Line × Tester analysis of combining ability in tomato (*Lycopersicon esculentum* Mill.)

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ABSTRACT

Nine parental lines were crossed in Line × Tester fashion to estimate heterosis and combining ability in tomato for fruit yield, yield components and fruit quality traits. Involvement of both additive and non additive gene action was operative for the control of fruits/plant, fruit weight, locules /fruit and equatorial diameter of fruit. All the fruit quality characters like, TSS and lycopene contents of the fruit were governed by non additive gene action. Taking into consideration the per se performance, heterosis and SCA effect in the hybrid, H-24 × NF-31 and H-24 × Hissar Arun were the best hybrid.

***Key Words*:** Combining ability, fruit character and heterosis.

In any sound breeding programme, the proper choice of parents based on their combining ability is a prerequisite. Such studies not only provide necessary information regarding the choice of the parents but also simultaneously illustrate the nature and magnitude of gene action involved in the expression of desirable traits. Tomato offers much scope for improvement through heterosis breeding which can further be utilized for the development of desirable recombinants. Information on the magnitude of heterosis in different cross combination is a basic requisite to assess for identifying the crosses that exhibit high amount of exploitable heterosis. Line × Tester analysis is a useful tool for preliminary evaluation of genetic stock for use in hybridization programme with a view to identify good combiners. The present investigation was thus undertaken to have an idea of the nature of gene action and magnitude of heterosis for fruit yield and fruit quality attributes in tomato.

MATERIALS AND METHOD

Nine diverse tomato parents were selected from the germplasm collection maintained at Department of Vegetable crops, Bidhan Chandra Krishi Viswavidyalaya. F1 hybrids were developed by Line × Tester (4 × 5) crossing scheme. Nine parents along with 20 F_1 hybrids were grown in Randomized Block Design with 3 replications in 60 cm × 45 cm spacing keeping 16 plants in each plot. Five randomly selected plants/plot were taken to record observation on different characters. Proximate compositions of the fruits were estimated in the laboratory of Dept. of Vegetable Crops, BCKV. Combining ability analysis was done as per Kempthorne (1957). Heterosis was determined as per method suggested by Wynne *et al*. (1970) and Bitzer *et al*. (1967).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant difference among all parents and hybrids for all the characters indicating the presence of considerable amount of genetic variability (Table 1). The parent *vs* hybrid components were significant for all the traits except polar diameter and locules/fruit indicating the expression of heterotic effects for the remaining traits. Combining ability variances were highly significant for line, tester and line × tester for most of the characters. Line × tester component of genetic variation was not significant for fruits/cluster and total sugar. The GCA and SCA variances showed wide range of variation for all the characters under study. It was evident from the Table 1 that the characters namely, days to first harvest, fruits/cluster and pulp volume were controlled by additive gene action. So, pure line selection in the advanced generations from the highly heterotic cross is suggested for the improvement of these characters. Both additive and non additive gene action was important for the conditioning of fruits/plant, locules/fruit, fruit weight and equatorial diameter of the fruit. There is a possibility of deriving high performing pure lines for these characters because longer proportion of non additive effects in self pollinated crops seems to be due to additive × additive epistatic effect. So, recurrent selection would be profitable for improving these characters.

Fruit quality characters like total soluble solids, total sugar, tritable acidity, carotene and lycopene content were governed by non additive gene action which were in agreement with earlier reports of Bhatt *et al*. (2001), Kalloo *et al*. (1974) for TSS content; Kumar *et al*. (1997), Kalloo *et al*. (1974) for titrable acidity; Kaul and Nandipuri (1972) for total sugar; Bhutani and Kalloo (1983) for carotene and

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lycopene contents. Heterosis breeding is the best possible option for improving the quality traits of tomato.

The estimates of GCA along with *per se* performance of parents for various characters are presented in Table 2. None of the parents proved to be good general combiners for all the characters. The parents H-24, DVRT-1, Punjab Chhuhara and Ratan were good general combiners for fruit weight. For fruits/plant, EC-321425, Punjab Chhuhara, Pusa Ruby and Ratan had significant positive GCV effect. Parents like H-24, Hissar Arun and NF-31 were good general combiners for carotene, lycopene, TSS and total sugar contents of fruit. Considering significant positive GCA and *per se* performance of the parents H-24 was the outstanding general combiner followed by Hissar Arun and NF-31.

The crosses showing desired significant SCA effect and their *per se* performance are presented in Table 3. Out of 20 crosses, seven and five crosses registered significant positive SCA effects for fruits/plant and fruit weight, respectively. Significant SCA effects were evident in eight crosses for earliness (days to 1st harvest). Eight hybrids showed significant positive SCA effect for both carotene and lycopene contents. Four hybrids showed a positive significant SCA effect for TSS and total sugar contents.

