Research Article Electronic Journal of Plant Breeding, Vol.17(3):

Estimation of heterosis, combining ability and gene action for productivity traits in tomato (*Solanum lycopersicum L.*)

S. Teja[1], S. S. Masaye[2], A. I. Patel[3], D. Swetha Priya[4] and J. Devika[5]

https://doi.org/10.37992/2026.1703.032

Abstract

The study aimed to evaluate the potential of seven parents and twenty-one hybrids for yield and associated traits developed through half diallel mating design at Vegetable Research Farm, NAU, Navsari during *Rabi* 2024-25. Analysis of variance revealed that mean sum of squares were highly significant for all the traits indicating both additive and non-additive gene action. Standard heterosis was estimated using Arka Rakshak as check and hybrids GP28 × GP29, GP17 × GP29 and GP28 × GP64 exhibited superior standard heterosis for fruit yield per plant. Combining ability analysis by using Griffing's Method Ⅱ, Model Ⅰ which revealed GP28, GP29 and GP17 as good general combiners, while hybrids GP28 × GP29 and GP17 × GP64 were identified as good specific combiners for yield and associated traits. These results suggest that the identified hybrids are promising for commercial cultivation after multi-location evaluation.

Keywords: Tomato, standard heterosis, combining ability and gene action.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) ranks among globally significant vegetables due to its utilization for both fresh consumption and processing purposes. It is a rich source of vitamins, minerals, dietary fibres, lycopene and antioxidants which offer protection against cardiovascular diseases and cancer. Therefore, serving as a vital "protective food". Tomato is a warm-season, day neutral and self-pollinated crop thrives in well drained sandy loam soils but sensitive to frost and extreme heat.

Hedrick and Booth (1907) were the pioneers in recognizing heterosis in yield of tomato and today the limited availability of high-yielding varieties has increased demand for hybrids. Heterosis is favoured by higher fruit set and more seeds per fruit. Standard heterosis, which measures hybrid superiority over check is essential for hybrid release and commercialization. Heterosis enhances marketable yield and its effective utilization depends on careful parent selection and evaluation (Javed *et al*., 2021; Madhavi *et al*., 2023). Developing hybrid tomato varieties strengthens farmer interests and increase marketable productivity (Kumar *et al*., 2023 a).

Combining ability analysis provides a framework for selecting superior parents and hybrids through General combining ability (GCA) and Specific combining ability (SCA). This study was conducted to evaluate parental lines exhibiting strong general performance. Additionally, cross combinations were developed and assessed for targeted levels of heterosis (Sankhala *et al.*, 2022). Selection of superior combining parents is crucial, as their crosses can produce desirable combinations. General combining ability is used to designate the average performance of a parent in hybrid combination, which arises from additive genetic effects making it theoretically fixable. In contrast, specific combining ability refers to cases where certain hybrid combination performs better or worse than expected based on the average performance of the parents. Such deviations are attributed to non-additive gene action and are considered non-fixable (Sharma *et al*., 2025). The estimates of GCA and SCA depends on the genetic makeup of the parental lines and nature of the gene action (Javed *et al*., 2021). Combining

[1]Department of Vegetable Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India
[2]Department of Vegetable Science, Polytechnic in Horticulture, Paria, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India
[3]Department of Fruit Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India
[4]Department of Genetics and Plant Breeding, N M College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India
[5]Department of Vegetable Science, Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal, India

Corresponding author: S. Teja, Department of Vegetable Science, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India. *E-Mail: tejas01032001@gmail.com

How to cite this artilce: Teja, S., Masaye, S. S. Patel,A. I., Swetha Priya, D. and Devika, J. 2026. Estimation of heterosis, combining ability and gene action for productivity traits in tomato (*Solanum lycopersicum* L.). *Electronic Journal of Plant Breeding. **17(3):***
doi:10.37992/2026.1703.032

Received: 08.05.2026 **Accepted**: 29.07.2026 **Online**: 06.08.2026

ability studies provide critical insights into parent selection for F_1 hybrids by revealing nature and magnitude of gene actions governing quantitative trait expression (Agarwal *et al*., 2017). However, despite extensive work on heterosis and combining ability, limited information is available on the performance of specific parental lines and their hybrids under the Agro-climatic conditions of Navsari. Therefore, the present study was undertaken to assess standard heterosis, combining ability and gene action for yield and quality traits in tomato to identify superior parents and promising hybrids.

MATERIALS AND METHODS

The present investigation was executed at Vegetable Research Farm (RHRS), ACH, Navsari Agricultural University, Navsari. The experiment was conducted from December 2024 to April 2025. In this experiment seven genotypes (GP17, GP28, GP29, GP64, GP65, GP74 and GP111) were selected from the same location and half diallel mating design was employed during January 2024 to February 2024. The experiment comprised 29 genotypes, including 7 parents, 21 F_1 hybrids and one standard check (Arka Rakshak) were transplanted in Randomized Block Design, with three replications including ten plants in each row for each particular entry with a spacing of 90 × 45 cm. The data were taken from the five randomly selected plants, except the ones planted at borders for different traits *viz*., days to 50 % flowering, number of branches per plant at final harvest, plant height at final harvest (cm), number of trusses per plant, days to first harvest, days to last harvest, number of locules per fruit, fruit equatorial diameter (cm), fruit polar diameter (cm), pericarp thickness (cm), fruit weight (g), number of total fruits per plant, total fruit yield per plant (kg), marketable fruit yield per plant (kg), total soluble solids (˚B) by using refractometer measurement, lycopene content (mg/100g) estimated by spectrophotometric method following Ranganna (1986), titrable acidity (%) was measured by acid-base titration using AOAC (1990) procedures, ascorbic acid content (mg/100g) was determined by the 2,6-dichlirophenol indophenol dye titration methods described by Ranganna (1986), shelf life of fruit (days). Statistical analysis was carried out by using Agri analyze recommended by Popat *et al*. (2024). Standard heterosis was estimated following Meredith and Bridge (1972) and combining ability analysis was conducted using Model-1 (Fixed effect) and Method-2 (Parents and one set of F_1s without reciprocals) as described by Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability (**Table 1**) revealed that mean sum of squares were highly significant for the all the traits except for days to first harvest indicating the presence of both additive and non-additive gene actions were important for inheritance of these traits. These results are in accordance with the works of Yadav *et al*. (2016) Huseynzade *et al*. (2020), Javed *et al*. (2021), Ibirinde *et al*. (2022), Kumar *et al*. (2022a), Singh *et al*. (2022), Reddy *et al*. (2023) and Chaudhary *et al*. (2024) in tomato.

