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Bhakti R Panchal
Scientist (Horticulture),
Krishi Vigyan Kendra, Surat
Navsari Agricultural University,
Surat, Gujarat, India

Harsidhdhi B Panchal
Scientist (Horticulture),
Krishi Vigyan Kendra, Surat
Navsari Agricultural University,
Surat, Gujarat, India

Mrs Aarti A Panchal
Scientist (Horticulture),
Krishi Vigyan Kendra, Surat
Navsari Agricultural University,
Surat, Gujarat, India

Dr. NB Patel
Scientist (Horticulture),
Krishi Vigyan Kendra, Surat
Navsari Agricultural University,
Surat, Gujarat, India

Corresponding Author:
Bhakti R Panchal
Scientist (Horticulture),
Krishi Vigyan Kendra, Surat
Navsari Agricultural University,
Surat, Gujarat, India

Combining ability analysis for processing characters and its related traits in tomato (*Solanum lycopersicum* L.)

Bhakti R Panchal, Harsidhdhi B Panchal, Mrs Aarti A Panchal, and Dr. NB Patel

Abstract
A set of 40 genotypes including seven females, four males, their 28 single F_1 combinations and one definitive check (Abhinav) existed planted at Vegetable Research Scheme, R.H.R.S., NAU, Navsari. During research the combining ability in tomato (*Solanum lycopersicum* L.) for 8 characters following Line x Tester mating method, Elevated public incorporating capacity experimental in parents of *viz*., JTL-12-04, JTL-12-10, JTL-12-12, JT-3 and AT-3 for one or more yield contributing traits. In hybrids, JTL-12-12 × JT-3, NTL-1 × AT-3, JTL-12-12 × GT-2, NTL-1 × JT-3, JTL-12-11 × GT-2, JTL-12-10 × GT-2, JTL-12-04 × AT-3 and JTL-12-04 × GT-1 exemplified increased heterosis bonded with huge SCA consequences for fruit result. Mixing skill analysis indicated that importance of SCA disagreements occurred elevated than GCA frictions for all the identities under research, which implied that prevalence of non-additive gene effort for heritage of all the characteristics. Therefore, distant breeding programme exploitation of heterosis is reasonable.

Keywords: general combining ability, specific combining ability, tomato, line × tester

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. Because of its wider adaptability and versatility, tomato is grown throughout the world either in outdoors or indoors. It is universally treated as "productive" as well as "protective food" having medicinal value, too. In many countries it is considered as "poor man's orange" because of its attractive appearance and nutritive value (Singh *et al*., 2004) [17]. 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 cancer of mouth, sore mouth, etc. The combining ability analysis helps in diagnosing or identifying additive or non-additive gene action would in turn lead a breeder to select desirable parents or cross combinations that would be exploited for crop improvement. A knowledge of general combining ability (gca) and specific combining ability (sca) helps in choice of parents and hybrids and the nature of gene action acts as bases of choosing effective breeding methods. The present investigation was undertaken to identify parental combination that are likely to produce superior hybrids having highest yield.

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 20º 37' North latitude and 72º54' 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 F_1 hybrids developed by crossing then in a Line × Tester mating design (sin, 1957).

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 refractometer. The refractometer 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:

$$\text{mg of lycopene per100g} = \frac{3.1206 \times \text{OD of sample} \times \text{Volume made up} \times \text{Dilution} \times 100}{1 \times \text{Weight of sample} \times 1000}$$

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 dichlorophenol indophenol and end point was a light pink colour.

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

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

4) Pulp: Skin ratio
The ratio measured by differences between the average pulp weight and average skin weight.

