Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 2044-2049
Received: 22-10-2020
Accepted: 02-12-2020

Saurabh Singh
Research Scholar, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Anand Kumar Singh
Professor, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

BK Singh
Professor, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Vaibhav Singh
Assistant Professor, Faculty of Agriculture Sciences, Mahatma Gandhi Kashi Vidyapith, Varanasi, Uttar Pradesh, India

Kumari Shikha
Research scholar, Department of Genetics and Plant Breeding, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Corresponding Author:
Anand Kumar Singh
Professor, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Line × tester analysis for yield and component traits in tomato (*Solanum lycopersicum* L.)

Saurabh Singh, Anand Kumar Singh, BK Singh, Vaibhav Singh and Kumari Shikha

Abstract
The present investigation aimed to estimate the general and specific combining ability variances and their effects for different quantitative characters in tomato. Line × Tester analysis including ten lines and five testers illustrated the preponderance SCA over GCA for all the traits studied. Based on desirable GCA effects, lines ToLcv-28, Pant T-5, Kashi Hemant and Kashi Amrit emerged out as good general combiner while, tester, H-86 for fruit yield quintal per hectare. High GCA for fruit yield quintal per hectare was associated with high fruit length, fruit width, days to 50 % flowering and plant height. Based on desirable SCA effects for fruit yield quintal per hectare, Pant T-5 × Selection-7, Pant T-5 × Punjab Barkha, Prestige × ToLcv-16, L-97/754 × Selection-7 and Roma × Tolcv-16 were marked as most promising crosses and recommended for further exploitation in the breeding program. The ratio of specific combining ability and general combining ability variance (σ^2_{SCA}:σ^2_{GCA}) was greater than unity, specifying non-additive genetic control for all studied traits. The above findings gesture towards the use of heterosis breeding as the key method for exploiting the available genetic variability in the pool of material studied.

Keywords: Component traits, *Solanum lycopersicum*, Tomato

1. Introduction
The cultivated tomato (*Solanum lycopersicum* var. *lycopersicum* L.; 2n = 2x= 24) is one of the most widely cultivated vegetable crops due to its wider adaptability, high yielding ability and enormous demand by consumers (Narasimhamurthy *et al*., 2013) [9]. Globally, India ranks second in the area as well as in the production of tomatoes after China. As per the third estimate of production statistics in India, 19397000 metric tons of tomatoes produced over 778000 hectare area in 2018-19 (*nhb.gov.in*). According to first advance estimate, the production of tomato in 2018-19 was estimated to be 3.8 % higher than that of the previous year. Meanwhile, it holds the fifth rank in crop value after maize, soybean, wheat and cotton (FAOSTAT, 2008) [2].

The cultivated tomato and its wild relatives originated from the Peruvian and Ecuadorian regions of South America (Peralta and Spooner, 2006; and Razifard *et al*., 2020) [11, 13]. It is an excellent crop model in reference to genetics, genomics and breeding; also supplemented with important nutrients, including lycopene, β-carotene, flavonoids, Vitamin C as well and hydroxycinnamic acid derivatives. It is regarded as a nutritional powerhouse or protective food as compared to other vegetable crops (Saleem *et al*., 2013) [16]. Tomatoes are rich and cheaper sources of protein, phosphorus, iron, iodine, vitamin A, vitamin B, vitamin C, vitamin K and minerals like Ca, P and Fe. Lycopene pigment of tomato serve as powerful antioxidant as it protect living cells and other structures in the body from oxidative damage and maintain DNA integrity in white blood cells. Tomato is mainly consumed as a basic ingredient in various raw, cooked or processed forms like paste, puree, syrup, juice, ketchup and whole canned tomato etc. Tomato fruit is a very good appetizer and its soup is supposed to be a good antidote for patients enduring from constipation (Kalloo, 2001) [5].

India has an increasing trend of area and production of total tomatoes in last five years due to shifting of farmers to the cultivation of high valuable tomato vegetables. Despite that, the current level of productivity is falling short to meet the demand of rapidly growing population. To meet the progressive increase in the demand, hybrid vegetables are becoming very popular in urban and semi-urban areas of the country. Hybridization or heterosis breeding is considered as one of the tools that enable tomatoes to better cope with climate change, natural disasters, and disease outbreaks (Premalakshme *et al*., 2005) [12]. It is of great significance to study combining ability of the parents to discriminate good combiners from poor one.

