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Heterosis analysis for biochemical fruit quality parameters in tomato (*Solanum lycopersicum* L.)

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Abstract

Tomato is one of the most important vegetable crop widely grown in the world's tropics and subtropics. In this study, 8 parents were crossed in a half diallel mating design to produce 28 F₁ hybrids. The experimental materials consisted 37 entries comprising of 28 crosses, 8 parents and one standard check hybrid Arka Rakshak were evaluated in a Randomized Complete Block Design. The standard heterosis for all the characters showed that none of the hybrids displayed consistent standard heterosis for all the characters under study. The Kashi Aman × ATL-21-18 cross showed a 26.05% higher fruit yield per plant, with desirable traits like increased ascorbic acid and lycopene content. The Kashi Aman × JTL-19-06 hybrid also showed desirable fruit quality.

Keywords: Tomato, hybrid, heterosis, standard heterosis

Introduction

Tomato (*Solanum lycopersicum* L., 2n=2x=24) is an important and one of the most widely grown vegetable crops in the world's tropics and subtropics. It belongs to the genus *Solanum* of the *Solanaceae* family and ranks third in priority after the potato and onion in India, but second after the potato worldwide. It is grown both in the field as well as in the greenhouse throughout the year. Tomatoes are widely used in a variety of culinary dishes, fresh and cooked. They are also used to make ketchup, sauce, paste and canned tomatoes. They are also used in juices and drinks.

China is the largest producer of tomato, followed by India, Turkey, United States, Egypt, Iran and Mexico. In India, total production is 20.3 million tonnes, where Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Orissa and Gujarat are major producers (Anonymous, 2022) [2].

Research on the genetic control of fruit quality traits has been dominated by studies of the ripening process, since this specific developmental process in fruit greatly affects the evolution of several quality parameters like colour, aroma, soluble sugar content, total soluble solids, reducing sugar, non-reducing sugar, moisture content, lycopene content and titratable acidity. Because sugars and acids contribute significantly to the overall flavour and nutritional value of tomatoes, high soluble sugar content and titratable acidity are particularly desirable in both processing and fresh-market cultivars (Cuartero and Munoz, 1999) [5]. Therefore, fruit quality characteristics (such as soluble solids) must be improved.

The combining ability of inbred lines provides information about the genetic nature of quantitative traits and also facilitates the selection of the most appropriate parents for heterosis breeding. The expected value of any particular cross, according to Allard (1960) [1], is the sum of the general combining ability (GCA) of its two parental lines, while the deviation from this expected value is called specific combining ability (SCA). The predominance of GCA is conducive to improving selection efficiency in segregating populations (Bocanski *et al.*, 2009) [3]. The specific combining ability is the cumulative performance of any two accessions in their specific hybrid combination. Combining ability is one of the powerful tools in identifying the best combiner that may be used in crosses, either to exploit heterosis or to accumulate fixable genes. Variance due to GCA is an indicator of the extent of additive gene action, while variance due to SCA shows the extent of non-additive gene action. Additive and non-additive types of gene action are very important for the genetic expression of yield and related traits [7].

The selection of an appropriate breeding programme for maximum genetic improvement is based on relative values of general and specific combining abilities.

Diallel cross analysis provides the estimates of genetic parameters regarding combining ability and a picture of the dominance relationship of the parents studied using the first filial generation (F₁) with or without reciprocals. Diallel analysis is widely and extensively used for estimating the types of gene action. Diallel mating designs developed by Griffing (1956) [23] have been widely used in combining ability analysis of inbred lines to provide an assessment of the relative merits of parents and crosses to guide selection and testing schemes. Considering the importance of tomato

in the World, the present investigation was undertaken to study the extent of heterosis and combining ability.

Materials and Methods

The experimental materials were developed by using 8 inbred lines in a half diallel mating design at the Center for Vegetable Research during *rabi* 2023-24. All the inbred lines were made available by at Center for Vegetable Research. The details of the genotypes are given in Table 1. The experimental materials consisted 37 entries comprising of 28 crosses, 8 parents and one standard check hybrid Arka Rakshak were evaluated in a Randomized Complete Block Design with three replications during *rabi* 2024-25.

