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Study of Heterosis Breeding for Processing Characters in Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

In the present study total 40 genotypes (11 parental genotypes, 28 F_1 hybrids and one commercial check- Abhinav) were evaluated during 2014 to 2015 in order to estimate the extent of heterosis and quality traits like, TSS, lycopene content, ascorbic acid content (vitamin-C), average pulp content, pulp: skin ratio, solid: acid ratio and titrable acidity. In which, significant differences among genotypes were obtained for all the traits. In the present investigation, mid parent heterosis ranged from -45.31 to 182.20 %, better parent ranged from -53.23 to 127.18 % and standard heterosis -0.79 to 295.83 % for fruit yield. The maximum standard heterosis recorded by cross JTL-12-12× JT-3 was 295.83 %, followed by NTL-1 × AT-3 (273.39 %), JTL-12-12 × GT-2 (196.52 %), JTL-12-12 × AT-3 (177.53 %), NTL-1 × JT-3 (160.31 %), JTL-12-10 × GT-2 (156.80 %) and JTL-12-11 × GT-2 (155.55 %). Positive significant heterosis was found for all the traits.

Key words: *Heterosis, Tomato, Quality parameters, Processing, Hybrids.*

INTRODUCTION

Tomato is an important and widely grown Solanaceous vegetable crop around the world, both for fresh market and processing. Tomato is an annual and short lived perennial herbaceous plant. It is typical day neutral plant and self pollinated crop, but certain percentage of cross pollination also occurs. It is grown for its edible fruits, which can be consumed either fresh or cooked or in the form of various processed products like, juice, ketchup, sauce, puree, paste and powder. The pulp and juice are digestible, mild aperients, a promoter of gastric secretion and blood purifier. It has antiseptic properties against intestinal infections. It is useful in useful in cancer of mouth, sore mouth, etc. it has antioxidant properties because of rich source of vitamin-C. It is one of the best vegetable, which keep our stomach and intestine in good order. It is known fact that heterosis leads to increase in yield, reproductive ability, adaptability to disease and insect resistance, general vigour, faster growth rate, earlier flowering and maturity and improvement of quality parameter as well.

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Recent studies indicated that lycopene give the ripe tomato its bright red colour, is a very effective natural antioxidant and quencher of free radicals. Lycopene is an important antioxidant which is reduces the risk of cancer. In tomato also present acid like, citric acid, maleic acid. Knowledge of the extent heterosis for quality component characters is a prerequisite to bring improvement through heterosis breeding. The improvement in different quantitative and qualitative traits in tomato through heterosis breeding was observed by Tiwari and Lal[10]. The present study was undertaken to estimate the extent of heterosis among the crosses, obtained from diverse tomato parental lines, crossed in Line × Tester pattern[3].

MATERIALS AND METHODS

The present investigation was conducted during winter-2015 at Regional Horticultural Research Station of Navsari Agricultural University, Navsari. There is situate at 20^{o} 37' North latitude and 72^{o}54' east longitude at a mean altitude of 11.98 meters above the sea level.

Experimental material:

The experimental material comprised genetically seven lines, NTL-1, NTL-50, JTL-12-04, JTL-12-10, JTL-12-11 and JTL-12-12 and four testers, GT-1, GT-2, JT-3 and AT-3 along with one commercial check-Abhinav. Their 28 F1 hybrids developed by crossing then in a Line × Tester mating design[3].

Evaluation of experimental material:

All the 40 genotypes (11 parental lines, 28 hybrids and one commercial check) were evaluated; the seedling were transplanted in a randomized block design with three replications at a spacing of 90 cm between rows and 60 cm between plants. Recommended cultural practices and plant protection measures were followed. The observations were recorded in respected of the following characters.

1. **Total Soluble Solids (TSS) %**

Total Soluble Solids of the selected samples were determined with the help of hand refractrometer. The refractrometer was washed with distilled water each time after use and dried with blotting paper.