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

6) 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
The concept of combining ability is considered to be a landmark in the development of efficient and effective breeding methodology in different crop plants. Analysis of combining ability provides guidelines for an early assessment of the relative breeding worth of the plant material. Utilizing this technique, breeder can choose the best general combining parents as well as specific cross combinations for further exploitation. The parental material may be used to develop hybrids or build up the favourable fixable genes depending upon the nature of gene action. The GCA variances comprises of fixable portion while the SCA represents non-fixable genetic variance. Selection is more effective and progress in evolving the economic character is much faster when genetic variance is primarily due to additive gene action. In such situation, not only the means of generation remain unchanged but the genetic variance is readily translatable from one generation to another.
In the present study, SCA variances were highly significant for all the (8) characters and GCA variances was significant for TSS, average pulp content and pulp: skin ratio. This suggested that both additive and non-additive variances were important in the expression of these traits. In analysis of variances, female was significant for traits *viz.*,TSS, in male was not significant for in all the traits. Also Females × Males interaction was highly significant for all the traits. After that contribution of female parents was always higher than the males for all the traits. For GCA and SCA variances, GCA variances were always lesser than the SCA variances in all the traits. Its indicate that the non-additive type gene action present in this materials. This types of results was also reported by, Singh *et al.* (2008) [16], Sekhar *et al.* (2010) [9], Singh *et al.* (2011) [15], Singh and Asati (2011) [13], Kumari and Sharma (2012) [5], Shende *et al.* (2012) [12], Angadi *et al.* (2012) [1], Souza *et al.* (2012) [18], Yadav *et al.* (2013) [19], Narasimhamurthy and Gowda (2013) [6] and Shankar *et al.* (2013^b) [11].
A close relationship between parents *per se* performance and their general combining ability is important in the choice of parents for crossing programme. In the present study, the best general combiners based on GCA and best parents based on *per se* performance were different, suggesting that inter allelic interaction was important for these characters. Similar results have been reported by Rai, (1992) [8] and Premalakshme *et al.* (2006) [7].
The character-wise estimates of general combining ability effects for each parent are presented in Table 2 and specific combining ability in Table 3.
General combining ability studies have successfully led to making choice of parent. Among the female parents, four female parents NTL-50 (-0.81), JTL-12-14 (-0.08), JTL-12-11 (-0.11) and JTL-12-14 (-0.76) had good GCA effects in negative direction and in males, two parents GT-1 (-0.38) and JT-3 (-0.06) were exhibited high significant GCA effects in negative direction. For lycopene, Among parents, four female

parents *viz.,* JTL-12-10 (0.53), JTL-12-11 (0.06), JTL-12-12 (1.04) and JTL-12-14 (1.05) showed highly significant GCA effects in positive direction and two male parents namely GT-2 (0.12) and JT-3 (0.57) were exhibited good GCA effects in positive direction. For Ascorbic acid content, among all parents, four females JTL-12-04 (0.45), JTL-12-11 (0.92), JTL-12-12 (0.43) and JTL-12-14 (1.42) exhibited highly significant GCA effects in positive direction. Among male, three parents GT-1 (0.63), GT-2 (0.46) and JT-3 (0.36) exhibited highly significant GCA effects in positive direction. For average pulp weight, The GCA effects of the female parents showed that two parents NTL-1 (8.69) and JTL-12-10 (43.42) were found to be good general combiner in positive direction. While, in male one parent AT-3 (23.74) showed highly significant GCA effects in positive direction. For pulp:skin ratio, For the trait under consideration, three female parents NTL-1 (0.15), JTL-12-04 (0.15) and JTL-12-12 (0.06) exhibited good GCA effects in positive direction and two male parents GT-2 (0.10) and AT-3 (0.05) showed good general combining ability effects in positive direction. For Solid: Acid ratio, for this character, three female parents NTL-1 (-0.45), NTL-50 (-0.47) and JTL-12-14 (-0.46) showed good GCA effects and two male parents GT-1(-0.53) and AT-3 (-0.28) expressed good GCA effects in negative direction. And for titrable acidity, among female parents, three parents *viz.,* JTL-12-10 (0.25), JTL-12-11 (0.60) and JTL-12-12 (0.29) showed good GCA effects and among males two parents GT-1 (0.06) and JT-3 (0.20) exhibited highly GCA effects in positive direction.