For each trait the total genetic variability was partitioned into components, *i.e*. general combining ability (GCA) and specific combining ability (SCA) as defined by Sprague (1946) [19] and reciprocal effects as proposed by Griffing (1956) [4]. They explained that GCA effects were mainly result of additive type of gene action and SCA effects were result of non-additive (dominant or epistatic) gene action. Additionally, information concerning GCA and SCA enables the plant breeders to choose parental material and a suitable breeding procedure for maximum character amelioration.

2. Materials and methods

The experimental materials for the present investigation comprised of 15 genotypes which were selected based on their *per se* performance for various traits. From these 15 genotypes, 50 crosses were evolved in a Line x Tester (Kempthorne, 1957) [6] design with ten genotypes as female (lines) and five genotypes as male (testers). The characteristic features of the parents involved in this study are given in Table 2.1. All the crosses were produced by hand emasculation and pollination to avoid chances of contamination. The parents were crossed in Line × Tester mating design. A set of 115 experimental materials including 15 parents (10 lines and 5 testers) with their 50 F_1's and 50 F_2's were evaluated at Vegetable Research Farm (South Block), Department of Horticulture, Institute of Agricultural Sciences, B.H.U, Varanasi, Uttar Pradesh during *Rabi* season in Randomized Block Design with three replications during 2017-18, 2018-19 and 2019-20. Average monthly temperature and rainfall recorded from a weather station at B.H.U in Varanasi during the growing period in 2017-18, 2018-19 and 2019-20 presented in figure 2.1. Six traits were measured namely, fruit length (cm), fruit width (cm), plant height (cm), days to 50 % flowering, total soluble solids (TSS) and fruit yield quintal per hectare (q/ha). Each plot in a replication comprised of a five rows and each row of 3 m length spaced at 60 cm. Plant to plant distance of 60 cm was maintained by thinning. Recommended package and practice was followed equally for all the entries in order to raise a good crop. The GCA and SCA effects in combining ability analysis were estimated using model as described by Kempthorne (1957) [6].

2.1 Statistical analysis

The estimation of Analysis of variance (ANOVA), general combining ability (GCA) and the specific combining ability (SCA) including the variance and its contribution effects were performed with the help of software package AGD-R Version 5.0. The heterosis was reckoned over the mid-parent values (H %) hybrids using the formula as $H = 100 \times ((F_1 - MP)/MP)$, where F_1 = hybrid mean, and MP = mean of the parents.

3. Results and discussion

A combined ANOVA of combining ability effects of studied traits are presented in Table 3.1. The combined ANOVA depicted highly significant ($p \leq 0.01$) difference among treatments and their sub-source of variation (parents, crosses and parents vs. crosses) for all studied traits. The results revealed the existence of substantial variability among parents, crosses as well as parents vs. crosses for most of the traits. Similar results were reported by Mondal *et al*. (2009) [8]; Singh *et al*. (2014) [17] and Kumar *et al.* (2015) [7].

3.1 Line × Tester analysis

The test of significance of variances due to lines and tester against their interaction component (Line × Tester) exhibited that differences among lines and testers were significant for studied characters namely days to 50 % flowering, plant height, fruit length, fruit width, total soluble solids and fruit yield quintal per hectare. The interaction component (Line × Tester) was highly significant for all the traits studied except days to 50 % flowering and plant height (Table 3.1). Vekariya *et al*. (2019) [20] also reported highly significant difference for interaction component with respect to all traits in tomato. These result showed the pertinence of SCA indicating greater role of non-additive genetic variance in the inheritance of studied attributes.

3.2 Contribution to Total Variance

The proportional contributions to the total variance of crosses by lines, testers and their interaction as intervarietal hybrids (Line × Tester) is provided in table 3.2. Most significant contributions in the expression of all the traits observed in the intervarietal hybrids, thereafter the lines and testers, as there were the higher values of SCA variance for the traits. The intervarietal hybrids (Line × Tester) contributed the largest portion of the variance. The contribution of Line × Tester was above 70 % for all the studied traits except plant height. Subsequently, lines contributed more than the testers for all the traits. Ghobary and Ibrahim (2010) [3] also observed the similar finding in tomato.