2. **Lycopene content (mg per 100 g)**

Ten gram fruit sample was taken and pigment was extracted with 10 ml 80 % acetone in portion, using 10 ml at a time until colourless residue was obtained. The acetone was evaporated to dryness. The volume was made 50 ml with petroleum ether. The optical density was read at 503 nm using spectrophotometer. Petroleum ether was used as blank. Lycopene content was calculated as:

$$\text{mg of lycopene per 100g} = \frac{3.1206 \times \text{OD of sample} \times \text{Volume made up} \times \text{Dilution} \times 100}{1 \times \text{Weight of sample} \times 1000}$$

1) **Ascorbic acid (mg per 100 g)**

The ascorbic acid content of juice was estimated by titration method. In which, added the 3 % metaphosphoric acid and made the volume of 100 ml. And after filtration taken the 10 ml extract which titration by dye of 2, 6 dichlorophenole indophenole and end point was a light pink colour.

$$\text{Ascorbic acid (mg per 100g)} = \frac{\text{Titre} \times \text{Dye equivalent (0.04)} \times \text{Dilution} \times 100}{\text{Weight of the sample (g)}}$$

2) Average pulp content

Average pulp content was measured in gram from weight of five mature fruit pulp (each) per plants.

3) Pulp: Skin ratio

The ratio measured by differences between the average pulp weight and average skin weight.

4) Solid: Acid ratio

The ratio measured by differences between the total soluble solids (%) and titrable acidity (%).

5) Titrable acidity (%)

Titrable acidity was determined by titrating 10 ml of juice against 0.1 n Sodium hydroxide (NaOH) using phenolphthalein as an indicator. Appearance of pink colour was taken as end point of titration. It was expressed in term of mg anhydrous citric acid 100 ml of juice and calculated as given below:

$$\text{Titrable acidity (\%)} = \frac{\text{Equivalent weight of the acid} \times \text{Normality of NaOH} \times \text{Titre} \times 100 \times \text{Volume made up}}{\text{Volume taken for estimation} \times 1000 \times \text{Weight of sample}}$$

RESULT AND DISCUSSION

Definite fruit shape index is the important quality character for increased marketing value of tomato. Mean of sum of squares were observed highly significance among the genotypes (parents, crosses and one commercial check) for all the qualitative traits under study (table 2). Among the parents, pericarp thickness ranges from 1.91 mm (JTL-12-04) to 7.46 mm (JTL-12-11) (table1). However for the hybrids, it was in the range of 1.73 mm (JTL-12-10 × JT-3) to 8.15 mm (NTL-50 × JT-3). The extent of heterosis exhibited by the F_1s over their corresponding mid-parent, better-parent and standard check ranged from -71.58 % (JTL-12-10 × JT-3) to 139.07 % (JTL-12-04 × AT-3), -72.95 % (JTL-12-10 × JT-3) to 88.92 % (JTL-12-04 × AT-3) and -81.80 % (JTL-12-10 × JT-3) to -14.11 % (NTL-50 × AT-3), respectively. The13 hybrids for mid-parent, 14 hybrids for better parent and 28 cross combinations showed highly significant heterosis in negative direction for processing purpose. These types of results were also dummerized by Angadi and Dharmati[1], Kumar *et al.*[5] and Patvary *et al*[8].

Among the parents, mean performance for fruit shape index range from 0.58 (JTL-12-10) to 1.14 (AT-3). However for the crosses, it was ranged from 0.59 (JTL-12-10 × GT-2) to 1.16 (JTL-12-04 × AT-3). The extent of heterosis exhibited by the F_1 s over their mid-parent, better parent and commercial check ranged from -30.30 % (JTL-12-10 × AT-3) to 49.54 % (NTL-50 × GT-1), -43.06 % (JTL-12-10 × AT-3) to 31.75 % (JTL-12-10 × GT-1) and -56.56 % (JTL-12-10 × GT-2) to 13.76 % (JTL-12-04 × AT-3). Almost identical result was reported by Joshi and Thakur[2].

