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Examining the general and specific combining ability by line × tester analysis for yield and quality attributes in Tomato (*Solanum lycopersicum* L.)

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ABSTRACT: Tomato being one of the popular nutritious vegetable, it's low productivity and quality can affect producers as well as consumers. To cope up with the present day need, there is need for continuous evaluation of potential parents and hybrids with improved quality and yield traits. Thus the present investigation was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi during *Rabi* season of 2017-18 and 2018-19 to analyze the general and specific combining ability of eleven genotypes of tomato (*Solanum lycopersicum* L.) using Line × Tester analysis. The experimental material was evaluated in RBD with three replications under study. Combining ability analysis is a potential tool for the evaluation of inbreds in terms of their genetic value. The information pertaining to GCA and SCA effect thus help for identifying suitable parents as well as for identifying desirable cross combinations respectively for breeding program. It was revealed from the analysis that the mean sum of squares due to Line × Tester were found significant for all traits excluding days to 50 % flowering indicating the presence of variability for exploitation for remaining traits under study. In the present investigation for early flowering, parental genotypes CO-3 (-1.96) followed by VRT-101-A (-1.85) and Angha (-1.29) were noted to be good general combiner showing maximum significant values of GCA in the desirable direction. Among the lines, CTS-07 was found to be good general combiner for days to 50 % flowering, number of primary branches per plant, fruit length, fruit width, average fruit weight, fruit yield qper hectare, number of seeds per fruit and number of locules per fruit. Only one cross CTS-07 × Arka Abha showed significantly negative SCA effect and thus was reported to have best specific combining ability for days to 50 % flowering. Similarly for total fruit yield, parent Angha, Solan Vajra and CTS-07 were found to be good general combiners exhibiting higher values for positive and significant GCA to the extent of 41.16, 39.12 and 37.93 respectively.

Keywords: Tomato, Line × Tester, Parents, General combiner, Breeding, Fruit yield.

INTRODUCTION

Vegetables are the cornerstone for a healthy diet because of their rich content in vitamins, minerals, phytochemical compounds, and dietary fiber. Consumption of vegetables with improved quality has now become very essential as a strategy for enhancing nutritional status of people. Tomato (*Solanum lycopersicum* L.) is an important day- neutral vegetable crop for the growers, consumers, as well as processing industries. Globally, tomato is recognized as the second most important vegetable crop after potato. The tomato production is over 180 million tons globally from an area of 5.03 million hectares. The cleistogamous flower makes tomato a highly self-pollinated crop. Although early domestication occurred in both the Andean region and Mexico, but presently Bolivia, Chile, Ecuador, the Galapagos Islands and Peru together are believed to constitute the centre of origin and distribution of tomatoes. Tomato is a diploid with chromosome number 24 and its size of genome approximately 950 Mb in size (Brake *et al*., 2022). It has got wider adaptability, high productivity potential and suitable for various processed product. Due to public awareness about its nutritional and therapeutic benefits, it has gained in commercial relevance and demand year round production (Pattnaik *et al*., 2020). Tomato has high nutritive and medicinal values containing many health-beneficial bioactive compounds and therefore can be easily integrated as a nutritious part of a balanced diet (Marti *et al*., 2016). These bioactive compounds have a wide range of physiological properties, including anti-inflammatory, antithrombotic, cardio-protective, anti-allergenic, antimicrobial, and antioxidant effects. Heterosis in case of tomato was first observed for higher yield and more number of fruits by Hedrick and Booth (1907). One of the goals while estimating heterosis is to assess the hybrid vigor for selecting promising hybrids. Tremendous progress has been achieved with regards to enhanced yield and other quality components of tomato after following hybrid vigour (Ahmad *et al*., 2011). But there is a continuous need to strengthen the crop improvement programme in tomato by developing new hybrids satisfying to the present day needs and ultimately identifying good general and specific combiners that is necessary for the development of improved tomato hybrids. Selecting suitable parents in any plant-breeding program is one of the most important decisions to be made by the breeders. In breeding, the relative capacity of a genotype to transmit or impart genetic superiority to its progeny when crossed with other individuals is known as combining ability (Kathimba *et al*., 2022). The GCA and SCA values rely on the gene structure of the parents involved in the crossing as well as the gene effects (Javed *et al*., 2022). Combining ability analysis helps in providing reliable information for selecting parents to form different hybrid combination by revealing the nature and magnitude of gene actions involved in expression of quantitative traits (Agarwal *et al*., 2017). GCA is an expression of the additive genetic effects that indicates the average effect that a line gives to its crosses whereas SCA ascertains non-additive genetic effects. Considering this pressing priority, the present investigation was undertaken including diverse genotypes of tomato to identify the good general combiners and best parental combination for different traits in tomato.