Specific combining is the manifestation of non-additive component of genetic variance and associated with interaction effects, which may due to dominance and epistatic component of genetic variation that are non-fixable in nature. It shows the highly specific combining abilities leading to the higher performance of some specific cross combinations and that is the reason why it is related to a particular cross. High SCA effects may arise not only in crosses involving high combiners but also in those involving low combiners. The results showed that the SCA effects among the hybrids were significant for all the traits. A summarized account of the best parent, *per se* performance, best general combiner, best F_1 *per se,* most heterotic crosses and best specific combination (Table 6) revealed that the best performing parents may not be a best general combiner. Further, the best general combiner or best parent *per se* may not always produce best specific combinations for all the characters. It is therefore more desirable to select crosses based on the *per se* performance rather than magnitude of SCA effects. The crosses showing low SCA effects may exhibit high *per se* performance. Eight cross combinations *viz.,* JTL-12-12 × JT-3, NTL-1 × AT-3, JTL-12-12 × GT-2, NTL-1 × JT-3, JTL-12-11 × GT-2, JTL-12-10 × GT-2, JTL-12-04 × AT-3 and JTL-12-04 × GT-1 manifested high heterosis coupled with high SCA effects for fruit yield. The ranking of crosses based on SCA effects and *per se* performance of crosses differ in 10 top yielding crosses. These 10 top yielding crosses involved at least one of parents as good/average combiner. It was interesting to note that crosses of good × good, good × average and average × poor general combining parents showed high degree of heterosis for fruit yield. However their SCA effects were not consistent. Out of 10 top yielding crosses, four *viz.,* JTL-12-12 × JT-3, JTL-12-12 × AT-3, JTL-12-04 × AT-3 and JTL-12-10 × JT-3 involving good × good general combining parents ranked first, fourth, eighth and tenth, respectively. The top yielding cross JTL-12-12 × JT-3 involved good × good general combining parents with high magnitude of heterosis through SCA effect was low compared to cross NTL-1 × AT-3. The crosses exhibiting high *per se* performance may result from either good × good, good × average, good × poor and poor × good general combining parents. The good general combining parents when crossed do not always produce high SCA effects. Similar poor general combining parents do not always produce low SCA effects. Similar results have been reported by Singh *et al.* (2010[a]) [14], Singh and Asati (2011) [13], Kumari and Sharma (2012) [5] and Kumar *et al.* (2013[c]) [4]. Negative or non-significant SCA effects were found in crosses *viz.,* JTL-12-12 × AT-3 and JTL-12-10 × JT-3. Marked negative or non-significant SCA effects in crosses between good × good general combiners could be attributed to the lack of co-adaptation between favourable alleles of the parents involved. Whereas marked positive effects in crosses between poor × good, average × good or good × poor general combiners could be ascribed to better complementation between favourable alleles of the parents involved. Similar results have been reported by Bhatt *et al.* (2004) [2], Singh and Asati (2011) [13], Kumari and Sharma (2012) [5], Kumar *et al.* (2013[c]) [4] and Shankar *et al.* (2013).

Increase in the yield, accompanied by a good standard of quality characters, *viz.,* lycopene, ascorbic acid content as well as titrable acidity are always desirable. In the present investigation, the parents JTL-12-11, JTL-12-12 and JT-3 could be spotted out as good general combiners for these traits. Thus, by using these parents in breeding programme, there is a good scope for increasing yield without loss in quality characters. From the observations were made in the present study the following relevant points are emerged, the correlation between *per se* performance and SCA effects of crosses for the characters indicated that SCA effects of a cross can reasonably be predicted from *per se* performance. However, the inspection of SCA effects and mean performance of individual crosses indicated that the crosses having high SCA effects did not always possess high mean (Table 6). Higher SCA effects than the GCA effects in all the traits it has been indicated that presence the predominance of non-additive type of gene action in the materials. It was revealed that for future breeding programme exploitation of heterosis was feasible. Hence, it is necessary to follow modified breeding methods such as bi-parental cross or triple test cross design or any other form of recurrent selection method in early generations. The crosses exhibiting high SCA effects do not always involve the parents having high GCA effects (Table 6). Any parental combination either good × good, average × good, average × average or poor × poor may result into high SCA effects (Table 5). The crosses exhibiting high SCA effects were not always the result of good × good combination with respect to mean performance. Hence choice of the parents on the basis of combining ability together with *per se* performance is advisable.

