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Studies on heterosis for quality parameters in tomato (*Solanum lycopersicum* L.)

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Abstract
A set of 18 F1 hybrids developed as a result of line x tester mating design involving six lines and three testers were evaluated in randomized block design in three replications for heterosis in tomato quality characters. Heterosis to the extent of -25.71, 35.03, 69.02, 52.66 and 57.91 over mid parent and -32.47, 31.76, 44.33, 33.18 and 56.95 over better parent was recorded for titrable acidity, total carotenoid content, reducing sugars, total sugars and lycopene content respectively. Standard heterosis over Lakshmi to the extent of -22.56, 45.66, 53.56, 66.14 and 73.62 was recorded for titrable acidity, total carotenoid content, reducing sugars, total sugars and lycopene content respectively and over US-618 to the extent of -18.25, 59.80, 66.57, 50.30 and 88.67 was recorded for titrable acidity, total carotenoid content, reducing sugars, total sugars and lycopene content respectively. The crosses *viz*., LE-64 × Punjab Chhuhara, LE-62 × Punjab Chhuhara, LE-62 × Punjab Chhuhara and LE-56 × Punjab Chhuhara exhibited highest standard heterosis for total carotenoid content, reducing sugars, total sugars and lycopene content, respectively. Hence, these are suitable for quality improvement through heterosis breeding.

Keywords: Tomato, heterosis, fruit, line x tester, quality parameters

Introduction
Tomato is the most important vegetable crop of the world, which is consumed as fresh as well as processed vegetable. In India, it has ample scope in the processing industry. The fruit quality and suitability for long distance transport, which has direct bearing on its effective utilization as processed vegetable. Keeping in view the present experiment was formulated to estimate the heterotic potential for quality traits in tomato.

Materials and Methods
The experimental material for the present study comprised six lines *viz*., EC-165749, LE-56, LE-62, LE-64, LE-65, LE-67, three testers *viz*., Punjab Chhuhara, Pant T-3 and Pusa Gaurav and two standard checks *i.e* Lakshmi and US-618. These lines were crossed in line x tester fashion (Kempthorne,1957) [1] to develop 18 F1 hybrids, which were evaluated along with their parents in randomized block design in three replications at the experimental farm of Vegetable Research Station, Dr. Y.S. R. Horticultural University, Rajendranagar, Hyderabad during kharif, 2011. The data was subjected to the analysis of variance for randomized block design as suggested by Panse and Sukhatme (1967) [2]. Observations were recorded for titrable acidity, total carotenoid content, reducing sugars, total sugars and lycopene content in F_1s, parents and checks. The mean over the replications for all parents and hybrids for each character was calculated and used in estimation of heterosis. Heterosis was calculated as the percentage increase or decrease of F_1 mean (F_1) over the mean of mid parent (MP) and better parent (BP) of the respective crosses.

Results and Discussion
Heterosis was estimated for quality characters studied in 18 hybrids and was expressed as increase or decrease over mid parental value (relative heterosis), over better parent (heterobeltiosis) and over commercial checks (standard heterosis). The results are presented in the table 1, 2 and 3.

Titrable acidity (%)
The range of relative heterosis was from -25.71 (LE-62 × Pant T-3) to -15.19 percent (LE-64 × Punjab chhuhara) with 5 hybrids exhibiting significant negative heterosis for titrable acidity.

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The heterobeltiosis ranged from -32.47 (LE-62 × Pant T-3) to -16.95 *percent* (LE-65 × Pusa Gaurav) and 12 hybrids recorded negative significant heterobeltiosis.

Standard heterosis ranged from -22.56 and -18.25 (LE-56 × Pant T-3) to 20.30 and 26.98 (LE-65 × Punjab chhuhara) over Lakshmi and US-618 respectively. Significant negative standard heterosis expressed by 2 hybrids over Lakshmi and none over US – 618. Negative heterois was preferred over positive heterosis for titrable acidity. For fruit quality, the cross LE-56 × Pant T-3 (-22.56% and -18.25%) exhibited highest standard heterosis over Lakshmi and US-618 for titrable acidity. Hence, these are suitable for quality improvement through heterosis breeding. Similar results were also reported by Kurian and Peter (2001) [3], Kaur *et al*. (2002) [4] and Makesh *et al*. (2002) [5] for titrable acidity.