A total soluble solid directly influences flavor of tomato and is an important parameter in the processing industry. Analysis of variances revealed highly significant differences of total soluble solids among the parents and their 28 F_1s cross combinations. Mean data showed that total soluble solids ranged from 2.10 % (JTL-12-10) to 4.52 % (JT-3) among the parents (table1). And in hybrids it's ranged from 2.13 % (NTL-50 × GT-2 and JTL-12-14 × GT-1) to 4.32 % (NTL-1 × GT-2 and JTL-12-11 × GT-2). Heterosis was found in a range from -36.18 % (JTL-12-04 × JT-3) to 75.38 % (JTL-12-12 × GT-1), for better parent ranged for -52.36 % (NTL-50 × JT-3) to 74.25 % (JTL-12-12 × GT-1) and for standard heterosis ranged from -8.09 % (JTL-12-14 × GT-1) to 87.28 % (JTL-12-11 × GT-2). Among this, for mid-parent 12 hybrids, for better parent 18 hybrids and for standard heterosis one cross showed highly significant heterosis in negative direction[8,11].

High lycopene content is the most important desirable quality parameter for increasing marketing value and consumer prefer the good color of tomato. Statistical analysis manifested that highly significant variation among the genotypes for lycopene content **(table 2)**.

Among the parents, mean value for lycopene content ranges from 2.24 mg (AT-3) to 5.15 mg (JTL-12-12) and hybrid displayed a range of 0.16 mg (JTL-12-04 × AT-3) to 5.47 mg (JTL-12-04 × JT-3, JTL-12-10 × AT-3 and JTL-12-12 × AT-3). The estimates of heterosis ranged from -95.61 % (JTL-12-04 × AT-3) to 69.24 % (JTL-12-10 × AT-3) for mid-parent, for better parent heterosis ranged from -96.79 % (JTL-12-04 × AT-3) to 67.71 % (NTL-50 × GT-1) and standard heterosis ranged from -92.16 % (JTL-12-04 × AT-3) to 176.18 % (JTL-12-12 × AT-3). In which, foe mid-parent 11 hybrids, better parent seven hybrids and for standard parent heterosis 20 hybrids showed highly significant heterosis in positive direction. Highest significant heterobeltiosis for lycopene content was also observed by Kumar *et al.*[4,5].

Ascorbic acid content is nutritionally an important constituent small fruited genotypes are generally richer is ascorbic acid content. Mean sum of squares were observed highly significance, among the genotypes (parents and crosses) for ascorbic acid **(table 2)**. Among the parents, ascorbic acid ranged from7.72 mg (JTL-12-10) to 17.21 mg (NTL-1) and for hybrids, 6.04 mg (JTL-12-10 × GT-2) to 21.86 mg (JTL-12-12 × GT-1). Mid-parent heterosis ranged from -48.05 % (NTL-1 × AT-3) to 84.11 % (JTL-12-12 × GT-1), for better parent ranged from -60.87 % (NTL-1 × AT-3) to 83.59 % (JTL-12-12 × GT-1) and for economic heterosis ranged from 60.93 % (JTL-12-10 × GT-2) to 41.40 % (JTL-12-12 × GT-1). In which, nine hybrids for mid-parent, seven hybrids for better parent and four crosses for economic heterosis expressed highly significant heterosis in positive direction over the parents and check. By Mulge *et al*.[7], Kumar *et al.*[4,5] were also conform these finding.