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

Genotypes	Fruit yield per plant (kg)	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	3.42	2.60	3.92	17.21	95.08	0.85	6.88	3.53
NTL-50	1.76	2.16	3.44	14.87	43.94	0.66	8.12	3.43
JTL-12-04	2.66	4.24	4.84	11.02	76.95	1.10	7.60	4.08
JTL-12-10	4.23	2.10	4.22	7.72	103.99	0.55	7.89	3.75
JTL-12-11	4.30	2.17	4.95	14.78	133.52	0.48	7.98	4.86
JTL-12-12	4.29	2.46	5.15	11.84	163.82	0.66	8.36	4.37
JTL-12-14	3.82	2.46	4.89	9.05	155.86	0.44	10.50	4.14
Male Parent								
GT-1	1.04	2.44	4.84	11.91	52.46	0.45	6.37	6.43
GT-2	3.78	4.4	2.87	12.14	54.42	0.69	6.40	7.08
JT-3	3.28	4.52	2.61	14.94	55.69	0.87	7.33	5.55
AT-3	3.12	2.78	2.24	8.72	94.84	0.91	6.58	3.45
Hybrids								
NTL-1 × GT-1	2.07	2.45	1.25	10.55	49.88	0.64	5.80	3.36
NTL-1 × GT-2	2.23	4.32	0.77	11.70	86.44	1.07	7.51	4.24
NTL-1 × JT-3	5.41	4.08	3.91	15.72	70.69	0.66	6.91	6.24
NTL-1 × AT-3	7.76	4.14	3.59	6.74	188.54	1.14	9.49	3.78
NTL-50 × GT-1	3.76	2.26	1.57	8.68	69.8	0.74	6.11	3.45
NTL-50 × GT-2	4.45	2.12	1.57	12.51	61.20	0.67	6.82	3.44
NTL-50 × JT-3	3.41	2.16	3.92	9.49	61.64	0.54	6.80	4.25
NTL-50 × AT-3	1.49	2.28	2.03	9.28	62.08	0.64	9.88	3.73
JTL-12-04 × GT-1	5.22	2.27	0.63	11.81	92.67	0.44	7.37	5.52
JTL-12-04 × GT-2	4.18	4.29	3.91	10.96	76.38	1.35	7.99	3.46
JTL-12-04 × JT-3	3.59	2.80	5.47	11.64	103.11	0.74	8.11	4.23
JTL-12-04 × AT-3	5.27	4.21	0.16	14.67	84.22	0.95	8.78	4.36
JTL-12-10 × GT-1	4.25	2.48	2.03	14.20	122.86	0.63	8.63	3.86
JTL-12-10 × GT-2	5.32	2.6	3.13	6.04	194.34	0.63	8.49	4.67
JTL-12-10 × JT-3	4.58	4.20	4.69	15.54	73.64	0.84	10.83	5.13
JTL-12-10 × AT-3	4.22	2.44	5.47	8.56	143.66	0.53	6.73	5.32
JTL-12-11 × GT-1	3.71	2.53	4.84	7.76	87.75	0.46	7.92	5.77
JTL-12-11 × GT-2	5.34	4.32	4.69	18.71	64.96	0.72	11.45	6.33
JTL-12-11 × JT-3	4.44	2.42	2.19	14.83	76.76	0.69	6.34	4.23
JTL-12-11 × AT-3	4.18	2.36	1.72	9.63	87.67	0.65	7.55	4.06
JTL-12-12 × GT-1	3.22	4.30	3.91	21.86	45.33	0.78	7.228	5.56
JTL-12-12 × GT-2	6.17	3.31	4.69	9.12	69.99	0.67	7.41	4.82
JTL-12-12 × JT-3	8.23	2.76	3.28	7.19	105.80	0.75	7.85	4.28
JTL-12-12 × AT-3	5.77	4.29	5.47	10.8	143.92	0.94	8.76	4.49
JTL-12-14 × GT-1	3.34	2.12	4.70	12.3	75.19	0.53	8.37	4.34
JTL-12-14 × GT-2	2.08	2.33	5.15	16.94	54.54	0.68	7.75	4.15
JTL-12-14 × JT-3	3.86	2.27	3.59	10.87	85.05	0.58	6.26	4.50
JTL-12-14 × AT-3	2.75	2.29	3.91	12.81	87.52	0.58	7.28	4.23
Standard Check								
Abhinav	2.08	2.31	1.98	15.46	63.75	0.53	4.28	3.58