Total carotenoid content (mg/100 g)
Relative heterosis ranged from -31.03 (LE-64 × Pant T-3) to 35.03 percent (LE-56 × Pusa Gaurav). Significant positive relative heterosis was recorded in 4 hybrids for total carotenoid content. Heterobeltiosis ranged from -37.88 (LE-64 × Pant T-3) to 31.76 percent (LE-56 × Pusa Gaurav) and 2 hybrids exhibited significant positive heterobeltiosis.

The range of standard heterosis was from 11.75 (LE-67 × Pusa Gaurav) to 45.66 percent (LE-64 × Punjab chhuhara) over Lakshmi and 18.39 (EC-165749 × Pant T-3) to 59.80 percent (LE-64 × Punjab chhuhara) over US-618. Significant positive standard heterosis was recorded by 11 hybrids over both the checks Lakshmi and US-618.

Reducing sugars (%)
The range of relative heterosis was from -48.85 (EC-165749 × Punjab chhuhara) to 69.02 percent (LE-56 × Pusa Gaurav) with 9 hybrids exhibiting significant positive heterosis for reducing sugars. The heterobeltiosis ranged from -50.85 (EC-165749 × Punjab chhuhara) to 44.33 percent (LE-56 × Pusa Gaurav) and 4 hybrids recorded positive significant heterobeltiosis.

Standard heterosis ranged from -28.49 and -22.44 (EC-165749 × Punjab Chhuhara) to 53.56 and 66.57 (LE-62 × Punjab Chhuhara) over Lakshmi and US-618 respectively.

Among 18 hybrids studied, 9 hybrids over Lakshmi and 12 hybrids over US – 618 exhibited significant positive standard heterosis.

Total sugars (%)
The range of relative heterosis was from -31.28 (LE-67 × Punjab chhuhara) to 52.66 percent (LE-56 × Pusa Gaurav) with 6 hybrids exhibiting significant positive heterosis for total sugars. The heterobeltiosis ranged from -35.45 (LE-64 × Pant T-3) to 33.18 percent (LE-56 × Pusa Gaurav) and 4 hybrids recorded positive significant heterobeltiosis.

The range of standard heterosis was from 29.51 (LE-64 × Punjab chhuhara) to 66.14 percent (LE-62 × Punjab chhuhara) over Lakshmi with 12 hybrids and over US-618 ranged from 17.16 (LE-64 × Punjab chhuhara) to 50.30 (LE-62 × Punjab chhuhara) with 12 hybrids showing desirable positive significant standard heterosis.

Lycopene content (mg/100 g)
Relative heterosis ranged from -42.44 (LE-64 × Pant T-3) to 57.91 percent (LE-56 × Pusa Gaurav). Significant positive relative heterosis was recorded in 7 hybrids for lycopene content. Heterobeltiosis ranged from -46.48 (LE-64 × Pant T-3) to 56.95 percent (LE-56 × Pusa Gaurav) and 5 hybrids exhibited significant positive heterobeltiosis.

Standard heterosis over Lakshmi ranged from -25.77 (LE-62 × Pusa Gaurav) to 73.62 percent (LE-56 × Punjab chhuhara) and over US-618 ranged from -19.33 (LE-62 × Pusa Gaurav) to 88.67 percent (LE-56 × Punjab chhuhara). Among 18 hybrids studied, 12 hybrids over both the checks Lakshmi and US – 618 exhibited significant positive standard heterosis.

For fruit quality, the crosses *viz*., LE-64 × Punjab Chhuhara (45.66% and 59.80%), LE-62 × Punjab Chhuhara (53.56% and 66.57), LE-62 × Punjab Chhuhara (66.14% and 50.30%) and LE-56 × Punjab Chhuhara (73.62% and 88.67) exhibited highest standard heterosis over Lakshmi and US-618 for total carotenoid content, reducing sugars, total sugars and lycopene content, respectively. Hence, these are suitable for quality improvement through heterosis breeding. These results are in agreement with the findings of Dharmatti (1995) [6] and Bhatt *et al.* (2004) [7] for lycopene.

