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RESEARCH ARTICLE

Development of tomato (*Solanum lycopersicum* L.) hybrids for protected cultivation

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Abstract

The present study was conducted during the *kharif* season of 2022-23 at the College of Horticulture, Bagalkot, Karnataka. Thirty F_1 hybrids, derived from line × tester mating design, were evaluated in two replications along with their parents and checked. Results showed that lines AVTO1920, AVTO1429, and AVTO1464 had good general combining ability (GCA) for growth, earliness, and yield traits. The crosses AVTO1920 × AVTO1464, AVTO1429 × AVTO1464, and AVTO1920 × Anagha exhibited positive specific combining ability (SCA) effects for yield traits. The GCA/SCA variance ratio indicated both additive and non-additive gene action. Significant heterosis over mid-parent, a better parent, and a standard check were observed across 20 traits. Notably, AVTO1920 × AVTO1464 and AVTO1429 × AVTO1464 showed maximum positive heterosis over the standard check, while III-5 × AVTO1464 and AVTO1915 × AVTO1464 excelled over the better parent for yield traits, making them suitable for polyhouse cultivation.

Keywords: Polyhouse, Line ×Tester, GCA, SCA, Heterosis, Tomato.

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Introduction

Tomato (*Solanum lycopersicum* L.) is a popular vegetable all over the world because of its high nutritive value and versatile uses (Kumar et al., 2011). It belongs to the nightshade family and is an autogamous crop having chromosome number 2n = 24. Tomato is a warm season crop and requires a relatively long growing season and moderately high temperature (20-28°C). It ensures that the optimum fruit setting is at night temperature and the optimum range is 15°-20°C (Jindal et al., 2015). In India, it occupies an area of 0.83 million ha with an annual production of 21.0 million tons and a productivity of 25.32 mha^{-1}. Tomato is universally treated as 'Protective Food' since it is very rich in minerals, vitamins, antioxidants, essential amino acids, sugars, and dietary fibers, which are important ingredients for culinary and table purposes, chutney, pickles, ketchup, soup, juice, puree etc. (Sekhar et al., 2010). It is typically a day-neutral plant and self-pollinated crop but a certain percentage of cross pollination also occurs.

Protected cultivation has become increasingly important for vegetable farming, enhancing production, yield, quality and protection from pests and diseases. Tomatoes, especially indeterminate types, thrive in polyhouse conditions, offering higher yields and extended growing seasons (Prakash et al., 2019). Combining ability analysis is crucial for selecting superior parents for hybridization, with general combining ability (GCA) aiding in the selection of parents with additive gene traits and specific combining ability (SCA) identifying superior hybrids with non-additive traits. Heterosis breeding, through F_1 hybrids, enhances yield and quality, making it vital for developing superior, stable hybrids.

Materials and Methods

The experiment was conducted in a naturally ventilated polyhouse of the Department of Vegetable Science, College of Horticulture, Bagalkot, Karnataka, India, during *Kharif* season of 2023 (June-July). It is located at an altitude of 533 meters above mean sea level (MSL)at 16°18'N latitude and 75°07' E longitude in the Northern Dry Zone of Karnataka (Zone-III) with North-South direction of polyhouse having 560 m^2 area. The experimental polyhouse consists raised beds of red sandy loam soil (Alfisol) with uniform soil fertility. 30 hybrids were produced from 10 lines and 3 testers in line × tester mating design. The parents, hybrids and check were randomized separately and sown using Randomized Block Design (RCBD) with two replications. The details of ten lines, three testers and one check were listed in Table 1. Eight plants of each genotype were planted at a spacing of 60 cm × 45 cm. Observations were recorded on five randomly selected plants in each replication for different growth, earliness, yield and quality traits.

Statistical analysis

Data analysis was done by using INDOSTAT. Average means of hybrids, parents and check were used for the analysis of variance (Steel and Torrie, 1980). The combining ability analysis was done following the model given by Kempthrone (1957). Heterosis was determined as per method suggested by Wynne et al. (1970). The estimation of heterosis value of hybrid was analyzed based on the heterobeltiosis value was analyzed based on the mean of the better parent. In case of standard check heterosis, Pusa Rakshith was taken as a commercial check.