3.3 General combining ability effects

General combining ability reflect genetic worth of the parental line for use in combination breeding. The line with high GCA effect for the character are expected to be more useful donors than those with poor GCA. GCA effects of all the parental lines and tester are summarized in table 3.3. Based on the GCA effects, parents used in the study were ranked (G= good general combiner, A= average general combiner and P= poor general combiner) given to each parents for various characters. An overall appraisal of GCA effects revealed that among parents Kashi Amrit emerged out as good general combiner for fruit length, fruit width, days to 50 % flowering and fruit yield per hectare while, line Pant T-5 observed as good general combiner for plant height, fruit length, fruit width and fruit yield quintal per hectare and Kashi Hemant for fruit length and fruit yield quintal per hectare. ToLcv-28 only good general combiner for fruit yield per hectare. Similarly, among testers, H-86 for fruit width and fruit yield quintal per hectare while, Tolcv-16 for plant height and TSS. EC- 620446 found as good combiner for plant height and fruit length. High GCA for fruit yield per hectare was found in ToLcv-28 followed by L-97/754 and Prestige genotype. This indicated high GCA effect of these genotypes was result of positive GCA effect fruit length, fruit width, days to 50 % flowering and plant height.

3.4 Specific combining ability effects

In context to findings of SCA effects, none of the hybrids manifested favourable SCA effect for all the traits (Table 3.4). Significant SCA effects in complimentary direction was observed in many crosses such as, for fruit length (13), fruit width (11), plant height (11), TSS% (10), days to 50% flowering (8) and fruit yield per hectare (12). This result getting support from the finding of Saleem *et al*. (2015) [15] and Akram *et al*. (2019) [1] in tomato. The estimates of SCA effects foster selection of hybrids with desirable transgressive segregants. The range of SCA effects for fruit yield quintal per hectare varied from 185.46 (Pant T-5 ×Selection-7) to 230.47 (Pant T-5 × Punjab Barkha). Thirty one hybrids showed significant SCA effects of which thirteen hybrids attributed towards positive direction for fruit yield quintal per hectare. Out of fifty crosses, the best five specific crosses were Pant T-5 × Punjab Barkha (230.48) followed by crosses Roma × H-86 (181.64), Prestige × ToLcv-16 (172.27), L-97/754 × Selection-7 (141.76) and Roma × ToLcv-16 (137.92) for fruit yield quintal per hectare (Table 3.4). The crosses having best specific combination for fruit yield quintal per hectare were obtained either through Pant T-5 × Punjab Barkha (good X poor) followed by crosses Roma × H-86 (poor X good), Prestige × ToLcv-16 (poor X poor), L-97/754 × Selection-7 (poor X poor) and Roma × ToLcv-16 (poor X poor) for fruit yield per hectare (Table 3.6). The best specific combination for fruit yield per hectare *viz*., Pant T-5 × Punjab Barkha recorded the desirable significant SCA effects for fruit length and fruit width. The second best cross *i.e*., Roma × H-86 had desirable significant SCA effects for fruit length, fruit width and plant height. Whereas, the third best cross Prestige × ToLcv-16 had significant SCA effects for fruit width and TSS. The forth best specific combination L-97/754 × Selection-7 had desirable significant SCA effects for fruit length, fruit width, plant height and TSS. The fifth best specific combination Roma×Tolcv-16 had desirable significant SCA effects for fruit length and fruit width.

3.5 GCA and SCA variance components

The understanding of nature and magnitude of fixable and non-fixable types of gene effects controlling the traits is fundamental in the interest of outlining an efficient and effectual breeding strategy to attain ultimate genetic improvement in tomato. The variance components and ratio of GCA and SCA effects are displayed in Table 3.5. As per estimates both additive and non-additive gene action was observed governing the studied traits. Although, there was a preponderance of σ^2_{sca} were found to be higher than σ^2_{gca} for all the traits. Ghobary and Ibrahim (2010) [3] also reported prevalence of non-additive gene action for all the studied traits suggesting that selection might not be made in the early generations and recurrent selection with periodic inter-crossing appeared to be the best method. The estimates of Additive variance (D) and dominance variance (H) at inbreeding coefficient (F) of 1, for different characters, showed that the relative magnitude for later was greater than former for all the traits studied. Further the estimate of average degree of dominance was in the range of over dominance for all studied traits (Table 3.5), which further substantiate the prevalence of non-additive genetic component. Similar findings have been observed by Solieman *et al*. (2013) [18] for the characters of plant height, total soluble solids, number of flowers per cluster and total fruits yield per plant. In contrast, Akram *et al*. (2019) [1] found predominance of non-additive gene action for all the traits excepting days to 50 % flowering. As non-additive variance is result of heterozygosity simple selection methods may not be effective due to its non-fixable inheritance.