Twelve hybrids exhibited significant relative heterosis for days to 1st flower and 10 crosses showed heterobeltiosis for the same character. EC-321425 × Punjab Chhuhara was the earliest (63.33 days) and had the maximum negative value of relative heterosis and heterobeltiosis. For fruit weight, DVRT-1 × Punjab Chhuhara had maximum relative heterosis (98.30%) as well as *per se* performance (121.11g) followed by H-24 × Pusa Ruby which had highest heterobeltiosis (45.96%). This performance of hybrids may be due to involvement of parents like H-24, DVRT-1 and Punjab Chhuhara which had high GCA values for fruit weight. Not a single cross showed significant heterosis for fruits/plant. H-24 × Pusa Ruby only showed positive heterosis over mid parent. Out of 20 crosses, 9 exhibited significant relative heterosis and 7 heterobeltiosis for fruits/cluster. Agata × Ratan had highest heterosis over better parent (54.18%) with good *per se* performance but its SCA effect was negative due to the poor combining ability of its parent Agata. Eleven and nine hybrids exhibited significant positive heterosis over mid parents for carotene and lycopene, respectively and five and seven hybrids respectively were heterotic over their better parents for these fruit quality traits. DVRT-1 × Pusa Ruby showed maximum heterobeltiosis for lycopene (488.47%) and carotene (311.29%) followed by H-24 × NF-31. Such high heterosis of these crosses was due to high *per se* performance as well as good GCA effect of parents like H-24, NF-31 and Pusa Ruby. Four crosses showed significant heterobeltiosis for total sugar. Among which H-24 × Ratan had highest heterosis over better parent (70.11%) due to good SCA and *per se* performance of this cross. The cross EC-321425 × Ratan had maximum heterobeltiosis (19.89%) for TSS with high *per se* performance and SCA effect. However, the cross EC-321425 × Pusa Ruby showing highest SCA effect and *per se* performance for TSS had negative heterosis over better parent. Crosses involving H-24 or Ratan as one of the parents exhibited high heterosis for pericarp thickness as those parents were good combines with good *per se* performance.

Two promising hybrids H-24 × NF-31 and H-24 × Hissar Arun were selected on the basis of *per se* performance, heterosis manifested in them and revelation of SCA effects for different characters. These two high yielding hybrids can be used commercially because of desirable fruit quality traits in them.

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Table 1 Analysis of variance and estimate of combining ability variances for different characters in tomato

Source	Replication	Parents	Lines	Testers	Line vs. Tester	Hybrids	Parents vs. Hybrids	Error	σ^2 GCA	σ^2 SCA	Predictability ratio
d.f	2	8	3	4	1	19	1	56			
Days to 1st harvest	4.40	445.26**	474.44**	391.56**	572.48**	382.39**	1109.92**	2.58	72.34	24.41	0.856
Fruits/cluster	0.536	9.04**	20.03**	2.31**	3.01**	0.792**	3.29**	0.27	0.133	0.032	0.901
Fruits/plant	3.53	3414.48**	6165.43**	2178.54**	105.41**	388.64**	14877.49**	24.49	50.38	49.30	0.672
Fruit weight	8.29	1801.94**	2245.18**	1910.42**	38.32	1839.36**	562.39**	17.9	295.25	195.53	0.751
Polar diameter	0.035	1.13**	0.112**	1.95**	0.897**	1.16**	0.0077	0.018	0.076	0.261	0.362
Equatorial diameter	0.055	4.33**	3.01**	5.03**	5.44**	3.14**	0.274*	0.059	0.398	0.50	0.619
locule no. /fruit	0.0178	6.45*	4.67	7.63*	7.13	2.46	7.65	2.98	0.306	0.279	0.684
Pericarp thickness	0.002	0.0137**	0.0093**	0.0136**	0.0275**	0.0179**	0.0945**	0.0016	0.002	0.00	0.00
Pulp volume	1.06	113.29**	117.68**	124.59**	54.95**	86.47**	10.25*	1.89	19.48	0.581	0.985
TSS	0.0053	1.98**	2.12**	2.17**	0.74**	0.78**	3.17**	0.0105	0.026	0.321	-0.196
Total sugar	0.0067	0.454**	0.545**	0.313**	0.743**	0.575**	2.75**	0.0039	0.030	0.243	-0.331
Titrable acidity	0.0012	0.013**	0.159**	0.139**	0.0004	0.059**	0.023*	0.0035	0.0031	0.01	0.555
Carotene	0.0064**	4.45**	4.55**	4.85**	2.54**	1.97**	0.252**	0.00055	0.034	0.572	0.110
Lycopene	0.000.45	3.97**	4.29**	4.58**	0.60**	2.54**	0.127**	0.00023	0.059	0.719	0.143