Table 1: List of inbred lines used as parents

Sr. No.	Name of inbred line	Source
1	Kashi Aman	Center for Vegetable Research, Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada.
2	Kashi Adarsh	
3	ATL-21-18	
4	SKT-7	
5	SKT-6	
6	GAT 5	
7	DVRT 2	
8	JTL-19-06	

Seedlings were transplanted in each plot in one row of ten dibbles with a distance of 90 cm between rows and 45 cm between plants. Five plants were randomly selected from each experiment unit in all the replications except the border plants and fruits from those plants were used for recording the observation like pericarp thickness (mm), moisture content (%), total soluble solids (^oBrix), total soluble sugar (%), titrable acidity (%), ascorbic acid (mg/100g), lycopene content (mg/100g) and Phenol (mg/100g). Analysis of variance, was as per the method given by Panse and Sukhatme (1978) [16]. Calculation of standard heterosis was done using formula given by Meredith and Bridge, 1972 [14].

Results and Discussion

The analysis of variance showed that mean squares due to genotypes were significant for all the characters, which revealed the existence of sufficient genetic variability in the experimental materials. The variance due to parents was also found to be significant for all the characters. The mean square due to the hybrid indicated a significant difference for all the traits under study. Mean sum of squares due to parents vs hybrids showed significant differences for characters under study, viz., fruit yield per plant, pericarp thickness, total soluble solids, total soluble sugar, titrable acidity, lycopene content and phenol, which suggested the existence of differences between parents and hybrids leading to the manifestation of heterosis. Mean sum of squares due to check vs hybrids were significant for characters like total soluble solids, total soluble sugar, titrable acidity, ascorbic acid and phenol (Table 2).

Fruit yield per plant

For fruit yield per plant, estimates of standard heterosis are desirable in positive direction. The standard heterosis ranged from -31.24 percent to 26.05 percent. Out of 16 significant crosses, 4 were found positively significant. The top three crosses were Kashi Aman × ATL-21-18 (26.05%), Kashi Aman × JTL-19-06 (25.80%) and SKT-7 × GAT 5

(18.31%). The results were similar to results of Choudhary *et al.* (2018) [4], Khar and Arti (2019) [9], Maurya and Yadav (2021) [13], Shirisha *et al.* (2021) [19], Kathimba *et al.* (2022) [8], Pavan *et al.* (2022) [17] and Kumar *et al.* (2023) [10].

Pericarp thickness

The standard heterosis in positive direction is desirable for pericarp thickness. The standard heterosis ranged from -34.25 percent to 28.16 percent. Out of 14 significant crosses, 8 were found significant in positive direction. The top crosses were Kashi Adarsh × GAT 5 (28.16%), SKT-7 × JTL-19-06 (26.03%) and Kashi Aman × SKT-7 (25.28%) (Table 3). The results were similar to the findings of Kumari *et al.* (2020) [12], Singh *et al.* (2020) [21], Kumar *et al.* (2021) [11], Maurya and Yadav (2021) [13] and Mishra *et al.* (2021) [15].

Moisture content

The standard heterosis in negative direction is desirable for moisture content. The standard heterosis ranged from -6.75 percent to 2.61 percent. All the 5 significant crosses were found significant in negative direction. The top crosses were GAT 5 × JTL-19-06 (-6.75%), DVRT 2 × JTL-19-06 (-6.62%), SKT-7 × JTL-19-06 (-5.51%) and Kashi Aman × JTL-19-06 (-5.1%). The results were in close agreement with the findings of Singh (2005) [22].

Total soluble solids

The estimates of standard heterosis in positive direction are desirable. The standard heterosis varied from -44.77 percent to 18.60 percent. Out of 26 significant crosses, 5 crosses were significant in positive direction. Top three crosses were SKT-6 × GAT 5 (18.60%), Kashi Aman × JTL-19-06 (15.12%) and Kashi Aman × SKT-6 (11.63%). The findings align with the studies conducted by Savale *et al.* (2017) [18], Maurya and Yadav (2021) [13], and Kathimba *et al.* (2022) [8], which demonstrated standard heterosis in both negative and positive directions.

Total soluble sugar

The standard heterosis in positive direction are desirable for total soluble sugar. While the standard heterosis ranged from -42.46 percent to 21.72 percent. Out of 26 significant crosses, 7 crosses were positively significant. The top crosses were SKT-7 × GAT 5 (21.72%), SKT-7 × DVRT 2 (19.61%) and Kashi Aman × JTL-19-06 (19.12%). The findings align with the studies conducted by Kumari *et al.* (2020)^[12], Singh *et al.* (2020)^[21], Maurya and Yadav (2021)^[21], Mishra *et al.* (2021)^[15], and Kumar *et al.* (2023)^[10].