In the present analysis, it was revealed that the ratio of σ^2GCA /σ^2SCA was less than unity i.e. σ^2SCA was higher than σ^2GCA for all the characters except fruit equatorial diameter, fruit polar diameter, pericarp thickness and fruit weight indicating the pre dominance of non-additive nature of genes governing those characters which indicate heterosis breeding is used for improvement of these characters (**Table 1**). The results of the present study can be compared with the works of Pavan *et al*. (2022), Singh *et al.* (2022), Sankhala *et al.* (2022), Reddy *et al*. (2023) Chaudhary *et al*. (2024), Sharma *et al.* (2025) in tomato. For fruit equatorial diameter, fruit polar diameter, pericarp thickness and fruit weight there is predominance of additive gene action representing the selection in done for improvement of these characters.

Standard heterosis

Days to 50% flowering was extended from -35.82 (GP29 × GP111) to -13.88 per cent (GP29 × GP74) (Table 2). Among 21 hybrids, top performing three hybrids were *viz*., GP29 × GP111, GP28 × GP64 and GP17 × GP65. All hybrids observed significantly negative heterosis which is desirable indicating earliness as reported by Sah *et al*. (2020), Javed *et al*. (2021), Tekkam *et al*. (2021) and Kumar *et al*. (2024) in tomato. With respect to number of branches per plant at final harvest was varied between -22.48 (GP28 × GP111) and 62.79 per cent (GP64 × GP111). Top hybrids *viz*., GP64 × GP111, GP74 × GP111 and GP65 × GP74 exhibited significant and positive heterosis. Similar results were reported by Kumar *et al.* (2023 b). Plant height at final harvest was extended from -31.22 (GP28 × GP111) to 69.88 per cent (GP28 × GP64). Top performing hybrids *viz*., GP28 × GP64, GP64 × GP74 and GP17 × GP65 exhibited positive and significant heterosis for this trait. Corresponding findings in tomato were observed by Javed *et al*. (2021), Liu *et al*. (2021) and Kumar *et al*. (2023 b).

Regarding, number of trusses per plant it was recorded in the range of -31.57 (GP28 × GP111) to 47.56 per cent (GP17 × GP65). Out of 21 hybrids GP17 × GP65, GP17 × GP28 and GP64 × GP74 were observed as significant and positive which is desirable as it contributes for number of fruits per plant. Comparable results of tomato were observed by Manjunath and Sikder (2020). In case of days to first harvest, negative and significant standard heterosis is desirable which matures earlier as reported by Nevani and Sridevi (2022). Hybrid values spanned from -10.54 (GP64 × GP111 and GP74 × GP111) to 5.48 per cent (GP29 × GP74). No hybrid combination revealed significant standard heterosis for this trait. Non-significant standard heterosis for this trait was observed by Kumari *et al*. (2020), Rana *et al*. (2025) and Sharma *et al*. (2025) in tomato. For days to last harvest, it was recorded from -37.43 (GP28 × GP111) to 7.24 per cent (GP64 × GP111)

Table 1. Analysis of variance for combining ability of different characters in tomato

		CHARACTERS									
Source	d.f.	DF	NB	PH	NT	DFH	DLH	NL	FED	FPD	PT
GCA	6	4.68**	15.60**	2935.15**	6.59**	14.31	331.38**	1.79**	2.57**	1.84**	0.02**
SCA	21	3.53**	7.92**	550.97**	2.45**	20.17	334.14**	0.72**	0.23**	0.10**	0.002*
Error	54	1.39	0.36	24.97	0.16	13.18	31.14	0.04	0.03	0.02	0.0009
σ^2gca	-	0.36	1.69	323.35	0.71	-	33.35	0.19	0.28	0.20	0.002
σ^2sca	-	2.14	7.55	525.99	2.29	-	303.00	0.68	0.19	0.07	0.001
σ^2gca/σ^2sca	-	0.17	0.22	0.61	0.31	-	0.11	0.28	1.43	2.77	2.16

		CHARACTERS								
Source	d.f.	FW	NTFP	TFYP	MFYP	TSS	LC	TA	AA	SL
GCA	6	635.21**	129.47**	0.65**	0.49**	0.83**	0.68**	0.07**	56.37**	8.00**
SCA	21	45.90**	110.43**	0.10**	0.09**	0.45**	0.84**	0.03**	59.70**	45.63**
Error	54	2.02	3.02	0.002	0.003	0.01	0.001	0.0004	0.38	0.23
σ^2gca	-	70.35	14.05	0.07	0.05	0.09	0.07	0.007	6.22	0.86
σ^2sca	-	43.88	107.41	0.09	0.09	0.43	0.84	0.03	59.31	45.39
σ^2gca/σ^2sca	-	1.60	0.13	0.73	0.59	0.20	0.08	0.22	0.38	0.01

* and ** indicates significance at 5% and 1% level of probability, respectively (d.f.: degree of freedom)

DF : Days to 50 % flowering
NB : Number of branches per plant at final harvest
PH : Plant height at final harvest
NT : Number of trusses per plant
DFH : Days to first harvest
DLH : Days to last harvest
NL : Number of locules per fruit
FED : Fruit equatorial diameter
FPD : Fruit polar diameter
PT : Pericarp thickness
FW : Fruit weight
NTFP : Number of total fruits per plant
TFYP : Total fruit yield per plant
MFYP : Total Marketable fruit yield per plant
TSS : Total soluble solids
LC : Lycopene content
TA : Titrable acidity
AA : Ascorbic acid content
SL : Shelf life of fruit

and top hybrids *viz*., GP64 × GP111 (7.24 per cent) and GP28 × GP64 (1.44 per cent) exhibited non-significant and positive heterosis and none of the hybrid combination revealed significant standard heterosis in desirable direction. These results are in accordance with tomato from the work of Tekkam *et al*. (2021). With respect to number of locules per fruit was extended from -32.89 (GP64 × GP111) to 115.46 per cent (GP17 × GP28). Significant and negative standard heterosis is beneficial for this trait. Top hybrids *viz*., GP64 × GP111 and GP74 × GP111 and GP29 × GP111 exhibited negative and significant standard heterosis. Identical results were reported by Singh *et al*. (2021), Kumar *et al*. (2023 a), Sharma *et al*. (2025) in tomato.