MATERIALS AND METHODS

For the present investigation to examine the combining ability of inbreds for different yield and quality traits in tomato, eleven diverse genotypes of Tomato (*Solanum lycopersicum* L.) in which eight lines namely CTS- 07, Angha, Solan Vajra, VRT-101-A, VRT-01, CO-3, VRT-06, H-88-78-1 and three testers namely Arka Abha, Pusa-120, Pant-T5 were used. The experimental material needed for the research were collected from Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Twenty four F_1hybrids were generated through Line × Tester mating design during *Rabi* seasons of 2017-18 and 2018-19. Observations were recorded for assessing best general and specific combiners in parameters like days to 50% flowering, plant height (cm), number of primary branches per plant, average fruit weight (g), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, fruit length (cm), fruit width (cm), number of seeds per fruit, number of locules per fruit, pericarp thickness (mm), total soluble solids (ºBrix), ascorbic acid content (mg/100g of edible fruit) and fruit yield (q/ha). The replication wise mean data was used for statistical analysis. The experiment was carried out in Randomized Complete Block Design with three replications under study. All the standard cultural practices and plant protection methods were undertaken both the seasons to raise a successful tomato crop. The analysis of variance(ANOVA) for RBD was estimated crosswise according to Panse and Sukhtame (1954). The Line × Tester approach given by Kempthorne (1957) is one of the most appropriate methods for screening the material for combining ability.

RESULT AND DISCUSSION

Combining ability analysis is a potential tool for the evaluation of inbreds in terms of their genetic value and for the selection of suitable parents for hybridization. It also helps in identifying superior cross combination which may be utilized in breeding programmes for commercial exploitation of heterosis. The analysis of variance for combining ability are demonstrated in Table 1 and 2. The lines and testers recorded substantial variability for all traits. The total genetic variance is divided into GCA which is associated with additive gene action and SCA variance indicating non-additive gene action. The mean sum of squares due to lines were significant for all traits except for number of primary branches per plant, number of fruit clusters per plant, pericarp thickness, number of locules and ascorbic acid content. The mean sum of squares due to tester were significant for all characters except days to 50% flowering, number of primary branches per plant, fruit length, fruit width, number of locules, pericarp thickness and ascorbic acid content. However, the mean sum of squares due to Line × Tester were found significant for all traits excluding days to 50% flowering indicating the presence of variability for exploitation.

These estimates indicated considerable variation in lines, testers and lines *vs.* testers. These results were found to be similar to that of investigation done by Kumari and Sharma (2011); Agarwal *et al*. (2014); Meena *et al*. (2015); and Izzo *et al*. (2022) for number of locules, ascorbic acid and total soluble solids. Yadav *et al*. (2013) reported similar results from the ANOVA of combining ability analysis.

Table 1: Analysis of variance of combining ability days to 50% flowering, plant height (cm), number of primary branches per plant, fruit length (cm), fruit width (cm), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant for in tomato.

Sources of variation	DF	Days to 50% flowering	Plant height(cm)	No. of primary branches per plant	Fruit length(cm)	Fruit width(cm)	No. of fruit clusters per plant	No. of fruits per cluster	No. of fruits per plant
Replicates	2	0.056	4.995	0.011	0.024	0.018	0.015	0.148	0.893
Crosses	23	9.941 **	2043.758**	1.030 **	0.859 **	0.900 **	6.998**	2.045 **	123.797**
Line Effect	7	27.109 **	2700.544 *	1.538	1.928 **	2.500 **	9.318	3.426 **	283.849**
Tester Effect	2	0.514	9499.208**	2.174	0.432	0.261	6.855**	7.188 **	41.727**
Line * Tester Eff.	14	2.704	650.302 **	0.612 **	0.386 **	0.192 **	5.859**	0.621 **	55.495 **
Error	46	2.041	1.474	0.05	0.021	0.015	0.294	0.043	0.606
Total	71	4.544	663.158	0.366	0.293	0.302	2.458	0.694	40.521
*Significant at p=0.05, **Significant at p=0.01									

Table 2: Analysis of variance of combining ability for average fruit weight (g), number of seeds per fruit, number of locules per fruit, pericarp thickness (mm), total soluble solids (ºBrix), ascorbic acid content (mg/100g of edible fruit) and fruit yield (q/ha) in tomato.