Table 2.1: Parent collected from/Pedigree and characteristics of the experimental material

S. No.	Parents	Collected from	Salient features
Lines (Female)			
1	Punjab Chhuhara	ICAR-IIVR, Varanasi	Medium-Size, pear-shaped fruit and a high-yielding variety.
2	Prestige	ICAR-IIVR, Varanasi	Semi-indeterminate variety that bears flat round fruits.
3	L-97/754	ICAR-IIVR, Varanasi	Determinate, round shape fruit and a high-yielding variety.
4	Pant T-5	ICAR-IIVR, Varanasi	Determinate and round shape fruit.
5	Roma	ICAR-IIVR, Varanasi	Determinate, fruit in cluster and High TSS.
6	Kashi Amrit	ICAR-IIVR, Varanasi	Determinate and Fruits spherical. Suitable for cultivation in TLCV infested period developed through back cross pedigree selection, high yielding.
7	Kashi Hemant	ICAR-IIVR, Varanasi	This has been developed through pedigree selection from a cross combination Sel-18 x Flora Dade. The plants are determinate, fruits attractive red and round, weight varies from 80 to 85 g; yield 400-420 q/ha.
8	ToLcv-28	ICAR-IIVR, Varanasi	Determinate, medium size and red color fruit.
9	VRT-01	ICAR-IIVR, Varanasi	Determinate, medium size fruit and high lycopene content
10	PBB-2	ICAR-IIVR, Varanasi	Semi determinate, high ascorbic acid content and average fruit weight 40-50 gram.
Testers (Male)			
1	H-86	ICAR-IIVR, Varanasi	Determinate, dark green, fruit red spherical, medium size
2	ToLcv-16	ICAR-IIVR, Varanasi	Determinate, fruit in cluster and yield 350-450 q/ha.
3	Selection-7	ICAR-IIVR, Varanasi	Determinate, extremely early maturing, dwarf erect, with cut leave and synchronized clustered flowering bearing 15-20 fruits. Fruits are round, red, medium developed through modified pedigree method from a cross Pusa Early Dwarf × K-1 at HAU, Hisar.
4	Punjab Barkha	ICAR-IIVR, Varanasi	Determinate, medium size fruit and fruit in cluster.
5	EC- 620446	ICAR-IIVR, Varanasi	Semi determinate, fruit are round in shape and thick stem.
Check			
1	Pant T-3	ICAR-IIVR, Varanasi	Plants are semi-determinate with thick round and hairy stem and dark green foliage. Fruit are round, smooth and uniformed.

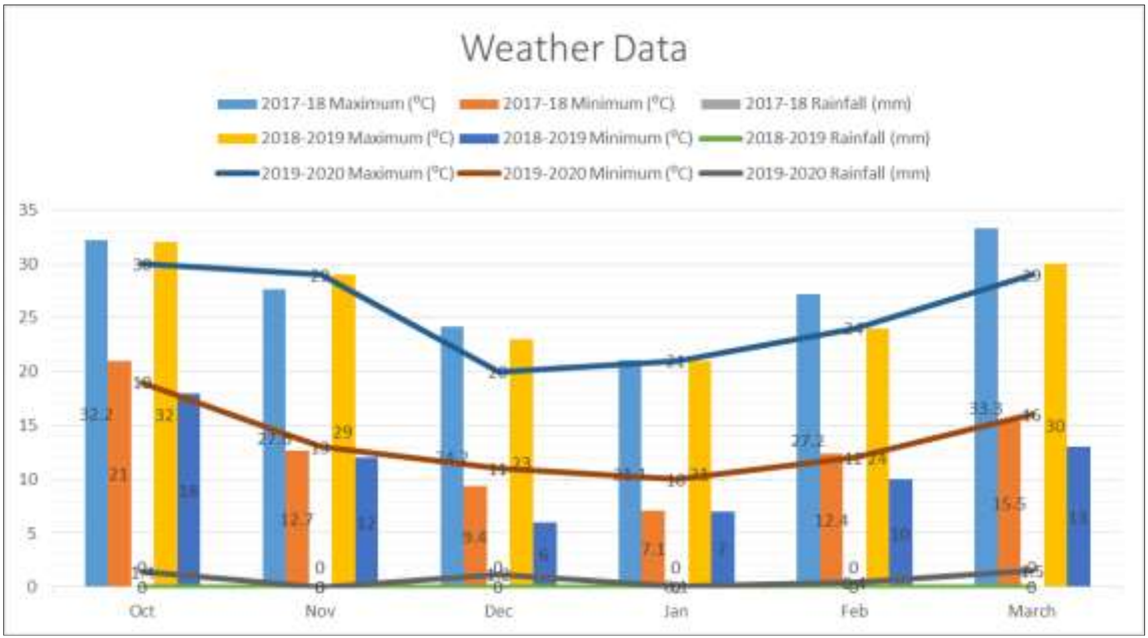

Fig 2.1: Average monthly temperature and rainfall recorded from a weather station at BHU in Varanasi during the growing period in 2018 and 2019