In tomato, processing point of view more pulp content is require. Among the parents, pulp content ranged from 43.94 g (NTL-50) to 163.82 g (JTL-12-12). Hybrids displayed a range of from 45.33 g (JTL-12-12 × GT-1) to 194.34 g (JTL-12-10 × GT-2). The estimates of heterosis ranged from -58.08 % (JTL-12-12 × GT-1) to 145.37 % (JTL-12-10 × GT-2) in mid-parent, for better parent ranged from -72.33 % (JTL-12-12 × GT-1) to 98.30 % (NTL-1 × AT-3) and for standard heterosis from -45.37 % (JTL-12-04 × GT-1) to 204.85 % (JTL-12-10 × GT-2). For standard heterosis 20 hybrids were showed significant heterosis over its parent and check[6]. For pulp: skin ratio, mean performance ranged from 0.44 (JTL-12-14) to 1.10 (JTL-12-04) and hybrids ranged from 0.44 (JTL-12-04 × GT-1) to 1.35 (JTL-12-04 × GT-2). For this character heterotic variation for mid parent ranged from -42.99 % (JTL-12-04 × GT-1) to 51.23 % (JTL-12-04 × GT-2), for better parent ranged from -59.84 % (JTL-12-04 × GT-1) to 26.01 % (NTL-1 × AT-3) and for standard heterosis -16.58 % (JTL-12-04 × GT-1) to 154.94 % (JTL-12-04 × GT-2). Among these 28 hybrids, significant heterosis in positive direction observed in 11 hybrids for mid parent, nine hybrids for better parent and 23 hybrids for standard check. For solid: acid ratio mean performance ranged from the parents performance ranged from 6.37 (GT-1) to 10.50 (JTL-12-14) and ranged from 5.80 (NTL-1 × GT-1) to 11.45 (JTL-12-11 × GT-2) in hybrids. For estimation of heterosis over mid parent ranged from -29.75 % (JTL-12-14 × JT-3) to 59.24 % (JTL-12-11 × GT-2), over better parent -43.53 % (JTL-12-11 × GT-2) to 37.89 % (NTL-1 × AT-3) and for standard heterosis ranged from 35.40 % (NTL-1 × GT-1) to 167.40 % (JTL-12-11 × GT-2). For mid parent nine cross combinations, for better parent 15 hybrids and for economic heterosis none of cross combinations were showed significant heterosis in negative direction. Among the parents *per se* performance for titrable acidity ranged from 3.43 % (NTL-50) to 7.08 % (GT-2) and hybrids ranged from 3.36 % (NTL-1 × GT-1) to 6.33 % (JTL-12-11 × GT-2). For this character, mid parent heterosis ranged from -37.97 % (JTL-12-04 × GT-2) to 48.08 % (JTL-12-10 × AT-3), better parent heterosis ranged from -51.45 % (NTL-50 × GT-2) to 42.12 % (JTL-12-10 × AT-3) and for standard heterosis ranged from -6.27 % (NTL-1 × GT-1) to 76.77 % (JTL-12-11 × GT-2). For mid parent 13 hybrids, for better parent seven hybrids and for standard heterosis 24 hybrids were performed significant heterosis over its parents and check in positive direction. This findings also studied by Mondal *et al.*[6], Shende *et al.*[9], Kumar *et al.*[4,5].

The results of the present study indicate that through heterosis over mid-parent, better parent and standard check contributed significantly to the contribution of the former was important for all the processing characters.