Table 1: Details of lines, testers and check used in this study

S. No	*Genotypes*	*Entry*	*Source*
Lines			
1	AVTO1706	AVTO1	World Vegetable Center, Taiwan
2	AVTO1920	AVTO2	
3	AVTO1429	AVTO3	
4	AVTO1954	AVTO4	
5	AVTO1914	AVTO5	
6	AVTO1915	AVTO6	
7	AVTO2017	AVTO7	
8	AVTO1701	AVTO8	
9	AVTO0301	AVTO9	
10	III-5	III-5	Improved line developed at COH, Bagalkot
Testers			
1	Anagha	T 1	KAU
2	AVTO1464	T 2	WVC, Taiwan
3	IV-106	T 3	COH, Bagalkot
Check			
1	Pusa Rakshith	C 1	IARI, ND

Results and Discussion

The analysis of variance (ANOVA) among parents (lines, testers) and crosses for 10 traits revealed highly significant differences ($p = 0.01$) across all traits (Table 2). Lines showed significant variance for all traits except days to first flowering, while testers showed significant variance for all but days to the first harvest. The lines × testers interaction and parents *vs* crosses also exhibited highly significant variance for all traits. 44 genotypes, including 30 hybrids, 10 lines, three testers and one check, were evaluated for the growth, earliness, yield and quality parameters and their *per se* performance was presented in Table 3. The analysis of variance for combining ability revealed significant variation due to both GCA and SCA for all traits, except fruit firmness and average fruit weight, which were non-significant for SCA. This highlights the roles of both additive and non-additive gene action in trait inheritance. GCA effects were estimated for parents, while SCA effects were calculated for hybrids. Understanding the magnitude of GCA helps identify superior parents for hybridization, while SCA aids breeders in selecting the best cross-combinations to achieve desirable transgressive segregants with higher probability. The character-wise categorization of combining ability effects in the GCA of the parents and SCA of the crosses have been presented in Tables 4 and 5. In the present study, among the lines, AVTO3, AVTO8 and tester-AVTO1464 were identified as the best general combiner for plant height at maturity, while in case of hybrids, AVTO7 × T3 was the best specific combiner. Similar results have been reported by Kumar et al. (2016), Bhalala and Acharya (2019), Pandey et al. (2006), Singh et al. (2008), and Chakrabarty et al. (2019) in tomato for the above-mentioned trait. Highly significant GCA and SCA effects in a negative direction for days to first harvest were recorded in parents, AVTO5, AVTO2 and in hybrids, AVTO6 × T1 and AVTO3 × T2, respectively. For days to first harvest, significant values were found in lines AVTO7, AVTO5 for GCA and hybrid III-5 × IV-106 for SCA. These findings for earliness traits were in support with the earlier research findings by Akram et al. (2012), Chakrabarty et al. (2019) and Kumar et al. (2018). For quality parameters like fruit firmness, significant, highest positive GCA effects were observed in III-5 and in case of shelf life, AVTO4, AVTO3, and AVTO2 revealed high significant positive GCA effects. Similar results were obtained by Bhalala and Acharya (2019)

Table 2: Analysis of variance for parents and hybrids (Line × Tester) in tomato for growth, earliness, quality and yield traits

S. No.	Source	*Mean sum of square*							
		Replications	*Parents*	*Lines*	*Testers*	*Lines vs. Testers*	*Parents vs. Crosses*	*Crosses*	*Error*
Degrees of freedom (df)		1	12	9	2	1	1	29	42
1	Plant height (cm)	0.189	2593.001**	2966.906**	524.579**	3364.699**	113.691**	2724.958**	14.413
2	Days to first flowering (No.)	0.740	2.292**	0.973	5.469**	7.808**	34.930**	1.901**	0.673
3	Days to first harvest (No.)	11.582	12.685**	11.468**	10.430*	28.150**	43.425**	17.638**	3.103
4	Shelf life (Days)	0.144	1.922**	1.540**	2.707**	3.790**	2.478**	1.528**	0.039
5	Number of fruits per cluster (No.)	0.001	1.110**	0.853**	1.742**	2.158**	0.866**	1.058**	0.013
6	Number of fruits per Plant (No.)	0.021	99.082**	107.375**	110.559**	1.500	38.014**	169.075**	1.222
7	Average fruit wt. (g)	8.84	294.588**	263.970**	355.375**	448.57**	34.593**	243.823**	4.238
8	Yield per plant (kg)	0.004	1.303**	1.589**	0.354**	0.624**	0.203**	2.050**	0.012
9	Yield per hectare (tonnes)	22.40	1147.561**	1430.865**	222.358**	448.3**	200.641**	1773.46**	11.087