Table 3.1: Analysis of variance for the six attributes of tomato

Source of variation	D.F.	FL	FW	PH	DTF	TSS	FY
Replicates	1	61.054 **	22.714	2.856	0.623	0.072	26988.520 **
Treatments	64	97.841 **	103.320 **	391.619 **	6.532 **	0.531 **	20033.260 **
Parents	14	132.667 **	106.036 **	173.737 **	4.271 **	0.822 **	13895.680 **
Parents (Line)	9	158.917 **	99.882 **	116.904 **	4.006 *	1.031 **	17265.100 **
Parents (Testers)	4	35.910 **	116.681 **	343.454 **	5.600 *	0.365 **	3055.273 *
Parents (L vs T)	1	283.446 **	118.835 **	6.370	1.350	0.764 **	26932.500 **
Parents vs Crosses	1	16.287	98.917 *	249.129 **	0.021	5.203 **	131706.400 **
Crosses	49	89.556 **	102.635 **	456.779 **	7.310 **	0.353 **	19507.810 **
Line Effect	9	104.089	102.197	943.361 *	7.490	0.436	21212.050
Tester Effect	4	71.599	69.420	248.741	3.865	0.262	5347.501
Line * Tester Eff.	36	87.917 **	106.434 **	358.249 **	7.648 **	0.342 **	20655.120 **
Error	64	6.777	15.811	14.680	1.623	0.054	909.264
Total	129	52.377	59.280	201.597	4.051	0.291	10599.300

*, ** Significant at 5% and 1% level, respectively.
'FL': Fruit length, 'FW': Fruit width, 'PH': Plant height, 'DTF': 50% Flowering, 'TSS%': Total soluble solids and 'FY': Fruit yield quintal per hectare (q/ha)

Table 3.2: Contribution of lines, testers and their cross (Line × Tester) in the expression of studied attributes.

Traits	Line	Tester	Line * Tester
FL	21.35%	6.53%	72.13%
FW	18.29%	5.52%	76.19%
PH	37.93%	4.45%	57.62%
DTF	18.82%	4.32%	76.87%
TSS	22.68%	6.06%	71.26%
FY	19.97%	2.24%	77.79%

'FL': Fruit length, 'FW': Fruit width, 'PH': Plant height, 'DTF': 50% Flowering, 'TSS%': Total soluble solids and 'FY': Fruit yield quintal per hectare (q/ha)

Table 3.3: General combining ability (GCA) effect estimates of 15 parents for six attributes of tomato

Parents	Symbol	FL	FW	PH	DTF	TSS	FY
			Lines				
Punjab Chhuhara	L_1	-0.916	-1.824	-1.300	-0.231 **	0.470	-37.518 **
Prestige	L_2	-3.804 **	-3.087 *	-1.395	0.113	0.370	-60.086 **
L-97/754	L_3	-6.011 **	-3.746 **	2.854 *	0.176 *	0.070	-62.260 **
Pant T-5	L_4	2.954 **	3.436 **	6.475 **	-0.048	-0.030	53.526 **
Roma	L_5	0.356	1.510	-3.032 *	0.192 *	-0.330	-15.540
Kashi Amrit	L_6	2.813 **	4.858 **	-11.417 **	0.111	-1.730 **	33.544 **
Kasha Hemant	L_7	4.620 **	2.402	-11.894 **	-0.077	-0.630	37.506 **
ToLcv-28	L_8	1.369	1.777	-7.474 **	0.136	1.670 **	63.020 **
VRT-01	L_9	-1.497	-4.129 **	6.921 **	0.090	0.270	-22.103 *