Table 1: Mean performance of parents and hybrids of different qualitative traits

Genotypes	TSS (%)	Lycopene (mg per 100 g)	Ascorbic acid (mg per 100 g)	Average pulp content (g)	Pulp : Skin ratio	Solid : Acid ratio	Titrable acidity (%)
Female Parents							
NTL-1	2.60	3.92	17.21	95.08	0.85	6.88	3.53
NTL-50	2.16	3.44	14.87	43.94	0.66	8.12	3.43
JTL-12-04	4.24	4.84	11.02	76.95	1.10	7.60	4.08
JTL-12-10	2.10	4.22	7.72	103.99	0.55	7.89	3.75
JTL-12-11	2.17	4.95	14.78	133.52	0.48	7.98	4.86
JTL-12-12	2.46	5.15	11.84	163.82	0.66	8.36	4.37
JTL-12-14	2.46	4.89	9.05	155.86	0.44	10.50	4.14
Male Parent							
GT-1	2.44	4.84	11.91	52.46	0.45	6.37	6.43
GT-2	4.4	2.87	12.14	54.42	0.69	6.40	7.08
JT-3	4.52	2.61	14.94	55.69	0.87	7.33	5.55
AT-3	2.78	2.24	8.72	94.84	0.91	6.58	3.45
Hybrids							
NTL-1 × GT-1	2.45	1.25	10.55	49.88	0.64	5.80	3.36
NTL-1 × GT-2	4.32	0.77	11.70	86.44	1.07	7.51	4.24
NTL-1 × JT-3	4.08	3.91	15.72	70.69	0.66	6.91	6.24
NTL-1 × AT-3	4.14	3.59	6.74	188.54	1.14	9.49	3.78
NTL-50 × GT-1	2.26	1.57	8.68	69.8	0.74	6.11	3.45
NTL-50 × GT-2	2.12	1.57	12.51	61.20	0.67	6.82	3.44
NTL-50 × JT-3	2.16	3.92	9.49	61.64	0.54	6.80	4.25
NTL-50 × AT-3	2.28	2.03	9.28	62.08	0.64	9.88	3.73
JTL-12-04 × GT-1	2.27	0.63	11.81	92.67	0.44	7.37	5.52
JTL-12-04 × GT-2	4.29	3.91	10.96	76.38	1.35	7.99	3.46
JTL-12-04 × JT-3	2.80	5.47	11.64	103.11	0.74	8.11	4.23
JTL-12-04 × AT-3	4.21	0.16	14.67	84.22	0.95	8.78	4.36
JTL-12-10 × GT-1	2.48	2.03	14.20	122.86	0.63	8.63	3.86
JTL-12-10 × GT-2	2.6	3.13	6.04	194.34	0.63	8.49	4.67
JTL-12-10 × JT-3	4.20	4.69	15.54	73.64	0.84	10.83	5.13
JTL-12-10 × AT-3	2.44	5.47	8.56	143.66	0.53	6.73	5.32
JTL-12-11 × GT-1	2.53	4.84	7.76	87.75	0.46	7.92	5.77
JTL-12-11 × GT-2	4.32	4.69	18.71	64.96	0.72	11.45	6.33
JTL-12-11 × JT-3	2.42	2.19	14.83	76.76	0.69	6.34	4.23
JTL-12-11 × AT-3	2.36	1.72	9.63	87.67	0.65	7.55	4.06
JTL-12-12 × GT-1	4.30	3.91	21.86	45.33	0.78	7.228	5.56
JTL-12-12 × GT-2	3.31	4.69	9.12	69.99	0.67	7.41	4.82
JTL-12-12 × JT-3	2.76	3.28	7.19	105.80	0.75	7.85	4.28
JTL-12-12 × AT-3	4.29	5.47	10.8	143.92	0.94	8.76	4.49
JTL-12-14 × GT-1	2.12	4.70	12.3	75.19	0.53	8.37	4.34
JTL-12-14 × GT-2	2.33	5.15	16.94	54.54	0.68	7.75	4.15
JTL-12-14 × JT-3	2.27	3.59	10.87	85.05	0.58	6.26	4.50
JTL-12-14 × AT-3	2.29	3.91	12.81	87.52	0.58	7.28	4.23
Standard Check							
Abhinav	2.31	1.98	15.46	63.75	0.53	4.28	3.58