Sources of variation	DF	Avg. fruit weight(g)	No. of seeds per fruit	No. of locules per fruit	Pericarp thickness (mm)	TSS(◦Brix)	Ascorbic acid content (mg/100g of fruit)	Fruit yield(q/ha)
Replicates	2	4.057	2.03	0.045	0.03	0.038	0.32	5.018
Crosses	23	551.503**	2040.453**	1.081 **	1.968 **	0.780 **	9.194 **	11983.830 **
Line Effect	7	1387.869**	4195.343**	1.653	3.104	1.048 **	11.135	15802.05 **
Tester Effect	2	386.362	4149.087 *	0.635	1.532	1.07 **	9.437	7151.715 **
Line * Tester Eff.	14	156.912**	661.776 **	0.858 **	1.463 **	0.604 **	8.188 **	10765.030 **
Error	46	2.175	2.799	0.04	0.014	0.027	2.283	35.112
Total	71	180.179	662.863	0.377	0.647	0.271	4.466	3904.977

After examining the data obtained for GCA of parents for all traits, it was revealed that many of the parental lines were good general combiner for the traits under study. But none of the parent was found to be a good general combiner for all the traits under study. The perusal of data on SCA effect of the cross combinations revealed that no particular crosses were consistently superior for all the traits under investigation. The values obtained after the analysis of GCA of lines and testers and SCA effects of the crosses for all traits are indicated in Table 3, 4, 5, 6.

Since earliness is preferred over late flowering, negative values of GCA and SCA are considered desirable for this character. Out of 11 parents, four parents showed significant negative GCA effects for this trait. Maximum GCA effect was observed in parent CO-3 (-1.96) followed by VRT-101-A (-1.85) and Angha (-1.29); thus were presumed to be good general combiner for this trait. Based on SCA values, only one cross CTS-07 × Arka Abha (-2.09) showed significantly negative SCA effect and thus was reported to be the best specific combiner for this trait. Similar results were observed for early flowering by Agarwal *et al*. (2017); Kathimba *et al*. (2022); and Negi *et al*. (2022).

Positive values of GCA is considered desirable in case of plant height. The range of GCA for the trait ranged from -15.23 (VRT-01) to 33.98 (VRT-101-A). The top three parents showing positive significant GCA were VRT-101-A (33.98), CO-3 (18.01) and Pusa-120 (22.92) as depicted in table.2.1.Among the crosses, Solan Vajra × Pant T-5 (23.11) followed by Angha × Pusa-120 (19.69) and CTS-07 × Pusa-120 (17.38) proved to be good specific combiner for this trait exhibiting high significant positive SCA effects in the desired direction. In case of the number of primary branches per plant, general combining ability for the parents varied from -0.56 (VRT-01) to 0.72 (CO-3). The parental genotypes CO-3 (0.72) followed by CTS-07 (0.33) and Angha (0.24) were found to be good combiner exhibiting significantly positive GCA effects for the trait. Similarly, the SCA values in the resulting crosses ranged from -0.62 (Angha × Pusa-120) to 0.78 (Angha × Pant T-5). Maximum significant positive value of SCA effect was noted for the cross Angha × Pant T-5 (0.78) followed by CTS-07 × Pusa-120 (0.49) and VRT-101-A × Arka Abha (0.46); which were assumed to be best specific combiners for the trait. Similar findings for higher plant height and number of primary branches per plant has been reported by Agarwal *et al*. (2017); Das *et al*. (2020); and Negi *et al*. (2022) that indicated involvement of both additive and non-additive gene action.