Considering the parameter fruit equatorial diameter magnitude of heterosis was ranged from -49.06 (GP64 × GP111) to 8.69 per cent (GP17 × GP28). Out of 21 hybrids, only two hybrids *viz*., GP17 × GP28 and GP17 × GP29 recorded positive standard heterosis for this trait. Majority of hybrid recorded negatively significant and these results were found with the works of Javed *et al*. (2021), Rana *et al*. (2025) and Sharma *et al*. (2025) in tomato. For fruit polar diameter extended from -48.75 (GP64 × GP111) to 4.37 per cent (GP28 × GP29) where, all hybrids exhibited negative and significant standard heterosis except GP28 × GP29. None of the hybrids revealed significantly positive standard heterosis. Significant negative standard heterosis were recorded by Javed *et al*. (2021), Kumar *et al*. (2023 a) and Patel *et al*. (2024) in tomato. Pericarp thickness varied between -55.39 (GP74 × GP111) and -14.70 per cent (GP28 × GP29). No hybrid has revealed positively significant standard heterosis in desirable direction. Negative and significant results can be compared in tomato with the work of Kumar *et al*. (2022 b). For the trait fruit weight observed values from -81.60 (GP64 × GP111) to 1.06 per cent (GP28 × GP29). No hybrid combination exhibited significantly positive standard heterosis for this trait. Negative and

Table 2. Per cent standard heterosis in different characters of tomato

S. No	HYBRID	DF	NB	PH	NT	DFH	DLH	NL	FED	FPD	PT
1	GP17 × GP28	-26.94**	-3.87	41.77 **	42.10 **	-2.53	-26.08 **	115.46 **	8.69	-16.87 **	-21.07 **
2	GP17 × GP29	-24.14 **	-6.97	-7.17	-5.26	-0.42	-1.20	15.021	3.72	-13.75 **	-24.50 **
3	GP17 × GP64	-13.96 **	-8.52	38.18 **	26.31 **	0.00	-2.17	-16.99	-34.78 **	-30.00 **	-26.47 **
4	GP17 × GP65	-27.80 **	-10.07	55.48 **	47.36 **	-0.42	-30.91 **	32.89 **	-12.42 *	-20.62 **	-27.45 **
5	GP17 × GP74	-23.58 **	13.17 *	52.10 **	26.31 **	-10.54	-11.59 *	2.41	-29.81 **	-25.62 **	-18.13 **
6	GP17 × GP111	-24.98 **	-10.07	2.74	-21.05 *	-10.54	-28.26 **	4.71	-34.78 **	-40.62 **	-39.21 **
7	GP28 × GP29	-21.71 **	3.87	-6.75	21.05 *	-7.59	-9.42	3.94	-16.14 **	4.37	-14.70 *
8	GP28 × GP64	-29.75 **	0.77	69.88 **	31.57 **	-10.12	1.44	50.21 **	-19.87 **	-33.12 **	-38.23 **
9	GP28 × GP65	-19.32 **	2.32	-11.81	-15.78	0.00	-30.67 **	1.42	-17.39 **	-23.75 **	-37.74 **
10	GP28 × GP74	-19.57 **	-3.87	35.02 **	26.31 **	0.00	-16.42 **	-9.53	-27.95 **	-31.25 **	-43.62 **
11	GP28 × GP111	-13.96 **	-22.48 **	-31.22 **	-31.57 **	0.00	-37.43 **	3.28	-36.02 **	-36.87 **	-44.11 **
12	GP29 × GP64	-15.36 **	-5.42	32.91 **	15.78	0.42	-34.29 **	2.63	-15.52 **	-20.62 **	-17.64 **
13	GP29 × GP65	-24.89 **	-14.72 *	-20.25 **	-26.31 **	-0.42	-16.90 **	1.64	-26.08 **	-29.37 **	-26.47 **
14	GP29 × GP74	-13.88 **	7.00	30.37 **	15.78	5.48	-26.08 **	-8.55	-21.11 **	-20.62 **	-21.56 **
15	GP29 × GP111	-35.82 **	-16.30 *	-20.46 **	-26.31 **	3.79	-27.53 **	-31.57 **	-40.37 **	-43.12 **	-35.78 **
16	GP64 × GP65	-19.10 **	-22.45 **	46.41 **	21.05 *	-0.42	-15.94 **	5.59	-31.67 **	-36.87 **	-30.39 **
17	GP64 × GP74	-21.25 **	11.62	62.02 **	36.84 **	0.84	-11.59 *	-30.37 **	-35.40 **	-37.50 **	-30.88 **
18	GP64 × GP111	-27.02 **	62.79 **	-18.35 *	-26.31 **	-10.54	7.24	-32.89 **	-49.06 **	-48.75 **	-39.70 **
19	GP65 × GP74	-22.09 **	50.38 **	20.25 **	5.26	-0.42	-26.81 **	57.34 **	-16.77 **	-34.37 **	-35.29 **
20	GP65 × GP111	-27.51 **	-10.07	6.75	21.05 *	-10.12	-14.49 *	-12.28	-41.61 **	-41.87 **	-38.72 **
21	GP74 × GP111	-27.27 **	61.24 **	33.75 **	36.84 **	-10.54	-1.20	-32.89 **	-43.47 **	-48.12 **	-55.39 **
	S Em (±)	1.17	0.60	5.04	0.40	3.59	5.53	0.22	0.18	0.17	0.03
	CD @ 5%	3.32	1.70	14.29	1.14	10.18	15.67	0.63	0.53	0.49	0.08

* and ** indicates significance at 5% and 1% level of probability, respectively

DF	:	Days to 50 % flowering	NB	:	Number of branches per plant at final harvest	PH	:	Plant height at final harvest
NT	:	Number of trusses per plant	DFH	:	Days to first harvest	DLH	:	Days to last harvest
NL	:	Number of locules per fruit	FED	:	Fruit equatorial diameter	FPD	:	Fruit polar diameter
PT	:	Pericarp thickness						

Table 2. Continued...