* - Significant at 5% and **- Significant at 1%,

Table 3: Estimates of general combining ability effects for growth, earliness, quality and yield traits in tomato

S. No	*Genotypes*	*PH*	*FF*	*FH*	*SL*	*FRC*	*NFP*	*AFW*	*FYP*	*FYH*
	Lines									
1	AVTO1	-38.68**	-0.19	-0.87	0.36**	0.32**	7.52**	-2.27*	0.53**	16.95**
2	AVTO2	-39.55**	-0.95**	-0.54	0.76**	1.30**	19.77**	10.51**	2.32**	65.70**
3	AVTO3	84.96**	0.18	-1.03	0.97**	-0.79**	-5.57**	14.83**	0.15**	4.49**
4	AVTO4	-8.81**	0.26	3.91**	1.42**	-0.86**	-9.16**	-5.68**	-1.06**	-31.82**
5	AVTO5	11.07**	-1.01**	-1.82*	-0.24**	0.05	-7.29**	0.39	-0.68**	-19.74**
6	AVTO6	-34.15**	-0.53	1.56*	-1.30**	0.167**	6.59**	-7.83**	0.122*	5.55**
7	AVTO7	16.59**	0.24	-3.10**	-0.39**	-0.31**	0.19	-21.33**	-0.94**	-28.12**
8	AVTO8	27.39**	0.94**	2.09**	0.09	0.30**	-8.39**	9.47**	-0.29**	-9.43**
9	AVTO9	-8.88**	-0.04	0.25	-1.03**	0.61**	-2.95**	-7.15**	-0.55**	-16.54**
10	III-5	-9.93**	1.11**	-0.44	-0.63**	-0.80**	-0.72	9.05**	0.41**	12.96**
	S.Em. ±	1.55	0.35	0.719	0.08	0.05	0.45	0.87	0.045	1.351
	C.D. @ 5%	3.17	0.68	1.47	0.17	0.01	0.92	1.78	0.091	2.780
	C.D. @ 1%	4.27	0.92	1.9823	0.23	0.13	1.24	2.40	0.123	3.747
	Testers									
1	T 1	-2.35**	-0.37	-0.676	-0.07	-0.21**	-2.59**	-0.79	-0.26**	-8.261**
2	T 2	5.83**	0.24	0.824*	0.06	0.30**	3.01**	3.05**	0.445**	13.91**
3	T 3	-3.48**	0.13	-0.148	0.08	-0.09**	-0.51**	-2.26**	-0.18**	-5.65**
	S.Em. ±	0.85	0.18	0.3939	0.04	0.03	0.25	0.48	0.03	0.745
	C.D. at 5%	1.74	0.37	0.8056	0.09	0.06	0.51	0.97	0.05	1.53
	C.D. at 1%	2.34	0.50	1.0858	0.12	0.07	0.68	1.31	0.06	2.05

Where, PH = Plant height; FF = Days to first flowering; FH = First harvest; FYP = Fruit yield per plant; FRC = Fruits per cluster, NFP = Number of fruits plant; AFW = Average fruit weight; SL = Shelf life; FYH = Fruit yield per hectare;

Table 4: Estimates of specific combining ability (SCA) effects for growth, earliness, quality and yield traits in tomato.

