka Abha x H-88-78-5 (-63.78)	Pant T-5 x H-88-78-5 (-20.88)	Azad T-6 x Kashi Vishesh (-59.40)	Pant T-7 x Kashi Aman (-43.15)	Pant T-7 x Kashi Aman (-67.32)
	Azad T-5 x Kashi Vishesh (42.00)	Pant T-7 x H-88-78-5 (-53.23)	Azad T-6 x Kashi Aman (-23.04)	Azad T-6 x Kashi Aman (-66.70)	S-22 x Kashi Aman (-36.60)	Angoorlata x H-88-78-5 (-38.61)	Pant T-5 x Kashi Aman (-18.68)	Arka Abha x H-88-78-5 (-52.45)	Pant T-7 x Kashi Vishesh (-41.18)	Pant T-7 x Kashi Vishesh (-61.55)
	Kashi Sharad x Kashi Vishesh (42.00)	Angoorlata x H-88-78-5 (-51.28)	Hisar Lalit x H-88-78-5 (-22.06)	Pant T-7 x H-88-78-5 (-47.81)	Angoorlata x Kashi Aman (-35.37)	Arka Abha x Kashi Vishesh (-34.86)	Pant T-5 x Kashi Aman (-16.19)	Hisar Lalit x Kashi Vishesh (-47.27)	Azad T-5 x Kashi Aman (-41.19)	Angoorlata x H-88-78-5 (-53.86)
3. Best F_1 hybrid										
	Azad T-6 x H-88-78-5	Angoorlata x H-88-78-5	Angoorlata x H-88-78-5	Pant T-7 x H-88-78-5	Angoorlata x Kashi Aman	Hisar Lalit x Kashi Aman	Pant T-5 x Kashi Aman	Hisar Lalit x Kashi Vishesh	Pant T-7 x Kashi Aman	Pant T-7 x Kashi Vishesh

REFERENCES

Chattopadhyay A and Paul A (2012). Studies on Heterosis in Tomato (*Solanum lycopersicum* L.). *Int.Journal of Bio-Resource & Stress Management* **3**(3): 278.

Chauhan VBS, Behera TK and Yadav RK (2014). Studies on Heterosis for yield and its Attributing Traits in Tomato (*Solanum lycopersicum* L.). *International Journal of Agriculture, Environment & Biotechnology* **7(**1): 95.

Gaikwad, A. K. and Cheema, D. S. (2009). Heterosis for quality traits using heat tolerant lines in tomato (*Solanum lycopersicum* L.). *Indian Journal of Ecology* 36 (2): 118-122.

Hayes MK (1955). Development of heterosis concept. In: Gowen J.W. (ed.) Heterosis, Lowa State University Press, USA.

Kumari N, Srivastava JP, Singh B and Deokaran (2010). Heterotic expression for yield and its component in tomato (*Lycopersicon esculentum* Mill.). *Annals of Horticulture*3(1):98-101.

Mali, B. and Patel, A. I. (2014). Heterosis study in Tomato (*Lycopersicon esculentum* Mill.). *Trends in Bioscience* 7(4) : 250-253.

Panse, V.G. and Sukhatme, P.V, (1967). Stastical method for agriculture workers. ICAR, New Delhi.

Sekhar, L., Prakash, B. G., Salimath, P. M., Hiremath, C. P., Sridevi, O. and Patil, A. A. (2010). Implication of heterosis and combining ability among productive single cross hybrids intomato. *Electronic Journal of Plant Breeding* 1(4): 706-711.

Singh NB, Paul A, Wani SH and Kumar MLJ (2012). Heterosis studies for yield and its components in tomato (*Solanum lycopersicum* L.). *International journal of Life Sciences*1(3): 224-232.

Yadav SK, Singh BK, Baranwal DK and Solankey SS (2013). Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum* L.), *African Journal of Agricultural Research,* Vol. **8** (44): 5585-5591.