	HYBRID	FW	NTFP	TFYP	MFYP	TSS	LC	TA	AA	SL
1	GP17 × GP28	-5.793	-10.60	-13.69	-13.69	6.25	-74.41 **	-10.00 *	18.00 **	-42.57 **
2	GP17 × GP29	-7.59	33.36 **	28.06 **	21.72 **	25.00 **	-71.31 **	-25.00 **	62.51 **	-4.82
3	GP17 × GP64	-48.65 **	119.26 **	16.89 **	16.96 *	71.87 **	-86.04 **	55.00 **	-3.09	6.66 *
4	GP17 × GP65	-27.10 **	18.98	-10.35	-14.28 *	6.25	-97.67 **	-25.00 **	62.79 **	-40.99 **
5	GP17 × GP74	-39.15 **	23.77 *	-22.61 **	-29.76 **	30.20 **	-72.86 **	-25.00 **	91.62 **	6.07 *
6	GP17 × GP111	-63.73 **	61.88 **	-38.69 **	-39.28 **	25.00 **	-72.09 **	-2.50	53.21 **	-52.58 **
7	GP28 × GP29	-1.06	88.53 **	93.18 **	93.15 **	28.12 **	-85.27 **	-5.00	13.68 **	13.39 **
8	GP28 × GP64	-42.51 **	97.54 **	17.43 **	14.58 *	18.75 **	-83.72 **	15.00 **	14.48 **	-53.91 **
9	GP28 × GP65	-55.00 **	36.05 **	-36.51 **	-43.75 **	31.25 **	-63.56 **	90.00 **	-3.39	-40.96 **
10	GP28 × GP74	-46.31 **	32.51 **	-26.15 **	-29.76 **	47.91 **	-76.74 **	30.00 **	51.67 **	-37.26 **
11	GP28 × GP111	-52.87 **	5.60	-48.22 **	-53.57 **	19.79 **	-86.82 **	55.00 **	-44.36 **	19.93 **
12	GP29 × GP64	-31.22 **	-17.75	-41.68 **	-45.23 **	20.83 **	-79.84 **	-25.00 **	54.24 **	-49.74 **
13	GP29 × GP65	-29.76 **	-1.22	-28.06 **	-30.35 **	25.00 **	-83.72 **	-25.00 **	-4.74	-42.06 **
14	GP29 × GP74	-38.50 **	-21.58 *	-49.86 **	-52.67 **	40.62 **	-70.54 **	0.00	64.61 **	6.11 *
15	GP29 × GP111	-72.73 **	119.53 **	-37.87 **	-37.20 **	44.79 **	-78.29 **	50.00 **	-26.19 **	-49.20 **
16	GP64 × GP65	-46.91 **	19.93 *	-34.05 **	-35.71 **	57.29 **	-66.66 **	15.00 **	67.61 **	-21.25 **
17	GP64 × GP74	-59.53 **	42.75 **	-40.05 **	-40.17 **	0.00	-66.66 **	-25.00 **	62.05 **	-25.93 **
18	GP64 × GP111	-81.60 **	75.54 **	-66.48 **	-66.96 **	78.12 **	-47.28 **	15.00 **	-20.72 **	1.33
19	GP65 × GP74	-70.35 **	34.69 **	-58.58 **	-59.22 **	47.91 **	-79.06 **	-5.00	-16.26 **	-14.84 **
20	GP65 × GP111	-64.38 **	73.51 **	-35.96 **	-35.11 **	26.04 **	-70.54 **	15.00 **	41.89 **	-53.59 **
21	GP74 × GP111	-74.27 **	89.61 **	-49.59 **	-49.10 **	50.00 **	-61.24 **	15.00 **	-35.70 **	-19.57 **
	S.Em. ±	1.46	1.71	0.04	0.05	0.12	0.03	0.02	0.61	0.48
	CD @ 5%	4.14	4.84	0.13	0.16	0.34	0.10	0.05	1.73	1.37

* and ** indicates significance at 5% and 1% level of probability, respectively

FW	:	Fruit weight	TFYP	:	Total fruit yield per plant	NTFP	:	Number of total fruits per plant
LC	:	Lycopene content	MFYP	:	Total Marketable fruit yield per plant	TSS	:	Total soluble solids
TA	:	Titrable acidity	SL	:	Shelf life of fruit	AA	:	Ascorbic acid content

significant standard heterosis for fruit weight reported by Kerketta *et al*. (2023).

Standard heterosis for number of total fruits per plant was fluctuated from -21.58 (GP29 × GP74) to 119.53 per cent (GP29 × GP111). Top hybrids *viz*., GP29 × GP111, GP17 × GP64 and GP28 × GP64 exhibited significant and positive standard heterosis as it directly affects to total yield of plant. Similar results were observed by Kumari *et al*. (2020) and Sairam *et al*. (2024) across tomato hybrids. In case of total fruit yield per plant standard heterosis was varied from -66.49 (GP64 × GP111) to 93.18 per cent (GP28 × GP29). Among 21 hybrids, top performing hybrids *viz*., GP28 × GP29, GP17 × GP29 and GP28 × GP64 due to yield contributing traits exhibited significant and positive standard heterosis on commercial check Arka Rakshak for this trait as it directly enhances productivity and economic value reported by Kumar *et al*. (2022 b), Kumar *et al*. (2023 b), Sairam *et al*. (2024) and Sharma *et al*. (2025) across tomato hybrids. For marketable fruit yield per plant, heterosis was spanned from -66.96 (GP64 × GP111) to 93.15 per cent (GP28 × GP29). Top hybrids *viz*., GP28 × GP29, GP17 × GP29 and GP17 × GP64 recorded positively significant standard heterosis for this trait. Comparable result was recorded by Sharma *et al*. (2025).

Heterotic performance of total soluble solids ranged from 0.00 (GP64 × GP74) to 78.12 per cent (GP64 × GP111). GP64 × GP111, GP17 × GP29 and GP64 × GP65 and the hybrids revealed significant and positive heterosis. Similar findings were reported by Kumar *et al*. (2023 b) in tomato. For Lycopene content extended from -97.67 (GP17 × GP65) to 47.28 per cent (GP64 × GP111). No hybrid combination exhibited positive standard heterosis. Significant and negative standard heterosis in tomato was also found by Kerketta *et al.* (2023). Titratable acidity varied between -25.00 (GP64 × GP74) and 90.00 per cent (GP28 × GP65). Top hybrids *viz*., GP28 × GP65, GP28 × GP111, and GP29 × GP111 recorded significant and positive standard heterosis for this trait and these results can be comparable with the work of Kumar *et al*. (2023 b) in tomato. Magnitude of ascorbic acid content was ranged from -44.36 (GP28 × GP111) to 91.62 per cent (GP17 × GP74). Top performing hybrids *viz*., GP17 × GP74, GP64 × GP65 and GP29 × GP74 recorded positive and significant standard heterosis. Identical results were observed by Kerketta *et al*. (2023) and Kumar *et al*. (2023 b) across tomato hybrids. For shelf life of fruit, heterosis varied between -53.91 (GP65 × GP111) and 19.93 per cent (GP28 × GP111) for this trait. Out of 21 hybrids, top hybrids *viz*., GP28 × GP111, GP28 × GP29, GP17 × GP64 revealed positive and significant standard heterosis. Similar results in tomato were observed in Sairam *et al*. (2024).