PBB-2	L_{10}	0.115	-1.194	20.262 **	-0.461 **	-0.130	9.911
Testers							
H-86	T_1	1.160	1.989 *	-5.195 **	0.048	0.620 *	23.911 **
ToLcv-16	T_2	0.493	0.734	3.144 **	0.154 **	0.170	-4.893
Selection-7	T_3	-3.319 **	-2.997 **	0.127	0.003	-0.280	-20.157 **
Punjab Barkha	T_4	0.428	-0.291	-1.385	-0.155 **	-0.530	-5.213
EC- 620446	T_5	1.239 *	0.566	3.309 **	-0.049	0.020	6.353
CD (5%) GCA(Line)		1.654	2.527	2.435	0.147	0.810	19.162
CD (5%) GCA(Tester)		1.170	1.787	1.722	0.104	0.572	13.550

*, ** Significant at 5% and 1%, respectively.
'FL': Fruit length, 'FW': Fruit width, 'PH': Plant height, 'DTF': 50% Flowering, 'TSS%': Total soluble solids and 'FY': Fruit yield quintal per hectare (q/ha)

Table 3.4: Specific combining ability (SCA) effect estimates of 50 crosses for six attributes of tomato

Crosses	FL	FW	PH	DTF	TSS	FY
Punjab Chhuhara × H-86	2.678	1.952	4.681	0.367 *	1.180	4.825
Punjab Chhuhara × ToLcv-16	-2.505	-3.378	-6.757 *	0.016	1.130	-35.125
Punjab Chhuhara × Selection-7	8.002 **	7.963 **	-7.661 **	-0.068	-2.420 **	102.753 **
Punjab Chhuhara × Punjab Barkha	-4.945 **	-4.848	10.171 **	-0.470 **	-1.670	-73.031 **
Punjab Chhuhara × EC-620446	-3.231	-1.690	-0.433	0.154	1.780	0.578
Prestige × H-86	-2.189	-2.330	19.871 **	0.110	-2.220 *	-2.864
Prestige ×ToLcv-16	2.808	5.770 *	-13.383 **	0.883 **	0.730	172.268 **
Prestige × Selection-7	0.685	0.501	4.354	-0.465 **	2.180 *	-57.826 **
Prestige × Punjab Barkha	-1.657	-3.115	-0.634	-0.053	1.430	-68.326 **
Prestige ×EC- 620446	0.352	-0.827	-10.208 **	-0.474 **	-2.120 *	-43.251 *
L-97/754 × H-86	-4.017 *	1.629	-11.889 **	-0.813 **	1.080	-7.624
L-97/754 × Tolcv-16	-4.575 *	-1.946	-18.752 **	-0.325	-1.970 *	-59.758 **
L-97/754 × Selection-7	6.102 **	8.345 **	6.310 *	0.677 **	2.480 **	141.756 **
L-97/754 × Punjab Barkha	4.780 *	-0.001	1.607	0.569 **	-1.770	-50.004 *
L-97/754 × EC- 620446	-2.291	-8.028 **	22.723 **	-0.107	0.180	-24.369
Pant T-5 × H-86	2.563	4.787	-5.989 *	0.306	1.680	-14.757
Pant T-5 × ToLcv-16	4.670 *	3.277	-12.513 **	0.114	-0.370	-17.381
Pant T-5 × Selection-7	-9.788 **	-12.767 **	23.484 **	-0.585 **	2.080 *	-185.467 **
Pant T-5 × Punjab Barkha	11.770 **	13.152 **	-12.204 **	0.113	-0.170	230.475 **
Pant T-5 × EC- 620446	-9.216 **	-8.450 **	7.222 *	0.052	-3.220 **	-12.870
Roma × H-86	9.256 **	7.398 *	6.943 *	0.056	0.980	181.639 **
Roma ×Tolcv-16	6.023 **	6.878 *	2.675	-0.226	-0.570	137.922 **
Roma × Selection-7	-1.415	-0.806	-3.529	0.171	-1.620	-23.576
Roma × Punjab Barkha	-7.012 **	-8.462 **	-2.197	-0.467 **	-0.370	-170.520 **
Roma × EC- 620446	-6.853 **	-5.009	-3.891	0.467 **	1.580	-125.464 **
Kashi Amrit × H-86	-2.136	-3.820	1.498	0.042	2.880 **	-17.296
Kashi Amrit × Tolcv-16	-2.049	-4.430	-8.926 **	-0.115	-1.170	-56.771 *
Kashi Amrit × Selection-7	-8.342 **	-8.589 **	-1.554	-0.469 **	-1.720	-67.489 **
Kashi Amrit × Punjab Barkha	2.326	4.705	6.688 *	0.364 *	1.530	19.180
Kashi Amrit × EC- 620446	10.200 **	12.133 **	2.294	0.178	-1.520	122.376 **
Kashi Hemant × H-86	-1.833	-3.234	4.975	0.488 **	0.780	-12.867
Kasha Hemant × Tolcv-16	8.004 **	8.496 **	-3.164	-0.108	-0.270	-68.070 **
Kashi Hemant × Selection-7	1.566	0.532	-1.547	0.093	0.180	51.804 *
Kashi Hemant × Punjab Barkha	-8.316 **	-8.484 **	0.865	0.066	-1.070	-15.509
Kashi Hemant × EC- 620446	0.578	2.689	-1.129	-0.540 **	0.380	44.642 *
ToLcv-28 × H-86	1.343	-0.844	-2.346	-0.239	-4.520 **	-30.201
ToLcv-28 × ToLcv-16	-6.945 **	-8.494 **	38.817 **	-0.140	0.930	19.669
ToLcv-28 × Selection-7	-1.898	-0.508	-17.267 **	0.112	0.380	-15.221
ToLcv-28 × Punjab Barkha	-4.895 *	-3.864	-12.655 **	-0.116	0.130	-53.638 *
Tolcv-28 × Ec- 620446	12.394 **	13.709 **	-6.549 *	0.383 *	3.080 **	79.391 **
VRT-01 × H-86	0.064	-0.608	-6.540 *	-0.429 *	0.380	-73.922 **
VRT-01 × Tolcv-16	-0.984	-2.283	26.822 **	-0.100	-0.170	-48.084 *
VRT-01 × Selection-7	7.028 **	7.998 **	-5.487 *	0.066	-2.220 *	132.877 **
VRT-01 × Punjab Barkha	0.186	2.907	-5.050	0.109	1.030	61.002 **
VRT-01 × EC- 620446	-6.295 **	-8.015 **	-9.744 **	0.353 *	0.980	-71.873 **
PBB-2 × H-86	-5.733 **	-4.928	-11.202 **	0.113	-2.220 *	-26.932
PBB-2 × Tolcv-16	-4.446 *	-3.893	-4.820	0.001	1.730	-44.670 *
PBB-2 × Selection-7	-1.939	-2.672	2.897	0.468 **	0.680	-79.609 **
PBB-2 × Punjab Barkha	7.759 **	8.007 **	13.409 **	-0.115	0.930	120.371 **
PBB-2 × EC- 620446	4.358 *	3.485	-0.285	-0.466 **	-1.120	30.841
CD (5%) SCA	3.699	5.650	5.444	0.329	1.810	42.848