Table 2: Analysis of variance for combining ability in respect of 8 characters in Tomato

Sr. No.	Source of variation	d. f.	Fruit yield per plant (kg)	TSS (%)	Lycopene (mg per 100 g)	Ascorbic acid (mg per 100 g)	Average pulp content (g)	Pulp: Skin ratio	Solid: Acid ratio	Titrable acidity (%)
1	Replications	2	0.26	0.001	0.00	0.14	6.70	0.00	0.02	0.003
2	Females (lines	6	10.56	4.70*	9.83	15.06	5999.79	0.17	3.00	2.35
3	Males (testers)	3	4.86	1.87	4.87	20.23	5558.02	0.21	4.88	0.63
4	Females × Males	18	6.84**	1.68**	7.61**	53.95**	3392.26**	0.09**	6.41**	2.16**
5	Error	54	0.09	0.005	0.00	0.15	6.85	0.00	0.01	0.002
6	Contribution of female (%)		31.52	43.98	27.99	8.05	31.65	29.15	12.18	25.71
7	Contribution of male (%)		7.25	8.74	6.94	5.40	14.66	18.24	9.90	3.46
8	Contribution of female × male (%)		61.22	47.27	65.07	86.54	53.69	52.61	77.93	70.83
9	σ^2 f		0.87	0.39	0.82	1.25	499.53	0.01	0.25	0.19
10	σ^2 m		0.23	0.09	0.23	0.96	264.41	0.009	0.23	0.30
11	σ^2_{gca}		0.46	0.20	0.45	1.06	349.91	0.011	0.24	0.09

12	σ^2_{sca}		2.26	0.56	2.54	17.95	1128.94	0.03	2.13	0.72
13	$\sigma^2_{gca} / \sigma^2_{sca}$		0.20	0.357	0.177	0.059	0.309	0.366	0.112	0.125

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

Table 3: Estimation of General Combining Ability (GCA) for 8 characters in Tomato

Parents	Fruit yield per plant (kg)	TSS (%)	Lycopene (mg per 100 g)	Ascorbic acid (mg per 100 g)	Average pulp content (g)	Pulp: Skin ratio	Solid: Acid ratio	Titrable acidity (%)
Females (Lines)								
NTL-1	0.07	0.72**	-0.91**	-0.64**	8.69**	0.15**	-0.45**	-0.09**
NTL-50	-1.02**	-0.81**	-1.02**	-1.83**	-26.52**	-0.07**	-0.47**	-0.78**
JTL-12-04	0.27**	0.38**	-0.75**	0.45**	-1.11	0.15**	0.19**	-0.10**
JTL-12-10	0.30**	-0.08**	0.53**	-0.73**	43.42**	-0.06 Table 5: Summary of GCA effects of the parents for different characters in tomato **	0.80**	0.25**
JTL-12-11	0.12	-0.11**	0.06**	0.92**	-10.91**	-0.09**	0.45**	0.60**
JTL-12-12	1.55**	0.65**	1.04**	0.43**	1.06	0.06**	-0.06	0.29**
JTL-12-14	-1.29**	-0.76**	1.045**	1.42**	-14.63**	-0.13**	-0.46**	-0.19**
S. Em. ± (gi)	0.07	0.03	0.018	0.09	0.67	0.004	0.05	0.014
Males (Testers)								
GT-1	-0.64**	-0.38**	-0.59**	0.63**	-12.56**	-0.12**	-0.53**	0.06**
GT-2	-0.05	0.31**	0.12**	0.46**	-3.36**	0.10**	0.33**	-0.05**
JT-3	0.49**	-0.06*	0.57**	0.36**	-7.82**	-0.04**	-0.28**	0.20**
AT-3	0.20**	0.13**	-0.10**	-1.46**	23.74**	0.05**	0.48**	-0.21**
S. Em. ± (gi)	0.06	0.02	0.014	0.07	0.51	0.003	0.03	0.010