*= significant at 5% level of significance , **= significant at 1% level of significance

Table 2 General combining ability effects and *per se* performance (bold) of the parents for different characters in tomato lines

Parents	Days to 1st harvest	Fruits/ cluster	Fruits/ plant	Fruit weight	Polar diameter	Equatorial diameter	Locule number	Pericarp thickness	Pulp volume	TSS	Total sugar	Titrable acidity	Carotene	Lycopene
H-24	**95.00**	**2.33**	**38.46**	**63.37**	**3.90**	**4.60**	**3.56**	**0.48**	**13.72**	**4.93**	**2.08**	**0.70**	**1.30**	**0.76**
	6.71**	-0.15*	-4.04**	12.14**	0.34**	0.43**	0.18	0.06**	2.15**	0.34**	0.19**	-0.01	0.24**	0.40**
Agata	**93.67**	**2.23**	**45.44**	**54.64**	**3.90**	**4.48**	**3.78**	**0.46**	**16.41**	**3.27**	**2.04**	**0.50**	**3.32**	**2.94**
	4.35**	-0.44**	-1.83*	-3.30**	-0.33**	-0.01	0.07	-0.02	3.19**	-0.06**	0.02	0.02	-0.02**	-0.04**
DVRT-1	**98.00**	**2.33**	**41.24**	**87.32**	**3.97**	**4.74**	**5.04**	**0.43**	**16.56**	**3.93**	**2.02**	**0.76**	**0.54**	**0.27**
	6.33**	-0.15*	-7.97**	23.80**	0.32**	0.89**	0.87**	0.02	3.33**	-0.22**	-0.14**	0.00	-0.08**	0.00
EC-321425	**70.67**	**7.47**	**132.20**	**21.22**	**3.54**	**2.61**	**2.00**	**0.35**	**3.31**	**3.07**	**2.90**	**1.06**	**2.47**	**1.90**
	-17.38**	0.74**	13.84**	-32.64**	-0.33**	-1.32**	-1.13**	-0.06**	-8.67**	-0.06**	-0.07**	-0.01	-0.14**	-0.35**
S.Em(±)	**0.18**	**0.07**	**0.79**	**0.70**	**0.02**	**0.03**	**0.11**	**0.01**	**0.13**	**0.02**	**0.01**	**0.01**	**0.00**	**0.00**

Testers

Parents	Days to 1st harvest	Fruits/ cluster	Fruits/ plant	Fruit weight	Polar diameter	Equatorial diameter	Locule number	Pericarp thickness	Pulp volume	TSS	Total sugar	Titrable acidity	Carotene	Lycopene
Punjab Chhuhara	**86.33**	**3.67**	**55.69**	**34.83**	**5.39**	**3.23**	**2.00**	**0.52**	**5.50**	**4.67**	**3.03**	**0.68**	**0.22**	**0.18**
	-3.90**	-0.08	4.90**	5.12**	0.44**	-0.14**	0.17	-0.03**	-1.34**	-0.19**	0.17**	-0.09**	-0.55**	-0.57**
Pusa Ruby	**90.60**	**4.07**	**106.45**	**32.17**	**3.23**	**4.33**	**4.73**	**0.38**	**15.56**	**4.47**	**2.75**	**1.13**	**0.68**	**0.50**
	0.74**	0.14	3.94**	-2.29**	-0.17**	0.02	-0.14	0.00	-0.14	-0.03	-0.07**	0.13**	0.08**	0.16**
Hissar Arun	**95.00**	**2.27**	**55.00**	**60.75**	**3.77**	**5.07**	**4.96**	**0.53**	**16.01**	**5.07**	**2.18**	**0.62**	**3.38**	**3.13**
	0.04	-0.11	-5.28**	1.05	-0.18**	-0.02	-0.17	0.01	-1.47**	0.17**	0.17**	-0.10**	0.07**	0.17**
Ratan	**108.00**	**2.20**	**36.00**	**80.69**	**4.14**	**6.50**	**5.11**	**0.52**	**16.20**	**3.13**	**2.59**	**0.62**	**1.59**	**1.63**
	0.32	0.06	2.23*	2.16*	0.29**	0.21**	0.17	0.06**	1.37**	-0.11**	-0.20**	0.12**	-0.48**	-0.62**
NF-31	**113.00**	**2.40**	**48.67**	**86.74**	**4.42**	**5.93**	**6.33**	**0.54**	**23.59**	**3.33**	**2.42**	**0.76**	**0.59**	**0.39**
	2.79**	0.00	-5.79**	-6.03**	-0.38**	-0.07*	-0.03	-0.04**	1.59**	0.16**	-0.06**	-0.05**	0.87**	0.86**
S.E.	**0.21**	**0.08**	**0.91**	**0.81**	**0.02**	**0.03**	**0.13**	**0.01**	**0.15**	**0.02**	**0.01**	**0.01**	**0.00**	**0.00**

*= significant at 5% level of significance , **= significant at 1% level of significance, bold digits are *per se* performance.