*, ** Significant at 5% and 1% level, respectively.
'FL': Fruit length, 'FW': Fruit width, 'PH': Plant height, 'DTF': 50% Flowering, 'TSS%': Total soluble solids and 'FY': Fruit yield quintal per hectare (q/ha)

Table 3.5: Estimates of genetic component of variance (additive and dominance variance), combining ability, degree of dominance and predictability ratio for respective traits in tomato

Characters	Genetic component of variance (F=1)		Degree of dominance (F=1)	Combining ability variance		Predictability ratio
	Additive (D)	Dominance (H)		GCA variance	SCA variance	
FL	0.541	3.013	2.361	0.270	3.013	0.152
FW	77.516	171.784	1.489	38.758	171.784	0.311
PH	10.809	40.570	1.937	5.404	40.570	0.210
DTF	9.333	45.312	2.203	4.667	45.312	0.171
TSS	0.039	0.144	1.915	0.020	0.144	0.214
FY	1649.401	9872.929	2.447	824.701	9872.929	0.143

Table 3.6: Prospective cross combinations based on per se performance, desirable GCA and SCA effects for fruit yield per hectare in tomato.

Cross combinations	Per se performance (q/ha)	GCA effect of combining parent	SCA effects	Other characters with significant SCA effects
Pant T-5×Punjab Barkha	744.94	(G) 53.53**X-5.213(P)	230.48**	FL, FW
Roma × H-86	656.17	(P) -15.54X23.91**(G)	181.64**	FL, FW, PH
Prestige × ToLcv-16	573.45	(P) -60.09**X-4.90(P)	172.27**	FW
L-97/754 × Selection-7	525.50	(P) -62.26**X-20.16**(P)	141.76**	FL, FW, PH, TSS
Roma × ToLcv-16	583.65	(P) -15.54X-4.90(P)	137.92**	FL, FW