S. No	*Genotypes*	*PH*	*FF*	*FH*	*SL*	*FRC*	*NFP*	*AFW*	*FYP*
AVTO1×T1	0.99	-0.486	-1.033	-0.486	0.26**	1.03	2	0.01	2.7
AVTO1×T2	0.06	-0.058	0.778	-0.058	-0.07	-3.0**	-0.93	-0.2*	-6.76**
AVTO1×T3	-1.06	0.544	0.255	0.544	-0.19*	1.98*	-1.06	0.2*	4.06
AVTO2×T1	-1.23	-0.244	-2.246	-0.244	0.26**	3.11**	0.16	0.2**	7.07**
AVTO2×T2	-2.29	-0.021	-0.541	-0.021	-0.16	-1.18	-1.29	0.05	-0.54
AVTO2×T3	3.52	0.266	2.787 *	0.266	-0.1	-1.93*	1.14	-0.28**	-6.53**
AVTO3×T1	4.19	1.142	-1.744	1.142	0.07	1.44	-0.12	0	-0.07
AVTO3×T2	0.95	-1.285*	3.691**	-1.28*	0.13	1.08	2	0.25**	7.96**
AVTO3×T3	-5.14	0.142	-1.947	0.142	-0.20*	-2.5**	-1.88	-0.25**	-7.88**
AVTO4×T1	5.8*	0.777	2.831*	0.777	-0.17*	-1.58	-1.19	-0.16	-4.93*
AVTO4×T2	0.06	0.26	-1.199	0.26	0.16	0.91	-0.4	0.04	2.37
AVTO4×T3	-5.8*	-1.038	-1.632	-1.038	0.01	0.68	1.59	0.12	2.57
AVTO5×T1	1.18	1.084	1.977	1.084	0.01	0.54	1.25	0.1	2.21
AVTO5×T2	5.5*	-0.843	-2.027	-0.843	0.14	0.79	-0.26	0.06	3.97
AVTO5×T3	-6.70	-0.241	0.05	-0.241	-0.14	-1.33	-0.99	-0.16*	-6.18*
AVTO6×T1	-2.64	-1.199*	-1.681	-1.11*	-0.02	0.23	-3.19*	-0.06	-5.35*
AVTO6×T2	-2.31	0.474	2.055	0.474	0.06	1.44	0.4	0.08	4.14
AVTO6×T3	4.95	0.726	-0.374	0.726	-0.04	-1.6*	2.79	-0.02	1.22*
AVTO7×T1	-5.45	-0.113	0.229	-0.113	-0.12	-1.6*	0.4	0.02	-1.62
AVTO7×T2	-4.44	0.9	-2.256	0.9	-0.08	0.09	-1.24	-0.20*	-4.88*
AVTO7×T3	9.9**	-0.788	2.026	-0.788	0.19*	1.56	0.84	0.19*	6.50**
AVTO8×T1	1.10	-0.203	-1.714	-0.203	-0.04	0.47	-1.52	-0.03	2.41
AVTO8×T2	-1.75	0.08	1.141	0.08	-0.08	-0.39	1.27	-0.06	-5.46*
AVTO8×T3	0.64	0.122	0.573	0.122	0.12	-0.09	0.25	0.08	3.06
AVTO9×T1	1.06	-0.621	-2.109	-0.621	-0.22*	-2.0*	2.34	-0.01	-0.51
AVTO9×T2	1.79	0.102	0.131	0.102	-0.07	-0.67	-1.61	-0.18*	-5.39*
AVTO9×T3	-2.85	0.519	1.978	0.519	0.29**	2.7**	-0.73	0.19*	5.89*
III-5 ×T1	-4.95	-0.138	5.491**	-0.138	-0.04	-1.54	-0.12	-0.09	-1.91
III-5 ×T2	2.40	0.39	-1.774	0.39	-0.04	0.96	2.07	0.16	4.6
III-5 ×T3	2.55	-0.253	-3.717**	-0.253	0.07	0.57	-1.95	-0.06	-2.69
S.Em. ±	2.65	0.58	1.2457	0.58	0.08	0.78	1.5	0.08	2.35
CD at 5%	5.49	1.1863	2.5477	1.19	0.17	1.6	3.08	0.16	4.82
CD at 1 %	7.40	1.5988	3.4335	1.59	0.22	2.15	4.15	0.21	6.49

Where, PH = Plant height; FF = Days to first flowering; FH = First harvest; FYP = Fruit yield per plant; FRC = Fruits per cluster, NFP = Number of fruits/plant; AFW = Average fruit weight; SL = Shelf life;

Table 5: Heterosis (%) over better parent & standard checks for growth and earliness traits in tomato