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

Table 4: Magnitude of Specific Combining Ability (SCA) for 10 characters in Tomato

Crosses	Fruit yield per plant (kg)	TSS (%)	Lycopene (mg per 100 g)	Ascorbic acid (mg per 100 g)	Average pulp content (g)	Pulp: Skin ratio	Solid: Acid ratio	Titrable acidity (%)
NTL-1 × GT-1	-1.66**	-0.91**	-0.54**	-1.26**	-36.45**	-0.12**	-1.10**	-1.10**
NTL-1 × GT-2	-2.09**	0.26**	-1.73**	0.06	-9.08**	0.09**	-0.24*	-0.11**
NTL-1 × JT-3	0.55**	0.39**	0.96**	4.18**	-20.38**	-0.18**	-0.23*	1.63**
NTL-1 × AT-3	3.20**	0.27**	1.31**	-2.98**	65.91**	0.21**	1.58**	-0.42**
NTL-50 × GT-1	1.12**	0.44**	-0.11**	-1.94**	18.68**	0.21**	-0.77**	-0.33**
NTL-50 × GT-2	1.22**	-0.40**	-0.83**	2.05**	0.88	-0.08**	-0.91**	-0.23**
NTL-50 × JT-3	-0.36*	0.02	1.08**	-0.86**	5.78**	-0.07**	-0.32**	0.33**
NTL-50 × AT-3	-1.98**	-0.06	-0.14**	0.75**	-25.35**	-0.06**	1.99**	0.23**
JTL-12-04 × GT-1	1.30**	-0.74**	-1.32**	-1.09**	16.14**	-0.31**	-0.17	1.06**
JTL-12-04 × GT-2	-0.34*	0.58**	1.25**	-1.78**	-9.34**	0.37**	-0.40**	-0.88**
JTL-12-04 × JT-3	-1.46**	-0.53**	2.35**	-0.99**	21.83**	-0.09**	0.33**	-0.36**
JTL-12-04 × AT-3	0.51**	0.69**	-2.28**	3.86**	-28.62**	0.02**	0.24*	0.18**
JTL-12-10 × GT-1	0.30*	-0.06	-1.21**	2.48**	1.80	0.09**	0.48**	-0.95**
JTL-12-10 × GT-2	0.77**	-0.64**	-0.82**	-5.50**	64.07**	-0.13**	-0.51**	-0.26
JTL-12-10 × JT-3	-0.50**	1.33**	0.29**	4.09**	-52.17**	0.21**	2.45**	0.18**
JTL-12-10 × AT-3	-0.57**	-0.62**	1.74**	-1.06**	-13.71**	-0.18**	-2.42**	0.79**
JTL-12-11 × GT-1	-0.06	0.00	2.07**	-5.60**	21.03**	-0.05**	0.13	0.62**
JTL-12-11 × GT-2	0.97**	1.10**	1.21**	5.51**	-10.96**	-0.01	2.80**	1.28**
JTL-12-11 × JT-3	-0.47**	-0.43**	-1.74**	1.73**	5.29**	0.09**	-1.69**	-1.07**
JTL-12-11 × AT-3	-0.43**	-0.68**	-1.54**	-1.64**	-15.36**	-0.03**	-1.25**	-0.83**
JTL-12-12 × GT-1	-1.98**	1.02**	0.17**	8.98**	-33.37**	0.11**	-0.05	0.71**
JTL-12-12 × GT-2	0.36*	-0.68**	0.23**	-3.59**	-17.90**	-0.22**	-0.73**	0.08**
JTL-12-12 × JT-3	1.89**	-0.85**	-1.63**	-5.42**	22.35**	0.00	0.32**	-0.71**
JTL-12-12 × AT-3	-0.27	0.49**	1.23**	0.02	28.92**	0.10**	0.46**	-0.08**
JTL-12-14 × GT-1	0.98**	0.25**	0.95**	-1.57**	12.17**	0.05**	1.48**	-0.02
JTL-12-14 × GT-2	-0.88**	-0.24**	0.69**	3.25**	-17.67**	-0.02*	0.00	-0.11**
JTL-12-14 × JT-3	0.35*	0.07	-1.32**	-2.72**	17.29**	0.02**	-0.86**	-0.00
JTL-12-14 × AT-3	-0.45**	-0.09	-0.32**	1.04**	-11.79**	-0.06**	-0.62**	0.14**
CD (5%)	0.30	0.12	0.07	0.37	2.71	0.01	0.19	0.05
CD (1%)	0.40	0016	0.09	0.50	3.60	0.02	0..26	0.07