4. References

1. Akram A, Khan TN, Minhas NM, Nawab NN, Javed A, Rashid S, *et al*. Line× tester analysis for studying various agronomic and yield related traits in field tomato (*Solanum lycopersicum* L.). Pakistan Journal of Botany 2019;51(5):1661-1665.
2. FAOSTAT. Production – Crops – Area harvested/ Production quantity – Tomatoes, FAO Statistics online database, Food and Agriculture Organization, Rome 2008. www.fao.org/faostat/en.
3. Ghobary HMM, Ibrahim KY. Combining ability and heterosis for some economic traits in tomato (*Lycopersicon esculentum* MILL.). Journal of Plant Production 2010;1(5):757-768.
4. Griffing BA. Generalized treatment of the use of diallel crosses, in quantitative inheritance Heredity. Australian Journal of Biological Sciences 1956;10(1):31-50.
5. Kalloo G, Banerjee MK, Tewari RN, Pachauri DC. Tomato. In: Thamburaj S., Singh, N (Eds.) Text book of vegetables, tuber crops and spices. Indian Council of Agricultural Research, New Delhi, India, 2001, 10-29.
6. Kempthorne O. An introduction to genetics statistic, John Wiley and Sons, Inc. New York, 1957, 468-471.
7. Kumar R, Singh SK, Srivastava K, Singh RK. Genetic Variability and Character Association for Yield and Quality Traits in Tomato (*Lycopersicon Esculentum* Mill). *Agriways* 2015;3(1):31-36.
8. Mondal C, Sarkar S, Hazra P. Line× Tester analysis of combining ability in tomato (*Lycopersicon esculentum* Mill.). Journal of Crop and Weed 20095;(1):53-57.
9. Narasimhamurthy YK, Gowda PHR. Line× tester analysis in tomato (*Solanum lycopersicum* L.): identification of superior parents for fruit quality and yield attributing traits. International Journal of Plant Breeding 2013;7(1):50-54.
10. National Horticulture Board. Ministry of Agriculture, Government of India. Website: http://nhb.gov.in/, 2018, 384-412.
11. Peralta IE, Spooner DM. History, origin and early cultivation of tomato (Solanaceae). Genetic Improvement of Solanaceous Crops 2006;2:1-27.
12. Premalakshme V, Thangaraj T, Veeraragavathatham, Arumugam T. Heterosis and combining ability in tomato, Vegetable Sciences 2005;32(1):47-50.
13. Razifard H, Ramos A, Della Valle AL, Bodary C, Goetz E, Manser EJ, *et al*. Genomic evidence for complex domestication history of the cultivated tomato in Latin America. Molecular Biology and Evolution 2020;37(4):1118-1132.
14. Rodriguez F, Alvarado G, Pacheco A, Crossa J, Burgueno J. AGD-R (Analysis of Genetic Designs with R for Windows) Version 5.0, hdl: 11529/10202. CIMMYT Research Data and Software Repository Network 2015, 13
15. Saleem MY, Akhtar KP, Iqbal Q, Asghar M, Shoaib M. Development of high yielding and blight resistant hybrids of tomato. Pakistan Journal of Agricultural Sciences 2015;52(2):293-295.
16. Saleem MY, Asghar M, Iqbal Q. Augmented analysis for yield and some yield components in tomato (*Lycopersicon esculentum* Mill.), Pakistan Journal of Botany 2013;45(1):215-218.
17. Singh BK, Singh AK, Yadav SK, Vani MV, Kumar H, Rajkumar BV. Combining ability for yield and quality attributes in tomato (*Lycopersicon esculentum* MILL). Annals of Agri-Bio Research 2014;19(3):479-482.
18. Solieman THI, El-Gabry MAH, Abido AI. Heterosis, potence ratio and correlation of some important characters in tomato (*Solanum lycopersicum* L.). Scientia Horticulturae 2013;150:25-30.
19. Sprague GF, Tatum LA. General versus specific combining ability in single crosses of corn. Journal of the American Society of Agronomy 1942;34(10):923-932.
20. Vekariya TA, Kulkarni GU, Vekaria DM, Dedaniya AP, Memon JT. Combining Ability Analysis for Yield and its Components in Tomato (*Solanum lycopersicum* L.) Acta Scientific Agriculture 2019;3(7):185-191.
21. Hosamani RM. Biometrical and transformation studies in tomato (*Solamum lycopersicum* L.) (Doctoral dissertation, UAS Dharwad) 2010, 114-152.