Fruit length, fruit width, number of fruit clusters per plant, number of fruits per cluster and number of fruits per plant are important attributes directly affecting productivity of crop. The GCA for parents in case of fruit length ranged from -1.00 (H-88-78-1) to 0.50 (Angha). Parent Angha (0.51) followed byCTS-07 (0.45) and VRT-06 (0.15) exhibited significant positive GCA effect; thus were recognized as good general combiner for the trait. As far as SCA values are concerned, seven hybrids were found to show positive significant specific combining ability. Cross Angha × Pusa-120 (0.52) proved to be best specific combiner with maximum significant positive value for SCA effect followed by cross VRT-06 × Arka Abha (0.48) and VRT-101-A × Pant T-5 (0.35) for the trait. In case of fruit width, parents CTS-07, VRT-101-A and Angha were presumed to have good general combining ability for this character that recorded maximum significant positive values of GCA effect to the extent of 0.61, 0.46and 0.22 respectively. By observing the SCA values, the top three hybrids which were found to be good specific combiner for the trait were Angha × Pusa-120 (0.43) followed by VRT-06 × Arka Abha (0.33) and VRT-01 × Pant T-5 (0.28). Considering the number of fruit clusters per plant, parent VRT-101-A (1.17) was noted to be good general combine rexpressing maximum positive significant value of GCA effect followed by genotype VRT-06 (1.09) and Pusa-120 (0.56) for the trait. Considering the values of SCA effect in the crosses for the trait, cross VRT-01 × Pusa-120 (2.49) exhibited maximum positive significant specific combining effect for the trait followed by Angha × Pant T-5 (1.31), Solan Vajra × Pant T-5 (1.11). In case of number of fruits per cluster, the range of general combining ability effect lied between -072 (CTS-07) to 1.01 (VRT-01). In order of merit, parent VRT-01, CO-3 and Arka Abha were found to have good general combining ability with maximum significant positive GCA values of 1.01, 0.71 and 0.52 respectively for the trait. Similarly, the values of SCA effect depicted that cross combinationH-88-78-1 × Arka Abha (0.68) followed by Solan Vajra × Arka Abha (0.54) and CTS-07 × Pant T-5 (0.51) were good combiners for this trait. For number of fruits per plant, only four out of 11 parents namely H-88-78-1 (8.44), CO-3 (7.75), Arka Abha (1.11) and Angha (0.67) recorded positive significant GCA effect; thus were found to be good general combiner for this trait. Regarding the SCA values of the crosses, ten out of 24 hybrids exhibited significantly positive SCA values. The top three hybrids which were found to have good significant positive specific combining ability were H-88-78-1 × Pusa-120 (5.06) followed by Solan Vajra × Arka Abha (4.95) and VRT-06 × Pusa-120 (4.41) for the trait.The findings of following workers were found similar with the present resultKumari and Sharma(2011); and Akshay *et al*. (2012). These results were also in conformity with the works of Singh *et al.* (2010); Farzane *et al.* (2012); Agarwal *et al*. (2017); Shakil *et al*. (2017); and Umesh and Patil (2021).

In case of average fruit weight, eight out of 11 genotypes showed significant positive values of GCA in the desired direction. Highest GCA values was recorded for VRT-101-A (10.57) followed by VRT-01 (10.26) and VRT-06 (7.50) for the trait. The values of SCA effect in the crosses showed that only eight F_1 hybrids expressed positive significant SCA effects. The cross combination VRT-01 × Arka Abha (13.36) followed by Angha × Pant T-5 (10.21) and Solan Vajra × Pusa-120 (8.66) in order of merit recorded significantly positive SCA effect for this trait. These results were also similar to the works by Singh and Asati (2011); Farzane *et al*. (2012); Agarwal *et al*. (2017); and Umesh and Patil (2021).

As far as GCA values for number of seeds per fruit are concerned, seven genotypes out of 11 parents were reported to exhibit positive significant GCA. Highest values of significant GCA for parent was observed in VRT-01 (28.56), Pusa-120 (14.72) and Solan Vajra (9.99) which were identified as good general combiner. Considering the SCA values of the crosses for this trait, cross VRT-01 × Pusa-120 (23.99) exhibited superior significant positive specific combining ability followed by H-88-78-1 × Arka Abha (17.84) and CO-3 × Pant T-5 (14.84) for the trait. For number of locules per fruit, five genotypes among all the parents were found to exhibit significantly positive values of GCA.