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

Table 5: Summary of GCA effects of the parents for different characters in tomato

Parents	FPP	TSS	L	AAC	APC	PSR	SAR	TA
Females (Lines)								
NTL-1	A	P	P	P	G	G	G	P
NTL-50	P	G	P	P	P	P	G	P
JTL-12-04	G	P	P	G	P	G	P	P
JTL-12-10	G	G	G	P	G	P	P	G
JTL-12-11	A	G	G	G	P	P	P	G
JTL-12-12	G	P	G	G	A	G	A	G
JTL-12-14	P	G	G	G	P	P	G	P
Males (Testers)								
GT-1	P	G	P	G	P	P	G	G
GT-2	P	P	G	G	P	G	P	P
JT-3	G	G	G	G	P	P	G	G
AT-3	G	P	P	P	G	G	P	P

Whereas,
G = good parent having significant GCA effects in desirable direction
A = average parent having either positive or negative but not significant effects
P = poor parent having significant for undesirable GCA effects

Table 6: Best parents, good general combiners and best specific crosses for different characters in tomato

Sr. no.	Characters	Best parents for *per se* performance		Best general combiners		Best specific cross	
		Parents	*Per se* performance	Parents	GCA effects	Crosses	SCA effects
1	FPP	JTL-12-11	4.30 kg	JTL-12-12	1.55**	NTL-1 × AT-3	3.20**
2	TSS	JTL-12-10	2.10%	NTL-50	-0.81**	JTL-12-12 × JT-3	-0.85**
3	L	JTL-12-12	5.15 mg	JTL-12-14	1.05**	JTL-12-11 × GT-1	2.07**
4	AAC	JT-3	14.94 mg	JTL-12-14	1.42**	JTL-12-12 × GT-1	8.98**
5	APW	JTL-12-12	163.82 g	JTL-12-10	43.42**	NTL-1 × AT-3	65.91**
6	PSR	JTL-12-04	1.10	NTL-1, JTL-12-04	0.15**	JTL-12-04 × GT-2	0.37**
7	SAR	GT-1	6.7	GT-1	-0.53**	JTL-12-10 × AT-3	-2.42**
8	TA	GT-2	7.08%	JTL-12-11	0.66**	NTL-1 × JT-3	1.63**

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

Whereas,
FPP: Fruit yield per plant (kg)
TSS: Total soluble solids
L: Lycopene (mg per 100 g)
AAC: Ascorbic acid content (mg per 100 g)
APC: Average pulp content (g)
PSR: Pulp: Skin ratio
SAR: Solid: Acid ratio
TA : Titrable acidity (%)

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