General combining ability of parents and specific combining ability of hybrids

General combining ability of parents are mentioned in **Table 3** and specific combining ability of hybrids are mentioned in **Table 4**. Parent GP111 (-1.25) was a good general combiner while GP74 (0.77) was poor general combiner and hybrid GP29 × GP111 (-3.41) and GP28 × GP64 (-3.30) recorded significant SCA effect in desirable negative direction for the trait days to 50% flowering which contributes for earliness. In case of number of branches per plant at final harvest, positive and significant effect is advantageous and found in parents GP74 (1.99) and GP111(1.81), they were identified as good general combiners, while remaining all parents were poor combiners and GP64 × GP111(6.46) and GP65 × GP74 (5.12) were found to be good specific combiners for this trait. With respect to plant height at final harvest, parents GP64 (22.01) and GP74 (27.45) were good general combiners, while parents *viz.,* GP28 (-3.97) and GP29 (-11.72) were poor general combiner. The hybrids *viz*., GP17 × GP65 (51.03) and GP28 × GP64 (33.79) were identified as good specific combiners. Parents GP64 (0.68) and GP74 (1.57) were observed as good general combiners for positive and significant GCA effect, while GP17 × GP65 (3.22) and GP17 × GP28 (2.59) showed positive and significant SCA effect in desirable direction for the trait number of trusses per plant. In case of days to last harvest, parents GP74 (6.26) and GP29 (5.15) were identified as good general combiners, while two parents *viz*., GP28 (-4.66) and GP65 (-10.55) exhibited poor general combiners. Hybrids GP64 × GP111 (30.46) and GP28 × GP64 (27.27) recorded positive and significant SCA effects showing prolonged harvesting period.

For the trait number of locules per fruit, which contribute to extend shelf life of fruit, negative and significant GCA effect is desirable hence parents *viz*., GP111 (-0.52), GP74 (-0.41) and GP64 (-0.25) revealed as good general combiners, while two parents GP17 (0.56) and GP28 (0.59) reported as poor general combiners and in hybrids, GP17 × GP64 (-1.05) and GP28 × GP65 (-0.82) showed negative and significant SCA effect which is desirable and considered as good specific combiner.

For fruit equatorial diameter, parents GP28 (0.60) and GP29 (0.52) exhibited significant and positive GCA effects and were considered good general combiners, whereas GP111 (0.86) and GP74 (0.30) showed poor general combining ability. The hybrids GP65 × GP74 (0.83) and GP17 × GP28 0.78 exhibited significant SCA effect in positive direction. For the trait fruit polar diameter parents GP28 (0.39) and GP29 (0.57) exhibited positive and significant GCA effect which is desirable and considered as good general combiners then GP64 (-0.14), GP65 (-0.11), GP74 (-0.75) and GP111 (-0.75) recorded as poor general combiners. Only one hybrid *viz*., GP28 × GP29 (0.82) revealed positive and significant SCA effect for this trait. Parents GP29 (0.06) and GP17 (0.04) were recorded as good general combiners for pericarp thickness, while parents *viz*., GP65 (-0.01) and GP74 (-0.03) were poor general combiners. one hybrid GP17 × GP74 (0.08) revealed positive and significant SCA effect for this trait.

Table 3. Estimates of general combining ability effects of different characters in tomato

Characters	GP 17	GP28	GP29	GP64	GP65	GP74	GP111	S.E.gi.
Days to 50 % flowering	-0.65	0.63	0.14	0.31	0.04	0.77 *	-1.25 **	0.36
Number of branches per plant at final harvest	-1.00 **	-0.64 **	-0.60 **	-0.55 **	-1.00 **	1.99 **	1.81 **	0.18
Plant height at final harvest	-1.7	-3.97 *	-11.72 **	22.01 **	-11.14 **	27.45 **	-20.92 **	1.54
Number of trusses per plant	-0.2	-0.2	-0.38 **	0.68 **	-0.49 **	1.57 **	-0.97 **	0.12
Days to first harvest	-	-	-	-	-	-	-	-
Days to last harvest	-0.95	-4.66 **	5.15 **	4.59 **	-10.55 **	6.26 **	0.15	1.72
Number of locules per fruit	0.56 **	0.59 **	-0.009	-0.25 **	0.04	-0.41 **	-0.52 **	0.06
Fruit equatorial diameter	0.39 **	0.60 **	0.52 **	-0.24 **	-0.1	-0.31 **	-0.86 **	0.05
Fruit polar diameter	0.29 **	0.39 **	0.57 **	-0.14 **	-0.11 *	-0.24 **	-0.75 **	0.05
Pericarp thickness	0.04 **	0.01	0.06 **	0.005	-0.01 *	-0.03 **	-0.07 **	0.009
Fruit weight	4.47 **	9.17 **	11.33 **	-4.12 **	-3.58 **	-6.26 **	-11.02 **	0.43
Number of total fruits per plant	1.46 **	0.76	-1.92 **	-0.13	-3.85 **	-3.54 **	7.23 **	0.53
Total fruit yield per plant	0.16 **	0.34 **	0.28 **	-0.11 **	-0.19 **	-0.26 **	-0.22 **	0.01
Total Marketable fruit yield per plant	0.14 **	0.31 **	0.25 **	-0.10 **	-0.17 **	-0.24 **	-0.19 **	0.01
Total soluble solids	-0.28 **	-0.37 **	-0.06	0.26 **	-0.18 **	0.42 **	0.21 **	0.03
Lycopene content	0.16 **	-0.16 **	0.55 **	-0.13 **	-0.17 **	-0.20 **	-0.04 **	0.01
Titrable acidity	-0.12 **	0.13 **	-0.07 **	0.04 **	-0.03 **	-0.001	0.06 **	0.006
Ascorbic acid content	1.03 **	-3.14 **	2.16 **	-1.07 **	1.29 **	2.95 **	-3.22 **	0.19
Shelf life of fruit	-0.71 **	-0.93 **	-0.72 **	-0.41 **	0.54 **	0.65 **	1.59 **	0.15

* and ** indicates significance at 5% and 1% level of probability, respectively

With respect to fruit weight, parents *viz*., GP29 (11.33) and GP28 (9.17) recorded good general combiners which contribute directly to yield, while GP74 (-6.26) and GP111 (-11.02) were identified as poor combiners for this trait and the hybrids viz., GP17 × GP65 (7.62) and GP64 × GP65 (5.94) were found to be good specific combiners.