Titration acidity

The magnitude of standard heterosis in positive direction is desirable for this trait. The magnitude of standard heterosis varied from -59.57 percent to 31.91 percent. Out of 21 significant crosses, 5 crosses were found significant in positive direction. Top crosses were ATL-21-18 × SKT-6 (31.91%), SKT-6 × GAT 5 (29.79%) and Kashi Aman × Kashi Adarsh (25.53%). The results of this character align with the studies conducted by Singh *et al.* (2020)^[21], Maurya and Yadav (2021)^[21], and Pavan *et al.* (2022)^[17] regarding standard heterosis.

Ascorbic acid: The estimates of standard heterosis in positive direction are desirable. The standard heterosis over standard check Arka Rakshak ranged from -37.86 percent to 37.02 percent. Out of 22 significant crosses, only 1 cross,

ATL-21-18 × DVRT 2 (37.02%), was found significant in positive direction. The results for this character are comparable with the findings observed by Singh *et al.* (2020)^[21], Mishra *et al.* (2021)^[15], Pavan *et al.* (2022)^[17] and Kumar *et al.* (2023)^[10].

Lycopene content: The heterosis over standard check in positive direction is desirable for this trait. The standard heterosis ranged from -40.30 percent to 58.51 percent. Out of 25 significant crosses, 14 were found positively significant. The top cross-combination reported was Kashi Aman × SKT-7 (58.51%) followed by Kashi Aman × DVRT 2 (52.02%) and ATL-21-18 × SKT-6 (49.76%). The findings were in accordance with Khar and Arti (2019)^[9], Singh *et al.* (2019)^[20] and Pavan *et al.* (2022)^[17].

Phenol

The standard heterosis in negative direction is desirable for phenol content to reduce bitterness. The standard heterosis varied from -26.79 percent to 134.35 percent. A total of 21 significant crosses, only 5 crosses were found significant in the negative direction. Top crosses were Kashi Aman × DVRT 2 (-26.79%), ATL-21-18 × DVRT 2 (-21.16%) and ATL-21-18 × SKT-6 (-18.57%). The results are in agreement with the findings of Figueiredo *et al.* (2015)^[6] for standard heterosis, as they reported positive as well as negative.

Table 2: Analysis of variance for fruit quality characters under study in tomato

Source of variation	d.f.	FYP	PT	MC	TSS	TSSu	TA	AA	LYC	PHE
Replications	2	33262.645	0.203	3.339	0.006	0.006 *	0.008	2.558	1.636	9.140
Genotypes	36	173237.326**	6.621 **	16.941 **	2.810 **	0.606 *	0.182 **	35.804 **	80.283 **	722.871 **
Parents	7	61787.440**	2.986 **	20.993 **	3.469 **	1.168 **	0.223 **	23.972 **	44.505 **	1360.851 **
Hybrids	27	201520.796**	6.534 **	16.781 **	2.513 **	0.487 **	0.182 **	39.403 **	89.269 **	603.458 **
Parents vs. Hybrids	1	286051.910**	40.343 **	7.429	3.268 **	0.213 **	0.035 *	12.431 **	168.380 **	30.271 **
Check vs. Hybrids	1	76918.230	0.683	2.411	5.758**	0.257 **	0.049 **	44.802 **	0.0297	173.758 **
Error	72	20211.712	0.300	2.665	0.042	0.002	0.0057637	1.370	0.795	4.306