Considering the values of GCA effect of the parents for this trait, the top three parental genotypes that proved to be good general combiners with maximum positive values of significant GCA were Angha (0.55) followed by VRT-101-A (0.37) and CTS-07 (0.26) for the trait. Out of 24 crosses, VRT-101-A × Arka Abha (0.81) expressed highest significant positive SCA value followed by VRT-06 × Pusa-120 (0.74) and H-88-78-1 × Arka Abha (0.43);thus were identified to have good specific combining ability for number of locules per fruit. In case of pericarp thickness, five out of 11 parents showed positive significant GCA effect for this trait. Maximum GCA values were observed for the parental genotypes VRT-06 (1.03) followed by H-88-78-1 (0.45) and Pusa-120 (0.27). As far as SCA values of crosses for pericarp thickness are concerned, 12 F_1 hybrids were found to have good specific combining ability. In order of merit, cross Solan Vajra × Pant T-5 (0.93) followed by H-88-78-1 × Pant T-5 (0.61) and VRT-01 × Pusa-120 (0.56) expressed maximum positive value of significant SCA for this trait. Study conducted by Kumar *et al*. (2018); Umesh and Patil (2021) have also shown the similar results for number of locules as well as pericarp thickness.

Analysing the values of GCA effect of parents for total soluble solids, highest value of significant GCA effect was exhibited by parent CO-3 (0.34) followed by Solan Vajra (0.26) and Pusa-120 (0.19) which were considered to have good general combining ability for this trait. Similarly observing the SCA values of the crosses, maximum positive value for SCA was recorded for cross VRT-101-A × Arka Abha (0.58) followed by CTS-07 × Pusa-120 (0.57**)** and Solan Vajra × Arka Abha (0.39) for this trait. The values of GCA effect for ascorbic acid content ranged from -1.21 (VRT-06) to 2.30 (Angha). Only two out of the eleven parents namely Angha (2.30) and Pusa-120 (0.66) showed positive significant values of GCA; thus were identified as good general combiner for this trait. The value of SCA effect for this trait varied from -2.39 (VRT-01 × Pant T-5) to 3.02 (VRT-01 × Arka Abha).

Table 3: Estimates of general combining ability (GCA) effect of parents for days to 50% flowering, plant height (cm), number of primary branches per plant, fruit length (cm), fruit width (cm), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, in tomato.

Lines	Days to 50 % flowering	Plant height (cm)	No. of primary branches per plant	Fruit length (cm)	Fruit width (cm)	No. of fruit clusters per plant	No. of fruits per cluster	No. of fruits per plant
CTS -07	-1.07 *	-4.43 **	0.33 **	0.45 **	0.61 **	-1.91**	-0.72 **	-0.76 **
Angha	-1.29 **	0.88	0.24 **	0.50 **	0.22 **	0.36	0.26 **	0.67 *
Solan Vajra	0.82	-10.72 **	-0.36 **	-0.05	0.16 **	0.09	-0.27 **	0.17
VRT-101-A	-1.85 **	33.99 **	-0.12	0.07	0.46 **	1.17 **	-0.41 **	-5.21**
VRT-01	1.04 *	-15.24 **	-0.56 **	-0.03	0.07	-0.96**	1.01 **	-5.75 **
CO-3	-1.96 **	18.01 **	0.72 **	-0.08	-0.89**	0.09	0.71 **	7.75 **
VRT-06	2.15 **	-10.78 **	-0.21 **	0.15 **	0.058	1.09**	-0.56 **	-5.31 **
H-88-78-1	2.15 **	-11.72**	-0.03	-1.00**	-0.69 **	0.06	-0.02	8.44 **
CD 95 %GCA(Line)	0.93	1.29	0.15	0.1	0.08	0.37	0.15	0.57
Tester								
Arka Abha	-0.01	-12.79**	0.03	-0.15**	-0.02	-0.50**	0.52 **	1.11**
Pusa-120	-0.14	22.92 **	0.29**	0.03	-0.09**	0.56 **	-0.57 **	0.34
Pant T-5	0.15	-10.13**	-0.31 **	0.11**	0.11 **	-0.06	0.05	-1.46**
CD 95% GCA (Tester)	0.57	0.79	0.09	0.06	0.05	0.23	0.09	0.35

Table 4: Estimates of general combining ability (GCA) effect of parents for Average fruit weight (g), number of seeds per fruit, number of locules per fruit, pericarp thickness (mm), total soluble solids (ºBrix), ascorbic acid content (mg/100g of edible fruit) and fruit yield (q/ha) and fruit yield (q/ha) in tomato.