Table: 2a. Heterosis of hybrids for different traits

Crosses	TSS (%)			Lycopene (mg per 100 g)			Ascorbic acid (mg per 100 g)		
	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	-2.78	-5.73	5.98	-71.50**	-74.23**	-36.97**	-27.55**	-38.71**	-31.78**
NTL-1 × GT-2	23.36**	-1.97	86.99**	-77.34**	-80.38**	-61.20**	-20.29**	-32.04**	-24.36**
NTL-1 × JT-3	14.50**	-9.90**	76.55**	20.03**	-0.09	97.61**	-2.23	-8.68**	1.64
NTL-1 × AT-3	54.29**	49.28**	79.48**	16.76**	-8.25**	81.46**	-48.05**	-60.87**	-56.45**
NTL-50 × GT-1	-1.80	-7.50*	-2.31	-62.23**	67.71**	-21.03**	-35.18**	-41.64**	-43.88**
NTL-50 × GT-2	-35.50**	-51.97**	8.38*	-50.34**	-54.48**	-20.99**	-7.38**	-15.90**	-19.12**
NTL-50 × JT-3	-35.46**	-52.36**	-6.65	29.81**	14.08**	97.98**	-36.34**	-36.49**	-38.64**
NTL-50 × AT-3	-7.71*	-18.03**	-1.45	-28.38**	-40.87**	2.63	-21.35**	-37.62**	-40.02**
JTL-12-04 × GT-1	-32.03**	-6.95	-1.73	-87.08**	-87.09**	-68.41**	3.00	-0.84	-23.63**
JTL-12-04 × GT-2	-0.69	-2.58	85.84**	1.53	-19.20**	97.58**	-5.38**	-9.73**	-29.15**
JTL-12-04 × JT-3	-36.18**	-38.20**	21.10**	46.90**	12.94**	176.17**	-10.31**	-22.07**	-24.71**
JTL-12-04 × AT-3	20.08**	51.68**	82.37**	-95.61**	-96.79**	-92.16**	48.65**	33.09**	-5.13**
JTL-12-10 × GT-1	9.21**	1.53	7.23	-55.19**	-58.05**	2.60	44.67**	19.23**	-8.17**
JTL-12-10 × GT-2	-19.92**	-40.91**	12.72**	-11.82**	-26.01**	57.84**	-39.15**	-50.22**	-60.93**
JTL-12-10 × JT-3	26.81**	-7.23**	81.79**	37.30**	10.97**	136.71**	37.12**	3.99*	0.47
JTL-12-10 × AT-3	0.00	-12.26**	5.49	69.24**	29.46**	176.17**	4.10	-1.84	-44.67**
JTL-12-11 × GT-1	9.79**	3.72	9.54*	-1.11	-2.18*	144.56**	-41.84**	-47.50**	-49.81**
JTL-12-11 × GT-2	31.57**	-1.82	87.28**	19.96**	-5.31**	136.73**	39.01**	26.57**	21.00**
JTL-12-11 × JT-3	-27.82**	-46.61**	4.62	-42.07**	-55.81**	10.49**	-0.21	-0.74	-4.10*
JTL-12-11 × AT-3	-4.45	-14.90**	2.31	-52.17**	-65.27**	-13.18**	-18.05**	-34.87**	-37.73**
JTL-12-12 × GT-1	75.38**	74.25**	86.13**	-21.69**	-24.05**	97.71**	84.11**	83.59**	41.40**
JTL-12-12 × GT-2	-3.60	-24.85**	43.35**	16.90**	-9.07**	136.73**	-23.97**	-24.89**	41.05**
JTL-12-12 × JT-3	-21.11**	-39.09**	19.36**	-15.42**	-36.35**	65.69**	-46.32**	-51.89**	-53.51**
JTL-12-12 × AT-3	63.82**	54.57**	85.84**	47.93**	6.09**	176.18**	5.09*	-8.78**	-30.14**
JTL-12-14 × GT-1	-13.40**	-12.97**	-8.09*	-3.47**	-3.98**	137.35**	17.40**	3.30	-20.44**
JTL-12-14 × GT-2	-32.17**	-47.12**	0.87	32.87**	5.32**	160.34**	59.96**	39.62**	9.57**
JTL-12-14 × JT-3	-35.05**	-49.85**	-1.73	-4.18**	-26.60**	81.43**	-9.33**	-27.20**	-29.67**
JTL-12-14 × AT-3	-12.36**	-17.31**	-0.58	9.79**	-20.00**	97.75**	44.29**	41.63**	-17.12**
CD (5%)	0.151	0.174	0.174	0.090	0.105	0.105	0.46	0.53	0.53
CD (1%)	0.201	0.232	0.232	0.120	0.139	0.139	0.61	0.70	0.70