Crosses	*Plant height (cm)*		*Days to first flowering (n)*		*Days to first harvest (n)*		*Shelf life (n)*		*Number of fruits per cluster*	
	BP	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*
AVTO1×T1	-9.84 **	-17.06 **	-5.6	-4.72	-0.97	-5.38	-2.17	-5.33 *	-3.83	44.48 **
AVTO1×T2	-19.62 **	-11.39 **	-6.25 *	-1.19	0.62	-0.97	-18.75 **	-3.61	0.41	50.86 **
AVTO1×T3	-6.35	-19.55 **	0.14	0.51	-4.52	-2.97	1.61	-1.35	-10.35 **	34.68 **
AVTO2×T1	-12.47 **	-19.48 **	-8.59 **	-6.45 *	-2.2	-6.56 **	-2.95	1.02	7.33 **	75.27 **
AVTO2×T2	-21.91 **	-13.91 **	-8.56 **	-3.63	-0.72	-2.29	-16.70 **	-1.18	9.43 **	78.69 **
AVTO2×T3	-5.19	-16.65 **	-5.21	-3	-0.76	0.85	-1.14	2.91	2.95	68.12 **
AVTO3×T1	-0.03	82.11 **	-5.32 *	2.09	-4.81	-6.54 **	2.75	4.63 *	-9.09 **	4.2
AVTO3×T2	2.1	85.98 **	-11.07 **	-4.1	4.35	2.7	-12.48 **	3.82	8.71 *	22.24 **
AVTO3×T3	-4.52 **	73.93 **	-6.88 *	0.41	-7.61 **	-6.11 *	-1	0.81	-27.08 **	-0.31
AVTO4×T1	6.22 *	10.05 **	-2.89	1.12	11.10 **	6.14 *	-0.5	8.24 **	-21.14 **	-5.44
AVTO4×T2	1.57	11.97 **	-3.76	1.43	4.42	2.77	-7.58 **	9.64 **	1.17	21.31 **
AVTO4×T3	-3.42	0.06	-7.18 *	-3.34	-0.71	0.9	-2.62	5.92 **	-23.89 **	4.04
AVTO5×T1	0.04	21.99 **	-6.31 *	-2.15	-1.73	-2.63	-7.07 **	-10.07 **	-11.40 **	28.15 **
AVTO5×T2	8.07 **	31.77 **	-11.42 **	-6.64 *	-5.10 *	-5.96 *	-22.15 **	-7.65 **	2.8	48.68 **
AVTO5×T3	-5.74 *	14.94 **	-8.98 **	-4.94	-6.02 *	-4.49	-9.48 **	-12.12 **	-11.83 **	27.53 **
AVTO6×T1	-23.63 **	-16.35 **	-14.70 **	-8.29 **	-2.09	-3	-20.42 **	-22.99 **	4.2	31.10 **
AVTO6×T2	-18.09 **	-9.70 **	-7.48 **	-0.53	4.96 *	3.98	-31.73 **	-19.01 **	19.28 **	50.08 **
AVTO6×T3	-19.03 **	-11.31 **	-7.00 *	-0.02	-2.14	-0.55	-19.91 **	-22.24 **	-1.71	34.37 **
AVTO7×T1	-12.72 **	21.08 **	-4.3	-1.96	-2.32	-6.67 **	-11.02 **	-13.89 **	-1.22	13.22 **
AVTO7×T2	-7.51 **	28.30 **	-1.74	3.56	-6.51 *	-7.98 **	-23.56 **	-9.32 **	19.12 **	30.79 **
AVTO7×T3	-4.65 *	32.27 **	-4.87	-2.54	-5.12 *	-3.57	-8.82 **	-11.47 **	-7.17 *	26.91 **
AVTO8×T1	-4.85 *	34.68 **	-5.27	0.1	1.46	-2.34	-2.02	-3.28	-6.77 *	34.84 **
AVTO8×T2	-1.9	38.86 **	-2.4	3.13	5.13 *	3.47	-23.83 **	-9.64 **	3.55	49.77 **
AVTO8×T3	-5.73 *	33.44 **	-2.59	2.93	-0.21	1.41	-4.80 *	-6.03 **	-0.75	43.55 **
AVTO9×T1	0.35	6.29 *	-9.34 **	-4.67	-0.9	-5.32 *	-20.26 **	-22.83 **	-2.19	38.88 **
AVTO9×T2	2.74	13.26 **	-5.25	-0.14	1.27	-0.33	-29.05 **	-15.83 **	12.49 **	59.72 **
AVTO9×T3	-3.37	2.34	-4.02	0.94	-0.78	0.83	-13.98 **	-16.48 **	11.72 **	58.63 **
III-5 ×T1	1.44	0.77	-4.97	0.92	6.49 *	3.89	-13.41 **	-16.21 **	-12.35 **	0.47
III-5 ×T2	2.42	12.91 **	-1.33	4.78	-2.25	-3.8	-27.37 **	-13.84 **	15.01 **	16.80 **
III-5 ×T3	6.45 *	5.75	-3.72	2.25	-9.16 **	-7.68 **	-9.71 **	-12.33 **	-21.05 **	7.93 *
S.Em. ±	3.8	3.8	0.82	0.82	1.76	1.76	0.2	0.2	0.12	0.12
CD at 5%	7.76	7.76	1.68	1.68	3.6	3.6	0.41	0.41	0.24	0.24
CD at 1%	10.46	10.46	2.3	2.3	4.86	4.86	0.55	0.55	0.32	0.32