Lines	Avg. fruit weight (g)	No. of seeds per fruit	No. of locules per fruit	Pericarp thickness (mm)	TSS(◦Brix)	Ascorbic acid content (mg/100g of fruit)	Fruit yield(q/ha)
CTS -07	4.57 **	6.87**	0.26 **	-0.31 **	-0.71 **	0.89	37.93 **
Angha	2.02 **	6.62 **	0.55 *	-0.83 *	0.04	2.30 **	41.16 **
Solan Vajra	3.67 **	9.99 **	-0.27 **	0.16 **	0.26 **	-0.69	39.12 **
VRT-101-A	10.56 **	6.37 **	0.37 **	0.21 **	0.03	-0.27	-0.90
VRT-01	10.26 **	28.56 **	-0.32 **	-0.49 **	0.17 **	0.01	-3.62
CO-3	-15.89 **	-32.99 **	-0.76 **	-0.22 **	0.34 **	-0.58	-13.97 **
VRT-06	7.49 **	7.34**	0.02	1.03 **	0.16 **	-1.21 *	-14.88 **
H-88-78-1	-22.70**	-32.77 **	0.15 *	0.45 **	-0.26 **	-0.45	-84.83 **
CD 95% GCA(Line)	1.034	1.38	0.13	0.08	0.11	1.02	5.53
Tester							
Arka Abha	-4.43 **	-4.13**	0.17 **	-0.23**	-0.23**	-0.06	-12.36 **
Pusa-120	3.39 **	14.72 **	-0.01	0.27 **	0.19 **	0.66 *	19.72 **
Pant T-5	1.03 **	-10.59 **	-0.16 **	-0.04	0.04	-0.59	-7.36 **
CD 95% GCA (Tester)	0.63	0.85	0.08	0.05	0.07	0.61	3.39

Table 5: Estimates of specific combining ability (SCA) effect of hybrids for days to 50% flowering, plant height (cm), number of primary branches per plant, fruit length (cm), fruit width (cm), number of fruit clusters per plant, number of fruits per cluster in tomato.

Crosses	Days to 50 % flowering	Plant height (cm)	No. of primary branches per plant	Fruit length (cm)	Fruit width (cm)	No. of fruit clusters per plant	No. of fruits per cluster
CTS-07 × Arka Abha	-2.09*	-3.76 **	-0.05	0.02	0.18**	-0.15	-0.96**
CTS-07 × Pusa-120	0.69	17.38 **	0.49 **	-0.28 **	-0.26 **	1.05 **	0.45 **
CTS-07 × Pant T-5	1.40	-13.62 **	-0.44 **	0.26 **	0.08	-0.89 **	0.51 **
Angha × Arka Abha	0.12	-17.76 **	-0.16	-0.28 **	-0.22 **	-0.76 *	-0.04
Angha × Pusa-120	-0.08	19.68 **	-0.62 **	0.52 **	0.43 **	-0.55	0.11
Angha × Pant T-5	-0.04	-1.93	0.78 **	-0.24 **	-0.21 **	1.31 **	-0.08
Solan Vajra × Arka Abha	-0.32	6.84**	0.44 **	0.31 **	-0.04	0.33	0.54 **
Solan Vajra × Pusa-120	-0.53	-29.95 **	-0.15	0.07	-0.08	-1.44 **	-0.33 *
Solan Vajra × Pant T-5	0.85	23.11 **	-0.29 *	-0.39 **	0.09	1.11 **	-0.21
VRT-101 A × Arka Abha	-0.32	6.72 **	0.46 **	-0.17	-0.17 *	-0.22	-0.15
VRT-101 A × Pusa-120	0.47	-5.69 **	-0.19	-0.17	0.07	-0.10	-0.12
VRT-101 A × Pant T-5	-0.15	-1.02	-0.26 *	0.34 **	0.09	0.32	0.27 *
VRT-01 × Arka Abha	0.79	6.29 **	-0.23	0.05	-0.09	0.48	0.24
VRT-01 × Pusa-120	-0.75	-2.44 *	0.31 *	-0.08	-0.19 **	2.49 **	-0.16
VRT-01 × Pant T-5	-0.04	-3.86 **	-0.09	0.02	0.28 **	-2.97 **	-0.07
CO-3 × Arka Abha	0.79	8.42 **	-0.45 **	-0.53 **	-0.23 **	0.87 **	-0.29 *
CO-3 × Pusa-120	-0.42	-6.97 **	0.16	0.23 **	0.13 *	-1.38 **	0.21
CO-3 × Pant T-5	-0.37	-1.45	0.29 *	0.30 **	0.09	0.51	0.07
VRT-06 × Arka Abha	0.68	-3.67 **	0.08	0.48 **	0.33 **	-0.69 *	-0.03
VRT-06 × Pusa-120	0.14	6.96 **	0.22	-0.26 **	-0.06	0.38	0.09
VRT-06 × Pant T-5	-0.82	-3.29 **	-0.31 *	-0.22 *	-0.27 **	0.31	-0.06
H-88-78-1 × Arka Abha	0.35	-3.09 **	-0.09	0.12	0.19 **	0.14	0.68 **
H-88-78-1 × Pusa-120	0.47	1.04	-0.22	-0.04	-0.04	-0.44	-0.25
H-88-78-1 × Pant T-5	-0.82	2.05	0.31 *	-0.08	-0.16 *	0.30	-0.43 **
CD 95% SCA	1.61	2.25	0.25	0.17	0.13	0.64	0.26
*Significant at p=0.05, **Significant at p=0.01							