Table: 2b. Heterosis of hybrids for different traits

Crosses	Average pulp content (g)			Pulp: Skin ratio			Solid: Acid ratio		
	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	-32.39**	-47.55**	-21.76**	-2.44	-25.53**	20.10**	-12.53**	-15.79**	35.40**
NTL-1 × GT-2	15.64**	-9.09**	35.60**	38.91**	25.20**	101.90**	13.03**	9.08**	75.38**
NTL-1 × JT-3	-6.23**	-25.66**	10.89**	-24.20**	-24.96**	23.48**	-2.73	-5.66**	61.41**
NTL-1 × AT-3	98.55**	98.30**	195.76**	29.90**	26.01**	116.14**	41.01**	37.89**	121.70**
NTL-50 × GT-1	44.83**	33.07**	9.50**	34.30**	13.32**	40.00**	-15.71**	-24.79**	42.65**
NTL-50 × GT-2	24.44**	12.46**	-4.01	0.08	-2.20	26.58**	-6.10**	-16.03**	59.27**
NTL-50 × JT-3	23.75**	10.69**	-3.30	-29.00**	-37.85**	2.28	-11.99**	16.30**	58.76**
NTL-50 × AT-3	-10.54**	-34.54**	-2.62	-18.32**	-29.74**	20.51**	34.47**	21.70**	130.84**
JTL-12-04 × GT-1	43.23**	20.43**	-45.37**	-42.99**	-59.84**	-16.58**	5.51**	-2.99	72.09**
JTL-12-04 × GT-2	16.29**	-0.74	19.82**	51.23**	22.73**	154.94**	14.10**	5.14**	86.52**
JTL-12-04 × JT-3	55.48**	34.00**	61.74**	-24.72**	-32.54**	40.13**	8.69**	6.75**	89.39**
JTL-12-04 × AT-3	-1.95	-11.20**	32.11**	-5.54**	-13.77**	79.11**	23.96**	15.66**	105.19**
JTL-12-10 × GT-1	57.07**	18.15**	92.73**	26.46**	14.84**	19.49**	21.07**	9.42**	101.60**
JTL-12-10 × GT-2	145.37**	86.88**	204.85**	2.03	-7.97**	19.11**	18.76**	7.58**	98.21**
JTL-12-10 × JT-3	-7.77**	-29.19**	15.51**	17.44**	-4.15**	57.72**	42.42**	37.34**	153.04**
JTL-12-10 × AT-3	44.51**	38.15**	125.36**	-27.24**	-41.55**	0.25	-6.94**	-14.66**	57.23**
JTL-12-11 × GT-1	-5.64**	-34.28**	37.65**	-2.01	-5.29*	-13.80**	10.48**	-0.64	85.10**
JTL-12-11 × GT-2	-30.88**	-51.35**	1.89	24.03**	5.62**	36.71**	59.24**	-43.53**	167.40**
JTL-12-11 × JT-3	-18.86**	-42.51**	20.41**	1.54	-21.15**	29.75**	-17.08**	-20.47**	48.18**
JTL-12-11 × AT-3	-23.22**	-34.34**	37.52**	-6.65**	-28.56**	22.53*	3.79*	-5.30**	76.43**
JTL-12-12 × GT-1	-58.08**	-72.33**	-28.90**	39.65**	17.34**	46.46**	-1.88	-13.60**	68.93**
JTL-12-12 × GT-2	-35.86**	-57.28**	9.79**	-0.72	-2.49	26.20**	0.31	-11.48**	73.08**
JTL-12-12 × JT-3	-3.61*	-35.42**	65.96**	-2.54	-14.31**	41.01**	0.06	-6.19**	83.42**
JTL-12-12 × AT-3	11.29**	-12.14**	125.77**	19.69**	3.39**	77.34**	17.21**	4.66**	104.64**
JTL-12-14 × GT-1	-27.82**	-51.76**	17.94**	20.17**	17.88**	0.13	-0.83	-20.34**	95.42**
JTL-12-14 × GT-2	-48.12**	-65.01**	-14.44**	22.06**	-0.44	28.86**	-8.37**	-26.26**	80.91**
JTL-12-14 × JT-3	-19.60**	-45.43**	33.41**	-10.87**	-33.31**	9.75**	-29.75**	-40.37**	46.28**
JTL-12-14 × AT-3	-30.18**	-43.85**	37.29**	-12.72**	-35.57**	10.51**	-14.74**	-30.67**	70.08**
CD (5%)	3.31	3.83	3.83	0.02	0.023	0.023	0.24	0.28	0.28
CD (1%)	4.41	5.09	5.09	0.026	0.030	0.030	0.32	0.37	0.37