*, ** indicate level of significance at 5% and 1%, respectively

Table 3: Magnitude of standard heterosis for various characters of tomato

Sr. No.	Crosses	Standard Heterosis (%)								
		FYP	PT	MC	TSS	TSSu	TA	AA	LYC	PHE
1	Kashi Aman × Kashi Adarsh	-29.49**	18.90**	-0.05	-26.74**	-18.15**	25.53**	-21.93**	36.96**	12.11*
2	Kashi Aman × ATL-21-18	26.05**	-10.81	0.90	-25.58**	-26.42**	-2.13	-1.22	17.08**	19.10**
3	Kashi Aman × SKT-7	-18.24*	25.28**	1.61	-33.14**	-7.46**	-2.13	-25.12**	58.51**	-10.37*
4	Kashi Aman × SKT-6	-12.04	-10.05	0.71	11.63**	-20.91**	-6.38	-10.78*	-23.10**	-4.15
5	Kashi Aman × GAT 5	-20.72**	-32.04**	-1.64	-23.84**	-0.32	-59.57**	-34.68**	-22.74**	9.08
6	Kashi Aman × DVRT 2	-18.85*	1.38	2.61	-43.02**	5.51**	-46.81**	-37.86**	52.02**	-26.79**
7	Kashi Aman × JTL-19-06	25.80**	22.28**	-5.10**	15.12**	19.12**	-8.51	-21.93**	-38.87**	79.41**
8	Kashi Adarsh × ATL-21-18	-27.61**	-8.72	0.13	-41.86**	12.48**	-27.66**	-37.86**	13.57**	2.35
9	Kashi Adarsh × SKT-7	-22.17**	-21.9**	-0.95	-35.47**	-36.63**	-27.66**	-9.18*	-20.95**	-1.17
10	Kashi Adarsh × SKT-6	-19.25*	-8.09	-1.45	-36.05**	-23.34**	-46.81**	-33.08**	34.94**	46.14**
11	Kashi Adarsh × GAT 5	-7.50	28.16**	-1.15	-27.33**	-2.11	4.26	-26.71**	12.86**	-14.94**
12	Kashi Adarsh × DVRT 2	-26.24**	3.17	2.39	-43.02**	16.37**	-14.89*	-31.49**	44.35**	2.26
13	Kashi Adarsh × JTL-19-06	-10.02	2.88	-1.06	10.47**	-10.05**	-12.77*	-20.34**	-35.18**	111.52**
14	ATL-21-18 × SKT-7	5.38	-21.61**	-2.89	-22.67**	-38.9**	-27.66**	-6.00	0.60	10.95*
15	ATL-21-18 × SKT-6	-12.07	-34.25**	2.06	-44.19**	-24.64**	31.91**	-28.3**	49.76**	-18.57**
16	ATL-21-18 × GAT 5	0.31	3.88	-1.56	-14.53**	4.05*	-25.53**	-10.78*	-38.04**	-6.43
17	ATL-21-18 × DVRT 2	5.77	16.40**	2.61	-26.16**	-12.48**	-42.55**	37.02**	-6.73	-21.16**
18	ATL-21-18 × JTL-19-06	-12.88	5.21	1.06	-27.91**	-34.52**	-29.79**	-33.08**	-21.31**	134.35**
19	SKT-7 × SKT-6	-7.06	-22.40**	1.91	-44.77**	-18.64**	12.77*	-20.34**	41.49**	17.9**
20	SKT-7 × GAT 5	18.31*	-34.21**	-0.23	-27.91**	21.72**	-6.38	0.37	-40.3**	-0.80
21	SKT-7 × DVRT 2	-27.35**	-9.55	-0.18	-27.91**	19.61**	-44.68**	-1.22	11.55**	16.72**
22	SKT-7 × JTL-19-06	15.50*	26.03**	-5.51**	8.14**	-17.02**	8.51	-20.34**	17.2**	79.86**
23	SKT-6 × GAT 5	15.01	-8.89	-1.63	18.60**	-22.69**	29.79**	-20.34**	-3.10	12.42*
24	SKT-6 × DVRT 2	-24.37**	-10.68	0.99	-37.79**	-13.13**	23.4**	-23.52**	33.1**	30.00**

25	SKT-6 × JTL-19-06	-0.99	15.35**	-3.65*	3.49	-42.46**	-27.66**	-6.00	-14.88**	84.11**
26	GAT 5 × DVRT 2	-14.84	15.31**	-0.94	-36.05**	-40.03**	-25.53**	-12.37**	15.12**	24.33**
27	GAT 5 × JTL-19-06	-31.24**	-9.18	-6.75**	3.49	-25.77**	-14.89*	-31.49**	-14.40**	15.65**
28	DVRT 2 × JTL-19-06	-16.81*	3	-6.62**	-36.63**	-35.49**	-25.53**	-25.12**	-36.43**	34.46**
S.Em. ±		116.08	0.45	1.33	0.18	0.04	0.06	0.96	0.73	1.69
Range	Minimum	-31.24	-34.25	-6.75	-44.77	-42.46	-59.57	-37.86	-40.30	-26.79
	Maximum	26.05	28.16	2.61	18.60	21.72	31.91	37.02	58.51	134.35
Positive significant		4	8	0	5	7	5	1	14	16
Negative significant		12	6	5	21	19	16	22	11	5
Total significant		16	14	5	26	26	21	23	25	21

*, ** indicate level of significance at 5% and 1%, respectively

FYP = Fruit yield per plant, **PT** = Pericarp thickness, **MC** = Moisture content, **TSS** = Total soluble solids, **TSSu** = Total soluble sugar, **TA** = Titrable acidity, **AA** = Ascorbic acid, **LYC** = Lycopene content and **PHE** = Phenol

Conclusion

The cross Kashi Aman × ATL-21-18 recorded 26.05 percent higher fruit yield per plant than standard check. This cross exhibited significant standard heterosis characters, such as increased ascorbic acid and lycopene content, in a desirable direction. The other superior hybrid, Kashi Aman × JTL-19-06, had higher standard heterosis for fruit yield per plant (25.80%). This cross also showed desirable, significant standard heterosis for fruit quality characters, such as pericarp thickness and total soluble sugar. This crosses can be released as hybrid variety after multiple trials.