Table 1: Estimates of heterosis over mid parent (MP), better parent (BP) and standard check for titrable acidity and total carotenoid content in tomato

S. No	Cross	Titrable acidity				Total carotenoid content (mg/100 g)			
		MP	BP	Lakshmi	US-618	MP	BP	Lakshmi	US-618
1	EC -165749 × Punjab Chhuhara	-4.05	-19.32**	6.77	12.70	8.88	-8.91*	16.26**	27.54**
2	EC -165749 × Pant T-3	1.99	-12.50	15.79	22.22*	5.06	-9.69*	7.92	18.39**
3	EC -165749 × Pusa Gaurav	-6.11	-17.05*	9.77	15.87	7.15	-1.28	0.67	10.44
4	LE-56 × Punjab Chhuhara	-5.00	-5.00	-14.29	-9.52	25.31**	10.30*	40.78**	54.44**
5	LE-56 × Pant T-3	-16.26	-18.25	-22.56*	-18.25	-8.38	-16.99**	-0.80	8.83
6	LE-56 × Pusa Gaurav	-8.24	-13.3	-12.03	-7.14	35.03**	31.76**	34.37**	47.41**
7	LE-62 × Punjab Chhuhara	-9.49	-19.48*	-6.77	-1.59	13.06**	2.87	31.30**	44.04**
8	LE-62 × Pant T-3	-25.71**	-32.47**	-21.80*	-17.46	1.48	-4.83	13.73*	24.77**
9	LE-62 × Pusa Gaurav	-12.80	-18.18*	-5.26	0.00	-15.35**	-16.43**	12.55*	-4.07
10	LE-64 × Punjab Chhuhara	-15.19*	-26.38**	-9.77	-4.76	5.27	-2.32	45.66**	59.80**
11	LE-64 × Pant T-3	-10.73	-20.86**	-3.01	2.38	-31.03**	-37.88**	-7.37	1.62
12	LE-64 × Pusa Gaurav	-16.78*	-23.93**	-6.77	-1.59	2.16	-13.98**	28.26**	40.71**
13	LE-65 × Punjab Chhuhara	7.74	-9.60	20.30*	26.98**	-29.70**	-31.56**	-7.75	1.20
14	LE-65 × Pant T-3	-6.27	-19.77**	6.77	12.70	-7.17	-12.44**	18.03**	29.48**
15	LE-65 × Pusa Gaurav	-5.77	-16.95*	10.53	16.67	16.35**	2.19	37.74**	51.11**
16	LE-67 × Punjab Chhuhara	-2.51	-14.47	2.26	7.94	-18.78**	-20.99**	0.84	10.63
17	LE-67 × Pant T-3	-15.79*	-24.53**	-9.77	-4.76	-22.66**	-23.04**	-7.12	1.89
18	LE-67 × Pusa Gaurav	-23.81**	-29.56**	-15.79	-11.11	0.38	-7.40	11.75*	22.60**
	S.Ed	0.03	0.04	0.04	0.04	0.38	0.44	0.44	0.44

* Significant at 5% level, ** Significant at 1% level

Table 2: Estimates of heterosisover mid parent (MP), better parent (BP) and standard check for reducing sugars and total sugars in tomato