* - Significant at 5% and **- Significant at 1% ; BP= better parent : SC= Standard check

Table 6: Heterosis (%) over better parent & standard check for yield attributing traits in tomato

Crosses	*Number of fruits per plant*		*Average fruit weight (g)*		*Fruit yield per plant (kg)*		*Fruit yield per hectare (t)*	
	BP	*SC*	*BP*	*SC*	*BP*	*SC*	*BP*	*SC*
AVTO1×T1	-1.62	46.05 **	-6.93 **	2.14	-7.28 **	45.29 **	-2.96	49.25 **
AVTO1×T2	1.33	50.43 **	-18.25 **	3.2	5.92 *	62.64 **	6.93 **	63.29 **
AVTO1×T3	3.82	54.12 **	-1.53	-3.06	0.32	54.05 **	0.61	53.63 **
AVTO2×T1	7.72 **	84.36 **	4.55	14.75 **	7.73 **	111.90 **	5.97 **	107.87 **
AVTO2×T2	9.89 **	88.07 **	-6.92 **	17.51 **	16.64 **	129.42 **	14.15 **	123.94 **
AVTO2×T3	3.09	76.43 **	4.29	14.20 **	0.67	98.02 **	-0.22	95.74 **
AVTO3×T1	-18.69 **	12.13 **	1.25	19.40 **	-15.40 **	32.56 **	-13.89 **	32.44 **
AVTO3×T2	9.44 **	26.35 **	0.02	26.27 **	18.76 **	64.30 **	16.69 **	65.77 **
AVTO3×T3	-23.41 **	7.10 *	-1.9	15.68 **	-10.15 **	27.27 **	-10.81 **	26.70 **
AVTO4×T1	-31.50 **	-5.55	-13.86 **	-5.46 *	-44.09 **	-12.40 **	-43.43 **	-13.00 **
AVTO4×T2	-1.62	16.30 **	-20.88 **	-0.12	-8.97 **	17.36 **	-8.58 **	19.53 **
AVTO4×T3	-24.16 **	6.04	0.52	-3.94	-29.75 **	-0.5	-29.68 **	-1.84
AVTO5×T1	-23.75 **	5.15	-4.92 *	4.35	-30.70 **	8.60 *	-29.64 **	8.22 *
AVTO5×T2	3.54	20.99 **	-15.20 **	7.05 **	1.41	30.74 **	2.97	34.62 **
AVTO5×T3	-24.41 **	5.7	2.83	0.09	-27.42 **	2.81	-27.04 **	1.84
AVTO6×T1	2.57	41.44 **	-18.21 **	-10.23 **	-17.09 **	29.92 **	-16.91 **	27.79 **
AVTO6×T2	21.48 **	59.85 **	-22.11 **	-1.67	22.44 **	57.85 **	24.47 **	62.73 **
AVTO6×T3	1.48	41.90 **	-0.61	-5.03 *	-5.37 *	34.05 **	-1.19	37.92 **
AVTO7×T1	-13.48 **	19.31 **	-28.61 **	-21.65 **	-37.87 **	-2.64	-38.40 **	-5.25
AVTO7×T2	21.47 **	39.14 **	-35.93 **	19.11 **	-11.92 **	13.55 **	-11.57 **	15.61 **
AVTO7×T3	-4.57 *	33.44 **	-19.24 **	-22.82 **	-25.32 **	5.79	-23.64 **	6.58
AVTO8×T1	-26.02 **	2.02	-1.94	11.62 **	-25.11 **	17.36 **	-22.10 **	19.81 **
AVTO8×T2	7.18 *	14.92 **	-5.53 **	19.26 **	8.46 **	39.83 **	3.71	35.59 **
AVTO8×T3	-24.14 **	6.07 *	-1.63	11.97 **	-12.72 **	23.64 **	-11.59 **	23.41 **
AVTO9×T1	-20.40 **	9.76 **	-11.70 **	-3.09	-30.38 **	9.09 *	-29.30 **	8.75 *
AVTO9×T2	10.44 **	28.71 **	-23.33 **	-3.21	-1.41	27.11 **	-2.23	27.82 **
AVTO9×T3	-8.33 **	28.19 **	-4.04	-8.30 **	-16.22 **	18.68 **	-14.97 **	18.69 **
III-5 ×T1	-15.06 **	17.13 **	2.73	12.74 **	-11.60 **	38.51 **	-9.13 **	39.75 **
III-5 ×T2	17.10 **	39.00 **	-5.19 *	19.69 **	23.53 **	70.08 **	25.23 **	71.41 **
III-5 ×T3	-8.23 **	28.32 **	-0.47	8.94 **	0.35	42.15 **	1.57	41.77 **
S.Em. ±	1.11	1.11	2.13	2.13	0.11	0.11	3.33	3.33
CD at 5%	2.26	3.50	4.35	4.35	0.22	0.22	6.81	6.81
CD at 1%	2.26	3.50	5.87	5.87	0.30	0.30	9.18	9.18