Table: 2c. Heterosis of hybrids for different traits

Crosses	Titrable acidity (%)		
	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	-32.51**	-47.75**	-6.27**
NTL-1 × GT-2	-20.03**	-40.11**	18.33**
NTL-1 × JT-3	37.58**	12.49**	74.19**
NTL-1 × AT-3	8.30**	7.08**	5.33**
NTL-50 × GT-1	-30.15**	-46.43**	-3.90**
NTL-50 × GT-2	-34.60**	-51.45**	-4.08**
NTL-50 × JT-3	-5.40**	-23.45**	18.54**
NTL-50 × AT-3	8.54**	8.32**	4.16**
JTL-12-04 × GT-1	4.99**	-14.19**	53.94**
JTL-12-04 × GT-2	-37.97**	-51.12**	-3.42**
JTL-12-04 × JT-3	-12.06**	-23.70**	18.15**
JTL-12-04 × AT-3	15.97**	6.96**	21.77**
JTL-12-10 × GT-1	-24.22**	-40.02**	7.59**
JTL-12-10 × GT-2	-13.68**	-34.00**	30.41**
JTL-12-10 × JT-3	10.45**	-7.48**	43.27**
JTL-12-10 × AT-3	48.08**	42.12**	48.62**
JTL-12-11 × GT-1	2.25**	-10.22**	61.06**
JTL-12-11 × GT-2	6.10**	-10.53**	76.77**
JTL-12-11 × JT-3	18.75**	-23.79**	18.02**
JTL-12-11 × AT-3	-2.16*	-16.40**	13.39**
JTL-12-12 × GT-1	2.97**	-13.55**	55.09**
JTL-12-12 × GT-2	-15.76**	-31.91**	34.54**
JTL-12-12 × JT-3	-13.75**	-22.95**	19.32**
JTL-12-12 × AT-3	14.99**	2.88**	25.33**
JTL-12-14 × GT-1	-17.94**	-32.53**	21.04**
JTL-12-14 × GT-2	-26.08**	-41.42**	15.74**
JTL-12-14 × JT-3	-7.01**	-18.80**	25.73**
JTL-12-14 × AT-3	11.57**	2.19*	18.12**
CD (5%)	0.070	0.081	0.081
CD (1%)	0.093	0.108	0.108

REFERENCES

1. Angadi, A. and Dharmatti, P.R., Heterosis for processing quality traits in tomato (*Solanum lycopersicum* L.). *Res. J. Agric. Sci.*, **3 (5):** 1028-1030,(2012[a]).
2. Joshi, A. and Thakur, M.C., Evaluation of diallel progenies for yield and its contributing traits in tomato. *Hort. J.*, **17:** 145-153, (2004).
3. Kempthorne, O., An introduction to Genetics Statistics. John Wiley

and Sons Inc., New York, Chapman and Hall, London, (1957).
4. Kumar, R., Srivastava, K., Singh, R.K. and Kumar, V., Heterosis for Quality Attributes in Tomato (*Lycopersicon esculentum* Mill.). *Society for Plant Research,* **26 (1):** 101-106, (2013[b]).
5. Kumar, V., Nandan, R.., Sharma, S.K., Srivastava, K., Kumar, R. and Singh, M.K., Heterosis study for quality attributing traits in different crosses in tomato (*Solanum lycopersicum* L.). *Plant Archives,* **13 (1):** 21-26, (2013[a]).
6. Mondal, C., Sarkar, S. and Hazra, P., Line × tester analysis of combining ability of tomato (*Solanum lycopersicum* L.). *Journal of Crop and Weed,* **5 (1):** 53-57,(2009).
7. Mulge, R., Mahendrakar, P. and Prashanth, S.J., prediction of heterosis based on genetic divergence in tomato. *Indian J. Hort.*, **69 (4):** 530-535, (2012).
8. Patwary, M.M.A., Raheman, M.M., Ahmad, S., Khaleque, M.A. and Barua, H., Study of heterosis in heat tolerant tomato (*Solanum lycopersicum* L.) during summer. *Bangladesh J. Agril. Res.*, **38 (3):** 531-544,(2013).
9. Shende, V.D., Seth, T., Mukherjee, S. and Chattopadhyay, A., Breeding tomato (*Solanum lycopersicum*) for higher productivity and better processing qualities. *SABRAO J. Breed. Genet.*, **44 (2):** 302-321,(2012).
10. Tiwari, A. and Lal, G., Studies on heterosis for quantitative and qualitative characters in tomato (*Lycopersicon esculentum* Mill.). *Prog. Hort.*, **36 (1):** 122-127, (2004).
11. Yadav, S.K., Singh, B.K., Baranwal, D.K. and Solankey, S.S. Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum* L.). *Glob. J. C., Soil Sci. and Plant Breed.*, **1(1):** 59-65, (2013).