Evaluation for the trait number of total fruits per plant, parents GP111 (7.23) and GP17 (1.46) were identified as good general combiners, while GP29 (-1.92) and GP65 (-3.85) recorded as poor general combiners. The hybrids viz., GP17 × GP64 (19.24) and GP29 × GP111 (15.33) were identified as good specific combiners. With respect to total fruit yield per plant parents *viz*., GP28 (0.34) and GP29 (0.28) were good general combiners contributing directly to hybrid performance, while GP64 (-0.11) and GP65 (-0.19) recorded as poor general combiners and in case of hybrids, GP28 × GP29 (0.80) and GP17 × GP64 (0.45) revealed significant in desirable direction which are considered as good specific combiners for this trait. For marketable fruit yield per plant, parents GP28 (0.31) and GP29 (0.25) exhibited significant and positive GCA effect which are considered as good general combiners, while for hybrids GP28 × GP29 (0.76) and GP17 × GP64 (0.44) were observed as significant in desirable direction and confirmed as good specific combiners.

The quality traits *viz.,* total soluble solids are important for processing purpose and recorded that parent GP74 (0.42) and GP64 (0.26) were identified as good general combiners whereas, GP17 (-0.28) and GP28 (-0.37) were found to be poor general combiners. The hybrids, GP17 × GP64 (1.14) and GP64 × GP111 (0.83) were good specific combiners. Regarding lycopene content, GP29 (0.55) and GP17 (0.16) parents exhibited significant and positive GCA effect, while GP28 (0.13) and GP64 (-0.13) were identified as poor general combiners. Significant SCA effect in desirable direction was exhibited by GP64 × GP111 (1.17) and GP74 × GP111 (0.65) and hence considered as good specific combiners for the above trait. Good general combiners for the trait titratable acidity were found in GP28 (0.13) and GP111 (0.06), while three parents *viz*., GP17 (-0.12), GP29 (-0.07) and GP65 (0.03) were showed as poor general combiners. The hybrids GP28 × GP65 (0.44) and GP17 × GP64 (0.40) showed significant and positive SCA effect. In case of ascorbic acid content, parents *viz*., GP74 (2.95) and GP29 (2.16) were shown significant and positive GCA effect for the above trait and considered as good general combiners, while GP111 (-3.22) and GP28 (-3.14) recorded significant in undesirable direction which were identified as poor general combiner for this trait. Significant and positive SCA effect was found in GP17 × GP74 (7.32) and GP64 ×

Table 4. Estimates of specific combining ability effects for different characters in tomato

S. NO.	Hybrids	DF	NB	PH	NT	DFH	DLH	NL	FED	FPD	PT	FW	NTFP	TFYP	MFYP	TSS	LC	TA	AA	SL
1	GP17 × GP28	-1.33	0.77	30.97 **	2.59 **	-	-5.16	2.11 **	0.78 **	-0.02	0.01	5.92 **	-13.33 **	-0.54 **	-0.32 **	-0.31 **	-0.16 **	-0.12 **	-0.38	-2.84 **
2	GP17 × GP29	0.15	0.32	-7.79	-0.22	-	19.35 **	-0.32	0.60 **	-0.04	-0.06 *	2.82 *	0.08	0.18 **	0.14 **	-0.03	-0.75 **	-0.01	2.65 **	6.02 **
3	GP17 × GP64	3.61 **	0.08	1.47	0.70	-	18.57 **	-1.05 **	-0.69 **	-0.19	-0.01	-3.01 *	19.24 **	0.45 **	0.44 **	1.14 **	-0.69 **	0.40 **	-6.40 **	8.48 **
4	GP17 × GP65	-1.05	0.32	51.03 **	3.22 **	-	-5.94	0.16	0.36 *	0.27	0.005	7.62 **	-1.49	0.19 **	0.16 **	-0.51 **	-1.15 **	-0.05 **	3.57 **	-3.93 **
5	GP17 × GP74	-0.28	0.32	9.23 *	-0.18	-	3.90	-0.30	-0.36 *	0.14	0.08 **	4.04 **	-0.64	0.12 **	0.06	-0.35 **	-0.05	-0.08 **	7.32 **	7.27 **
6	GP17 × GP111	1.24	-2.49 **	10.81 *	-0.62	-	-12.98 *	-0.12	-0.07	-0.15	-0.01	-3.94 **	-2.12	-0.11 **	-0.09	-0.31 **	-0.18 **	-0.002	6.29 **	-7.77 **
7	GP28 × GP29	-0.26	1.37 *	-5.11	1.44 **	-	11.72 *	-0.69 **	-0.67 **	0.82 **	0.02	1.51	14.24 **	0.80 **	0.76 **	0.15	-1.03 **	-0.14 **	-2.31 **	10.61 **
8	GP28 × GP64	-3.30 **	0.92	33.79 **	1.03 **	-	27.27 **	0.95 **	-0.10	-0.45 **	-0.06 *	-4.53 **	14.65 **	0.28 **	0.24 **	-0.47 **	-0.27 **	-0.13 **	1.07	-5.87 **
9	GP28 × GP65	0.67	1.57 **	-10.49 *	-0.77 *	-	-1.90	-0.82 **	-0.11	0.01	-0.041	-11.55 **	3.37 *	-0.30 **	-0.33 **	0.37 **	0.63 **	0.44 **	-4.65 **	-3.71 **
10	GP28 × GP74	-0.13	-2.22 **	-4.69	-0.18	-	0.94	-0.70 **	-0.47 **	-0.25	-0.06 *	-4.37 **	2.19	-0.10 *	-0.10 *	0.30 **	0.09 **	0.01	4.01 **	-2.93 **
11	GP28 × GP111	3.89 **	-4.44 **	-19.12 **	-1.29 **	-	-21.94 **	-0.20	-0.35 *	-0.04	-0.02	-3.01 *	-15.15 **	-0.41 **	-0.42 **	-0.38 **	-0.49 **	0.11 **	-7.82 **	9.87 **
12	GP29 × GP64	2.31 *	0.08	6.49	0.22	-	-31.87 **	0.11	0.21	0.02	0.02	-0.83	-10.79 **	-0.37 **	-0.35 **	-0.71 **	-0.82 **	-0.18 **	3.21 **	-5.07 **
13	GP29 × GP65	-0.81	-0.67	-10.74 *	-1.25 **	-	7.27	-0.21	-0.49 **	-0.46 **	-0.01	-0.61	-3.03	-0.13 **	-0.11 *	-0.13	-0.95 **	-0.10 **	-10.21 **	-4.18 **
14	GP29 × GP74	2.38 *	-0.86	-1.35	-0.66	-	-22.20 **	-0.06	-0.02	0.12	0.03	-2.47	-8.31 **	-0.32 **	-0.29 **	-0.24 *	-0.35 **	0.02	1.13 *	7.28 **
15	GP29 × GP111	-3.41 **	-3.69 **	-1.16	-0.77 *	-	-18.09 **	-0.65 **	-0.50 **	-0.56 **	-0.01	-15.47**	15.33 **	-0.21 **	-0.18 **	0.09	-0.84 **	0.29 **	-9.72 **	-6.95 **
16	GP64 × GP65	1.07	-1.71 **	18.71 **	0.66	-	9.16	0.15	-0.02	-0.14	0.02	5.94 **	0.33	0.19 **	0.18 **	0.57 **	0.47 **	0.04 *	6.58 **	0.50
17	GP64 × GP74	-0.41	-0.31	-5.08	-0.40	-	-1.64	-0.48 *	-0.02	-0.05	0.03	2.06	5.58 **	0.19 **	0.20 **	-1.87 **	0.50 **	-0.25 **	3.89 **	-0.72
18	GP64 × GP111	-0.44	6.46 **	-32.90 **	-1.85 **	-	30.46 **	-0.44 *	-0.19	-0.14	0.01	-4.62 **	2.80	-0.17 **	-0.15 **	0.83 **	1.17 **	-0.05 **	-5.45 **	4.88 **
19	GP65 × GP74	-0.45	5.12 **	-11.52 *	-1.22 **	-	-7.50	1.88 **	0.83 **	0.08	0.02	-4.08 **	7.34 **	0.03	0.05	0.11	0.01	-0.04 **	-13.16 **	0.98 *
20	GP65 × GP111	-0.35	-2.49 **	24.05 **	2.33 **	-	15.61 **	-0.12	0.05	0.19	0.04	3.78 **	6.03 **	0.27 **	0.27 **	-0.38 **	0.22 **	0.01	3.91 **	-9.28 **
21	GP74 × GP111	-1.00	3.70 **	11.05 *	1.25 **	-	17.12 **	-0.28	0.16	-0.01	-0.05	1.31	9.64 **	0.18 **	0.18 **	-0.22	0.65 **	-0.01	-12.29 **	-1.20 **
	S.E.sij	1.05	0.54	4.48	0.33	-	5.00	0.19	0.16	0.15	0.02	1.27	1.56	0.04	0.05	0.11	0.03	0.01	0.55	0.43