Table 6: Estimates of specific combining ability (SCA) effect of hybrids for number of fruits per plant, average fruit weight(g), number of seeds per fruit, no. of locules per fruit, Pericarp thickness (mm), TSS(◦Brix), Ascorbic acid content (mg/100g of fruit) and Fruit yield (q/ha) in tomato.

Crosses	No. of fruits per plant	Av. fruit weight (g)	No. of seeds per fruit	No. of locule per fruit	Pericarp thickness (mm)	TSS (◦Brix)	Ascorbic acid content (mg/100g of fruit)	Fruit yield (q/ha)
CTS-07 × Arka Abha	2.79 **	-1.99 *	-14.22 **	0.19	0.45**	0.01	-0.49	25.11**
CTS-07 × Pusa-120	-1.03 *	3.17 **	1.11	-0.57**	0.49**	0.57**	0.08	18.13 **
CTS-07 × Pant T-5	-1.77 **	-1.17	13.11 **	0.38**	-0.94 **	-0.59 **	0.41	-43.25 **
Angha × Arka Abha	0.86	-8.04 **	-0.78	-0.57**	0.27**	-0.21 *	-0.97	-55.60 **
Angha × Pusa-120	-1.43 **	-2.16 *	-0.30	0.81**	-0.13	0.21*	0.67	-24.38 **
Angha × Pant T-5	0.58	10.21 **	1.08	-0.24 *	-0.14 *	0.01	0.30	79.98 **
Solan Vajra × Arka Abha	4.95 **	-4.35 **	13.86 **	-0.14	-0.58 **	0.39**	-1.27	39.09 **
Solan Vajra × Pusa-120	-6.67 **	8.65 **	5.87**	-0.17	-0.35**	-0.44**	1.12	-40.82 **
Solan Vajra × Pant T-5	1.72 **	-4.30 **	-19.73	0.31 **	0.93**	0.05	0.15	1.73
VRT-101-A × Arka Abha	4.01 **	-3.01 **	1.48	0.81 **	0.06	0.58**	-2.25 *	54.31**
VRT-101-A × Pusa-120	-5.68 **	1.37	-3.51	-0.41 **	0.40**	-0.68 **	0.13	-87.22
VRT-101-A × Pant T-5	1.67 **	1.64	2.04	-0.39 **	-0.46 **	0.10	2.13 *	32.92
VRT-01 × Arka Abha	-2.25 **	13.36 **	-5.72 **	-0.30 *	0.41**	0.01	3.02 **	39.12 **
VRT-01 × Pusa-120	2.54 **	-1.01	23.99 **	0.07	0.56**	0.05	-0.62	43.92 **
VRT-01 × Pant T-5	-0.29	-12.35 **	-18.26 **	0.22	-0.96**	-0.06	-2.39 **	-83.03 **
CO-3 × Arka Abha	-5.26 **	3.18**	-10.17 **	0.01	-0.67 **	0.19*	0.24	-39.12 **
CO-3 × Pusa-120	2.80 **	-2.82 **	-4.67 **	-0.08	0.166 *	-0.15	-1.02	17.04 **
CO-3 × Pant T-5	2.45 **	-0.36	14.84 **	0.07	0.50**	-0.04	0.78	22.08 **
VRT-06 × Arka Abha	-2.33 **	-1.59	-2.28	-0.43**	-0.21*	-0.32 **	-0.03	-42.84 **
VRT-06 × Pusa-120	4.41 **	-1.14	-10.89**	0.74**	-0.26 **	0.11	0.97	76.69 **
VRT-06 × Pant T-5	-2.07 **	2.73 **	13.18 **	-0.31**	0.47**	0.21 *	-0.93	-33.85 **
H-88-78-1 × Arka Abha	-2.77 **	2.45 **	17.84 **	0.43**	0.27**	-0.66**	1.76 *	-20.07 **
H-88-78-1 × Pusa-120	5.06 **	-6.06 **	-11.57**	-0.39**	-0.87 **	0.32*	-1.32	-3.35
H-88-78-1 × Pant T-5	-2.28 **	3.61 **	-6.27 **	-0.04	0.61**	0.33**	-0.44	23.43 **
CD 95% SCA	0.99	1.79	2.39	0.23	0.13	0.19	1.73	9.59
*Significant at p=0.05, **Significant at p=0.01								