* - Significant at 5% and **- Significant at 1%; BP= better parent: SC= Standard check

and Arun Kumar et al. (2020). Parents *viz*., AVTO2, AVTO1 and tester AVTO1464 noticed significant positive GCA effects in fruit yield per plant and yield per hectare, which was also coupled with positive GCA effects in the number of fruits per cluster, average fruit weight and number of fruits per plant. For fruit yield per plant and yield per hectare, crosses, AVTO3×T2, AVTO2×T1, AVTO7×T3 and AVTO1×T3 noticed higher positive SCA effects coupled with significant SCA effects for a number of fruits per plant fruits per cluster. These findings were in line with the previous results reported by Dagade et al. (2015), Agarwal et al. (2017), Vekariya et al. (2019), Kumar and Gowda (2016) and Dharva et al. (2018)

The ultimate objective of any breeding program is to achieve maximum productivity, which is considered as the key factor that helps farmers in deciding whether to adopt or reject a hybrid. Heterosis over better parent and standard check for plant growth was observed to be significant in the positive direction *viz.,* AVTO3×T1, AVTO3×T3 and AVTO3×T2 reported maximum average heterosis. Crosses AVTO5×T2, III-5×T3 and AVTO4×T1 revealed maximum heterosis over better parent and hybrids AVTO3×T2, AVTO3×T1 and AVTO3×T3 recorded significantly highest heterosis over standard check. The data on heterosis also supports that hybrids in general, were taller for plant height. Almost identical results have been reported by Kumari and Sharma (2011) and Yadav et al., (2013). Before time, blossoming is generally an indication of early yield and earliness. Among 14, AVTO6×T1, AVTO5×T2 and AVTO3×T2 were top three crosses over better parent heterosis and three crosses, namely AVTO6×T1, AVTO5×T2 and AVTO2×T1, revealed significant negative heterosis over a standard check. Similar results were reported by Singh et al., 2013. Among six crosses, III-5×T3, AVTO3×T3 and AVTO7×T2 expressed the highest significant heterobeltiosis. In order of merit, AVTO7×T2, III-5 ×T3 and AVTO7×T1 were said to be superior with maximum value of standard heterosis for days to first harvest. The shelf life of tomatoes is a critical parameter influencing their quality and marketability. Among 30 crosses, AVTO3× T1 and AVTO4 × T1 were significant over mid heterosis and AVTO4 × T2, and AVTO4 × T1 were top hybrids significant over check, Pusa Rakshith. These results were supported by by Thakkur et al. (2019) in tomato. For all yield and yield attributing traits like number of fruits per cluster, number of fruits per plant, average fruit weight, fruit yield per plant and yield per hectare, heterosis in positive direction is desirable. A number of fruiting clusters per plant is an important trait that determines yield of tomatoes. Top three crosses, AVTO2×T2, AVTO6×T2 and AVTO9×T2 indicated significant and positive average heterosis. Hybrids, namely AVTO6×T2, AVTO7×T2 and III-5×T2 showed significant positive heterosis over better parents and AVTO2×T2, AVTO2×T1 and AVTO2×T3 were significant over standard check. Number of fruits per plant is the most important component trait, which is directly related to increased fruit yield per plant. Among all the crosses, seven hybrids over better parents. Whereas significant positive heterosis over the check (Pusa Rakshit) was revealed by three top cross combinations *viz,*. AVTO2×T2, AVTO2×T1 and AVTO2×T3. Similar results were in conformity with those reported by Kumar et al. (2017), Kumari and Sharma (2011), Ahmed et al. (2011) and Singh et al. (2011). Fruit weight is an important index for polyhouse tomatoes. Hybrids AVTO3×T2, III-5×T2 and AVTO3×T1 were found good with respect to significant standard heterosis in a desirable direction. These results are in line with study by Farzane et al. (2012), Yadav and Venkat (2013) and Arun Kumar et al. (2020). The ultimate goal of any breeding programme is to achieve more marketable yield per unit of plant (kg). The hybrids, AVTO2×T2, AVTO2×T1 revealed significant positive heterosis over the check 'Pusa Rakshit'. Positive heterosis for fruit yield was reported earlier by Arun Kumar et al. (2020). In the case of fruit yield per hectare hybrids, III-5×T2, AVTO6× T2 and AVTO3×T2 for better parent. Crosses AVTO2×T2, AVTO2×T1 and AVTO2×T3 recorded maximum significant heterosis over standard check.