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References

- Allard RW. Principles of plant breeding. New York: John Wiley and Sons; 1960.
- Agricultural and Processed Food Products Export Development Authority. 2022 [cited 2025 Jul 10]. Available from: <https://agriexchange.apeda.gov.in>
- Boćanski J, Srećkov Z, Nastasić A. Genetic and phenotypic relationship between grain yield and components of grain yield of maize (*Zea mays* L.). Genetika. 2009;41(2):145-54.
- Choudhary P, Rai GK, Bagati S, Jamwal D, Bhadwal D, Raj SV, et al. Evaluation of genetic variability in tomato (*Solanum lycopersicum* L. Mill) genotypes using microsatellite markers. Int J Curr Microbiol Appl Sci. 2018;7(1):2117-24.
- Cuartro J, Fernandez-Munoz R. Tomato and salinity. Sci Hortic. 1999;78:83-125.
- Figueiredo AST, Resende JTV, Faria MV, Paula JT, Schwarz K, Zanin DS. Combining ability and heterosis of relevant fruit traits of tomato genotypes for industrial processing. Crop Breed Appl Biotechnol. 2015;15(3):154-61.
- Sirba HY, Begna T, Gojam M. Evaluating performance of recently released tomato *Lycopersicon esculentum* Mill. varieties at highland areas of West Hararghe, Ethiopia. Int J Res Agron. 2022;5(2):18-24.
- Kathimba FK, Kimani PK, Narla RD, Kiriika LM. Heterosis and combining ability for related traits in tomato. Afr Crop Sci J. 2022;30(Suppl 1):109-25.
- Khar S, Arti D. Heterosis studies for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.) under north western Himalayan region, India. Int J Curr Microbiol Appl Sci. 2019;8(1):52-61.
- Kumar BS, Mali SC, Patel AI, Prajapati MR. Appraisal of combining ability and gene action for yield, its governing characters and quality traits in tomato (*Solanum lycopersicum* L.). Electron J Plant Breed. 2023;14(2):752-7.
- Kumar K, Sharma D, Singh J, Chandel N. Heterosis for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.). Veg Sci. 2021;48(1):41-8.
- Kumari S, Khanna A, Dogra BS. Heterotic expression for yield and its components in tomato (*Solanum lycopersicum* L.). J Pharmacogn Phytochem. 2020;9(6):270-275.
- Maurya N, Yadav GC. Estimates of heterosis for yield and its attributing traits in tomato (*Solanum lycopersicum* L.) crop. Pharma Innov J. 2021;10(7):1124-1132.
- Meredith WE, Bridge RR. Heterosis and gene action in cotton (*Gossypium hirsutum* L.). Crop Sci. 1972;12:304-310.
- Mishra A, Nandi A, Thriveni V, Das S, Mohanty IC, Pattanayak SK. Heterosis in tomato (*Solanum lycopersicum*) hybrids for growth, yield and quality traits. Pharma Innov J. 2021;10(6):220-9.
- Panse VG, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: ICAR; 1978. p. 87-9.
- Pavan MP, Gangaprasad S, Dushyanthakumar BM, Adivappar N, Shashikumara P. 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. 2022;218(7):1-20.
- Savale SV, Patel AI, Sante PR. Study of heterosis over environments in tomato (*Solanum lycopersicum* L.). Int J Chem Stud. 2017;5(3):284-9.
- Shirisha T, Saidaiah P, Kumar AK, Sivaraj N, Geetha A. Studies on heterosis for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). Pharma Innov J. 2021;10(8):465-71.
- Singh AK, Solankey SS, Kumari M, Singh N. Morpho-chemical quality improvement in tomato (*Solanum lycopersicum*) through heterosis breeding. Indian J Agric Sci. 2019;89(8):1251-5.
- Singh N, Kumar R, Chaudhary N, Singh RP. Line × tester analysis for yield and quality traits in tomato. Agriways. 2020;8(1):9-16.
- Singh S. Genetic analysis of fruit yield and quality characters in tomato (*Lycopersicon esculentum* Mill.) [master's thesis]. Anand: Anand Agricultural University; 2005.

23. Griffing B. A generalized treatment of the use of diallel crosses in quantitative inheritance. *Heredity*. 1956;10:31-50.