S. No	Cross	Reducing sugars (%)				Total sugars (%)			
		MP	BP	Lakshmi	US-618	MP	BP	Lakshmi	US-618
1	EC -165749 × Punjab Chhuhara	-48.85**	-50.85**	-28.49**	-22.44**	-31.13**	-32.13**	-1.19	-10.61
2	EC -165749 × Pant T-3	-38.48**	-43.69**	-18.08*	-11.14	-25.39**	-26.75**	3.56	-6.32
3	EC -165749 × Pusa Gaurav	41.38**	3.11	50.00**	62.70**	34.69**	8.20	52.96**	38.38**
4	LE-56 × Punjab Chhuhara	13.26*	-3.58	29.32**	40.27**	7.33	-3.89	39.92**	26.58**
5	LE-56 × Pant T-3	16.69**	3.85	25.48**	36.11**	8.28	-0.10	36.10**	23.12**
6	LE-56 × Pusa Gaurav	69.02**	44.33**	36.03**	47.55**	52.66**	33.18**	53.36**	38.74**
7	LE-62 × Punjab Chhuhara	37.80**	14.50*	53.56**	66.57**	32.60**	14.12*	66.14**	50.30**
8	LE-62 × Pant T-3	44.71**	25.51**	51.64**	64.49**	32.06**	16.92*	59.29**	44.10**
9	LE-62 × Pusa Gaurav	49.07**	30.56**	15.89*	25.71**	42.27**	29.23**	35.70**	22.77**
10	LE-64 × Punjab Chhuhara	-14.42**	-16.04**	12.60	22.14*	-16.80**	-21.86**	29.51**	17.16*
11	LE-64 × Pant T-3	-23.25**	-25.69**	-4.11	4.01	-29.14**	-35.45**	6.98	-3.22
12	LE-64 × Pusa Gaurav	15.05*	-12.74*	12.60	22.14*	3.30	-21.62**	29.91**	17.52*
13	LE-65 × Punjab Chhuhara	-13.58*	-21.04**	5.89	14.86	-13.89*	-21.18**	14.76	3.81
14	LE-65 × Pant T-3	5.91	1.59	22.74**	33.14**	3.07	-2.71	32.54**	19.90*
15	LE-65 × Pusa Gaurav	34.46**	7.65	19.45*	29.57**	26.07**	7.73	30.30**	17.88*
16	LE-67 × Punjab Chhuhara	-36.09**	-36.16**	-14.38	-7.13	-31.28**	-32.31**	-1.45	-10.85
17	LE-67 × Pant T-3	-11.35*	-15.66**	12.88	22.44**	-5.70	-7.37	30.83**	18.36*
18	LE-67 × Pusa Gaurav	-9.84	-32.45**	-9.59	-1.93	-6.56	-24.91**	6.06	-4.05
	S.Ed	0.16	0.18	0.18	0.18	0.19	0.22	0.22	0.22

* Significant at 5% level ** Significant at 1% level

Table 3: Estimates of heterosisover mid parent (MP), better parent (BP) and standard check for Lycopene content in tomato

S. No	Cross	Lycopene content (mg/100 g)			
		MP	BP	Lakshmi	US-618
1	EC -165749 × Punjab Chhuhara	17.22**	-7.73	27.36**	38.40**
2	EC -165749 × Pant T-3	12.62	-11.11	21.78**	32.33**
3	EC -165749 × Pusa Gaurav	32.61**	18.54*	19.26*	29.60**
4	LE-56 × Punjab Chhuhara	46.25**	25.78**	73.62**	88.67**
5	LE-56 × Pant T-3	-15.65*	-27.23**	-0.31	8.33
6	LE-56 × Pusa Gaurav	57.91**	56.95**	57.91**	71.60**
7	LE-62 × Punjab Chhuhara	34.06**	19.47**	64.91**	79.20**
8	LE-62 × Pant T-3	7.29	-4.08	31.41**	42.80**
9	LE-62 × Pusa Gaurav	-28.82**	-31.25**	-25.77**	-19.33*
10	LE-64 × Punjab Chhuhara	15.12**	7.43	71.17**	86.00**
11	LE-64 × Pant T-3	-42.44**	-46.48**	-14.72	-7.33
12	LE-64 × Pusa Gaurav	6.87	-12.82*	38.90**	50.93**
13	LE-65 × Punjab Chhuhara	-40.83**	-41.04**	-18.04*	-10.93
14	LE-65 × Pant T-3	-7.98	-8.65	26.99**	38.00**
15	LE-65 × Pusa Gaurav	32.05**	13.81*	58.22**	71.93**
16	LE-67 × Punjab Chhuhara	-22.87**	-23.56**	5.52	14.67
17	LE-67 × Pant T-3	-26.99**	-27.36**	-0.49	8.13
18	LE-67 × Pusa Gaurav	-1.19	-13.94*	16.69*	26.80**
	S.Ed	0.37	0.43	0.43	0.43

* Significant at 5% level ** Significant at 1% level

Conclusion

Studies on heterosis revealed that majority of the hybrids exhibited relative heterosis, heterobeltiosis and standard heterosis in desirable direction. For fruit quality, the crosses *viz.*, LE-64 × Punjab Chhuhara (45.66% and 59.80%), LE-62 × Punjab Chhuhara (53.56% and 66.57), LE-62 × Punjab Chhuhara (66.14% and 50.30%) and LE-56 × Punjab Chhuhara (73.62% and 88.67) exhibited highest standard heterosis over Lakshmi and US-618 for total carotenoid content, reducing sugars, total sugars and lycopene content, respectively. Hence, these are suitable for quality improvement through heterosis breeding.

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