Conclusion

The indeterminate growth line AVTO3 and tester AVTO1464 exhibited positive GCA effects for traits like plant height, shelf life, and fruit weight, making them ideal for protected cultivation. The parental line AVTO2 and tester AVTO1464 demonstrated a strong GCA effect for earliness and yield attributes, such as the number of fruits per plant and cluster. AVTO5 showed positive GCA effects for early maturity, enabling quicker harvests and multiple crop cycles. Crosses AVTO3 × T2 and AVTO2 × T1 exhibited positive SCA effects for fruit yield per plant and per hectare, indicating the effectiveness of heterosis breeding. The GCA/SCA variance ratios suggested a mix of additive and non-additive gene action for the traits. The best combiners identified can be used to develop hybrids with specific traits, particularly earliness, yield, and processing suitability. Hybrids AVTO2 × T2, AVTO2 × T1, and AVTO3 × T2 showed maximum positive heterosis for yield-related attributes.

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सारांश

खरीफ मौसम २०२२- २०२३ के दौरान बागलकोट, कर्नाटक के बागवानी महाविद्यालय के सब्जी विज्ञान विभाग मे प्राकृतिक हवादार पॉलीहाउस के तहत “टमाटर” (*Solanum lycopersicum* L.) संकरों में भिन्नाश्रय और संयोग्यता पर अन्वेषण किया गया। लाइन टेस्टर मेटिंग डिजाइन में तीस एफ-१ संकरों का उत्पादन किया गया और उनके नर वंश और मादा वंश और चेक के साथ दो प्रतिकृतियों के लिए मूल्यांकन किया गया। प्रयोगात्मक परिणाम संकरों, नर वंश और मादा वंश और चेक के प्रदर्शन पर आधारित थे। विभिन्नताओं के विश्लेषण से पता चला कि अधिकतर गुणों के लिए लाइनों, टेस्टर्स, संकरों और नर-मादा रेखाएँ बनाम संयोग में महत्वपूर्ण अंतर थे। लाइनों और टेस्टर्स में, एवीटीओ-१९२०, एवीटीओ-१४२९ और एवीटीओ-१६६४ को विकास, समय पूर्वता और उपज गुणों के लिए अच्छी सामान्य संयोजन क्षमता के लिए पाया गया। क्रॉस में, एवीटीओ-१९२० x एवीटीओ-१४६४ , एवीटीओ-१४२९ x एवीटीओ- १४६४ और एवीटीओ-१९२० x अनघा ने उपज गुणों के लिए सकारात्मक विशेष संयोजन क्षमता प्रभाव प्रदर्शित किए। gca/sca विभेदों का अनुपात कुछ गुणों में एक से अधिक और शेष गुणों में एक से कम दर्ज किया गया, जो अध्ययन किए गए गुणों के लिए अनुवांशिक और गैर-अनुवांशिक जीन क्रियाओं की उपस्थिति को दर्शाता है। सभी 20 गुणों के लिए मध्य, बेहतर नर वंश और मादा वंश और मानक चेक पर एफ-१ संकरों के लिए भिन्नाश्रय के अनुमान लगाए गए और महत्वपूर्ण भिन्नताएँ दिखीं। क्रॉस में, एवीटीओ-१९२० x एवीटीओ-१४६४, एवीटीओ-१४२९ x एवीटीओ-१४६४ ने मानक चेक पर अधिकतम सकारात्मक हेटेरोसिस दर्ज किया, जबकि आइ आइ आइ-५ x एवीटीओ-१४६४, एवीटीओ-१९१५ x एवीटीओ-१४६४ ने उपज गुणों के लिए बेहतर माता-पिता पर सर्वाधिक दर्ज किया। इसे पॉलीहाउस की स्थिति के तहत विकास और उपज गुणों के लिए खेती के लिए अनुशंसित किया जा सकता है।