* and ** indicates significance at 5% and 1% level of probability, respectively

DF : Days to 50 % flowering
NB : Number of branches per plant at final harvest
PH : Plant height at final harvest
NT : Number of trusses per plant
DFH : Days to first harvest
DLH : Days to last harvest
NL : Number of locules per fruit
FED : Fruit equatorial diameter
FPD : Fruit polar diameter
PT : Pericarp thickness
FW : Fruit weight
NTFP : Number of total fruits per plant
TFYP : Total fruit yield per plant
MFYP : Total Marketable fruit yield per plant
TSS : Total soluble solids
LC : Lycopene content
TA : Titrable acidity
AA : Ascorbic acid content
SL : Shelf life of fruit

GP65 (6.58) for the above trait. Assessment of trait shelf life of fruit parents *viz*., GP111 (1.59) and GP74 (0.65) were identified as good general combiners, while GP28 (-0.93) and GP29 (-0.72) were poor general combiners. The hybrids, GP28 × GP29 (10.61) and GP28 × GP111 (9.87) were identified as good specific combiners for shelf life.

The present investigation revealed several hybrids exhibited significant positive standard heterosis over the commercial check for yield and yield related traits. These results indicate the presence of substantial genetic variability and the effectiveness of hybrid breeding in enhancing tomato productivity. Superior hybrids such as GP28 × GP29, GP17 × GP29 and GP28 × GP64 exhibited positive standard heterosis for yield. Among the parents, GP28, GP29, and GP17 were identified as good general combiners, while the highest specific combining ability was observed in GP28 × GP29 and GP17 × GP64 hybrids. These combinations consistently showed superior performance for fruit yield and associated traits. Therefore, these genotypes can be effectively utilized in hybrid breeding programs to exploit their genetic potential and may be recommended for commercial cultivation after multi-location evaluation.

ACKNOWLEDGMENT

All the authors like to express their gratitude towards ASPEE College of Horticulture, Navsari for providing planting material and facilities for the research. A special thanks to both major and minor guide for their support throughout the research journey.

REFERENCES

Agarwal, A., Sharma, U., Ranjan, R. and Nasim, M. 2017. Combining ability analysis for yield, quality, earliness, and yield-attributing traits in tomato. *International Journal of Vegetable Science*, **23**(6):605–615. [Cross Ref]

AOAC. 1990. *Official Methods of Analysis of the Association of Official Analytical Chemists*. 15th Edition. Washington, D.C., USA.

Chaudhary, Y.J., Patel, D.A., Patel, N.A. and Patel, K.C. 2024. Combining ability analysis for fruit yield and its contributing traits in tomato (*Solanum lycopersicum* L.). *Biological Forum – An International Journal*, **16**(7):123–134.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences*, **9**:463–493. [Cross Ref]

Huseynzade, G., Akperov, Z. and Hasanov, S. 2020. Combining ability and gene action of tomato hybrids (*Lycopersicum esculentum* L.) genotypes in Azerbaijan. *American Journal of Agricultural Research*, **5**:80.

Hedrick, U.P. and Booth, N.O. 1907. Inheritance in the tomato. Proceedings of the Society for Horticultural Science, **3**:19–24.

Ibirinde, D.O., Oladokun, L., Kolawole, A.O., Aremu, C.O. and Iliya, M.N. 2022. Combining ability, heritability and genetic variance in tomato (*Lycopersicon lycopersicum*) genotypes. *Asian Journal of Agricultural and Horticultural Research*, **9**(4):238–248. [Cross Ref]

Javed, A., Akram, A., Tabassum, M.I., Ahmad, N., Sarwar, M. and Atif, M.J. 2021. Heterotic estimation and adaptability of tomato hybrids for fruit yield and its related traits in Pakistan. *Revista De Agricultura Neotropical*, **8**(4):e6582. [Cross Ref]

Kerketta, A., Bahadur, V., Srivastava, R., Luthra, S., Yadav, A. and Lal, L. 2023. Studies on heterosis for fruit yield, quality and ToLCV resistance in tomato (*Solanum lycopersicum* L.). *International Journal of Environment and Climate Change*, **13**(10):1667–1676. [Cross Ref]

Kumari, N., Srivastava, J.P. and Singh, B. 2020. Heterotic expression for yield and its component in tomato (*Lycopersicon esculentum* Mill.). *Annals of Horticulture*, **3**(1):98–101.