Only three out of 24 crosses showed significant positive SCA effect in the desired direction which included the cross VRT-01 × Arka Abha (3.02) followed by VRT-101-A × Pant T-5 (2.13), H-88-78-1 × Arka Abha (1.76). These results were in agreement with the results of Kumari and Sharma (2011); Kumar *et al*. (2013); Cheema *et al.* (2014); Agarwal *et al*. (2017); Kumar *et al*. (2018) who also have reported good general combiners and good specific combinations for ascorbic acid content of fruits. Perusal of data for fruit yield revealed that only four genotypes out of eleven parents showed significant values of GCA in the desired direction. Out of 11 parents, highest significant positive GCA effect was recorded for parent Angha (41.16) followed by Solan Vajra (39.12) and CTS-07 (37.93) depicting their good general combining ability. Similarly the values of SCA effect in the crosses showed that ten out of 24 F_1 hybrids had good specific combining ability effect exhibiting significantly positive SCA for the trait. The cross Angha × Pant T-5 (79.98) followed by VRT-06 × Pusa-120 (76.69) and VRT-101-A × Arka Abha (54.31) indicated maximum significant SCA effect for fruit yield in the desired direction. Investigation done by Sekhar *et al*. (2010); Agarwal *et al.* (2014); Chauhan *et al.* (2014); Shakil *et al*. (2017); Umesh and Patil (2021); and Pavan *et al*. (2022)also reported good general and specific combiners for higher fruit yield.

CONCLUSION

These information pertaining to GCA and SCA effect of different parameters related to yield and quality are important tool for identifying suitable parents to be used in breeding program as well as for identifying highly desirable cross combinations respectively. Among the lines, CTS-07 was found to be good general combiner for days to 50 % flowering, number of primary branches per plant, fruit length, fruit width, average fruit weight, fruit yield per plant, fruit yield per hectare, number of seeds per fruit and number of locules per fruit. Following CTS-07, Angha was reported to be a good general combiner for traits like fruit length, fruit yield per plant, number of locules and ascorbic acid content. Similarly, the hybrid Angha × Pusa-120 was found to be good specific combiner for both fruit length and fruit width; cross Angha × Pant T-5 for number of primary branches per plant and fruit yield per plant; hybrid Solan Vajra × Pant T-5 for plant height and pericarp thickness. Thus, the obtained results can help in deciding the suitable parents as well as suitable crosses for a particular trait that can be further utilized in breeding programmes for development of good hybrids in tomato.

FUTURE SCOPE

This study involving diverse genotypes of tomato thus help in identifying most desirable inbred lines to be further used in breeding program. The GCA effects indicated that none of the parents was a good general combiner for all the characters, which points out that specific parents will have to be used for genetic improvement based on particular attributes under considerations. Tomato being highly consumed, is a vegetable of focus which draws the attention of researchers for crop improvement program to develop improved hybrids involving desirable parent combination. Also, hybrids resulting in higher yield help the farmers to cope up with the continuous market demand.

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