Kumar, P., Ram, C.N., Singh, M.K. and Saini, S. 2020. Studies on analysis of variance and mean performance of parents and their crosses among various quantitative traits in tomato (*Solanum lycopersicum* L.). *International Journal of Communication Systems*, **8**(1):1992–2003. [Cross Ref]

Kumar, V. and Singh, S.K. 2022a. Estimation of general and specific combining abilities of parents and crosses in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal of Agricultural Research*, **56**(4):442–448. [Cross Ref]

Kumar, V. and Singh, S.K. 2022b. Exploitation of heterosis and inbreeding depression for yield and nutritional quality improvement in tomato (*Lycopersicon esculentum* Mill.). *Agri Ways*, **10**(1).

Kumar, B.S., Mali, S.C., Patel, A.I. and Prajapati, M.R. 2023a. Appraisal of combining ability and gene action for yield, its governing characters and quality traits in tomato (*Solanum lycopersicum* L.). *Electronic Journal of Plant Breeding*, **14**(2):752–757. [Cross Ref]

Kumar, V., Thapa, R.S., Kumar, N. and Singh, S.K. 2023b. Heterosis and inbreeding depression for yield and quality traits in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Plant and Environment*, **9**(1):73–80. [Cross Ref]

Kumar, B., Pal, A.K., Singh, A.K., Arya, D., Pattnaik, P. and Yadav, N. 2024. Studies of heterosis and inbreeding depression for growth parameters in tomato hybrids (*Solanum lycopersicum* L.). *International Journal of Advanced Biochemistry Research*, **8**(1S):16–20. [Cross Ref]

Liu, Z., Jiang, J., Ren, A., Xu, X., Zhang, H., Zhao, T., Jiang, X., Sun, Y., Li, J. and Yang, H. 2021. Heterosis and combining ability analysis of fruit yield, early maturity, and quality in tomato. *Agronomy*, **11**(4):807. [Cross Ref]

Madhavi, Y., Reddy, R.V.S.K., Reddy, C.S., Reddy, S., Rajani, A. and Kumari, N.R. 2023. Studies on heterosis for growth and yield characters in tomato (*Solanum lycopersicum* L.). *The Pharma Innovation Journal*, **12**(5):2632–2636.

Manjunath, K.V. and Sikder, S. 2020. Combining ability, gene action and heterotic expression studies for yield contributing traits in tomato. *International Journal of Current Microbiology and Applied Sciences*, **9**(10):2838–2850. [Cross Ref]

Meredith, W.R. and Bridge, R.R. 1972. Heterosis and gene action in cotton (*Gossypium hirsutum* L.). *Crop Science*, **12**:304–310. [Cross Ref]

Nevani, S. and Sridevi, O. 2022. Study of heterosis, residual heterosis and inbreeding depression in two crosses of tomato (*Solanum lycopersicum* L.). *International Journal of Agriculture, Environment and Biotechnology*, **8**(1):307.

Patel, G.M., Patel, A.I., Intwala, C.G., Patel, H.R., Patel, A., Prajapati, M.R. and Mali, S.C. 2024. Estimation of standard heterosis over environments for fruit yield and its attributes in tomato (*Solanum lycopersicum* L.). *Journal of Advances in Biology and Biotechnology*, **27**(9):131–139. [Cross Ref]

Pavan, M.P., Gangaprasad, S., Dushyanthakumar, B.M., Adivappar, N. and Shashikumara, P. 2022. Heterosis and combining ability studies by line × tester analysis for fruit biochemical, morpho-physiological, and yield traits governing shelf life in tomato (*Solanum lycopersicum* L.). *Euphytica*, **218**(7):90. [Cross Ref]

Popat, R., Patel, H. and Popat, P. 2024 Agri Analyze [Online tool]. www. agrianalyze.com

Rana, S., Pant, S.C., Devrani, A., Shah, I. and Panwar, P. 2025. Assessment of heterosis and combining ability for yield and yield contributing traits in tomato genotypes under mid-hill conditions. *Plant Archives*, **25**(1):1910–1917. [Cross Ref]

Ranganna, S. 1986. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw-Hill Publishing Co., New Delhi, India.

Reddy, B.R., Singh, A.K., Pal, A.K. and Reddy, G.E. 2023. Combining ability studies on yield and yield related traits in tomato (*Solanum lycopersicum* L.). *International Journal of Plant and Soil Science*, **35**(19):537–545. [Cross Ref]

Sankhala, P.M., Patil, S.S. and Abhishek, D. 2022. Combining ability analysis of fruit yield and quality traits in tomato (*Solanum lycopersicum* L.). *Journal of Agriculture Research and Technology*, **47**:178–182. [Cross Ref]

Sah, S.K., Singh, A.K., Singh, B.K., Barman, K., Pal, A.K. and Kumar, A. 2020. Heterosis studies for growth and yield traits in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences*, **9**:2732–2738. [Cross Ref]

Sairam, V., Raut, N., Kumar Bhavidoddi, A., Chittapur, R., Mallayya, V. and Hiremath, R.S.J. 2024. Development of tomato (*Solanum lycopersicum* L.) hybrids for protected cultivation. *Vegetable Science*, **51**(2):249–256. [Cross Ref]

Singh, N., Ram, C.N., Singh, V. and Kumar, D. 2022. Line × Tester analysis and estimating combining abilities for yield and some quality attributes in tomato (*Solanum lycopersicum* L.). *International Journal of Plant & Soil Science*, **34**(21):176–194. [Cross Ref]

Singh, S.S. 2021. Studies of heterosis for yield related traits in tomato (*Solanum lycopersicum* L.). *Biological Forum – An International Journal*, **13**(4):800–803.

Sharma, K.K., Pramila, K.K. and Kumar, S. 2025. Combining ability assessment in tomato (*Solanum lycopersicum* L.) for growth and yield. Plant Archives, **25**(1):868–874.

Tekkam, S., Pidigam, S., Adapa, K.K., Natarajan, S. and Amarapalli, G. 2021. Evaluation of parents and hybrids for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.) for per se performance. *Journal of Pharmacognosy and Phytochemistry*, **10**(1):1770–1776.

Yadav, S., Yadav, G.C., Kumar, V. and Yadav, S.K. 2016. Combining ability analysis for growth, yield and quality traits of tomato (*Solanum lycopersicon* (Mill.) Wettsd.) genotypes. *Electronic Journal of Plant Breeding*, **7**(3):761–766. [Cross Ref]