Table 3: Crosses showing desired significant and desirable SCA effect and their *per se* performance and heterobeltiosis for different characters.

Characters	Crosses	SCA effect	Mean value	Heterobeltiosis (%)	SEm ±
Days to 1st harvest	EC-321425 × Punjab Chhuhara	-2.14	63.33	-10.38	0.36
	DVRT-1 × NF-31	-7.77	88.11	-10.09	
	H-24 × Ratan	-6.79	87.23	-8.42	
	H-24 × Hissar Arun	-3.51	90.16	-5.26	
	EC-321425 × Pusa Ruby	-3.21	67.44	-5.19	
	EC-321425 × Hissar Arun	-2.20	67.22	-4.87	
Fruits /cluster	H-24 × Punjab Chhuhara	O.48	3.89	6.09	0.14
	EC 321425 x Hisar Arun	0.29	4.56	- 38.97	
Fruits /plant	H-24 × Ratan	5.96	38.56	-1.24	1.57
	DVRT-1 × Ratan	9.05	37.17	-9.87	
	Agata × Pusa Ruby	7.08	43.06	-59.55	
	EC-321425 × Punjab Chhuhara	9.73	62.33	-52.85	
	EC-321425 × Pusa Ruby	7.69	59.33	-55.12	
Fruit weight (g)	H-24 × Pusa Ruby	19.19	92.50	45.96	1.41
	DVRT-1 × Punjab Chhuhara	28.72	121.11	38.70	
	Agata × Hissar Arun	6.34	67.56	11.20	
	Agata × Ratan	12.67	75.00	-7.05	
Polar diameter(cm)	H-24 × Ratan	0.73	5.37	29.21	0.04
	EC-321425 × Pusa Ruby	0.62	4.13	16.76	
	DVRT-1 × Pusa Ruby	0.37	4.53	14.29	
Equatorial diameter (cm)	DVRT-1 × Punjab Chhuhara	1.35	6.83	44.26	0.05
	H-24 × Pusa Ruby	1.08	6.27	36.13	
	DVRT-1 × Pusa Ruby	-0.24	5.40	14.00	
	Agata × Ratan	0.71	5.63	-13.33	
Locule number	Agata × Pusa Ruby	-0.90	2.56	-32.36	0.22
	DVRT-1 × Ratan	-0.57	4.00	-20.63	
Pericarp thickness (cm)	H-24 × Pusa Ruby	0.06	0.66	36.81	0.01
	EC-321425 × Pusa Ruby	0.02	0.50	32.74	
	H-24 × Ratan	-0.01	0.66	27.10	
	DVRT-1 × Pusa Ruby	-0.01	0.55	26.92	
	H-24 × Punjab Chhuhara	0.08	0.65	25.81	
Pulp volume (cc)	Agata × Ratan	0.39	19.78	20.54	0.26
	DVRT-1 × NF-31	0.53	20.28	-14.01	
	H-24 × Pusa Ruby	0.60	17.44	12.13	
	Agata × Punjab Chhuhara	0.61	17.29	5.36	
TSS (^{o} Brix)	EC-321425 × Ratan	0.35	3.76	19.89	0.04
	Agata × NF-31	0.18	3.84	15.30	
	EC-321425 × Hissar Arun	0.12	3.80	-25.00	
Total sugar	H-24 × Ratan	0.72	2.77	18.79	0.02
	DVRT-1× Hissar Arun	0.42	2.50	14.69	
	H-24 × NF-31	0.48	2.67	10.50	
	Agata × Hissar Arun	0.12	2.37	8.58	
Titrable acidity (%)	Agata × Ratan	0.12	1.05	69.17	0.02
	H-24 × Ratan	0.04	0.94	33.82	
	DVRT-1 × NF-31	0.08	0.82	8.55	
	H-24 × Punjab Chhuhara	0.03	0.72	2.98	
	EC-321425 × Punjab Chhuhara	0.18	0.88	-17.55	
Carotene content (mg/100 g fresh)	DVRT-1 × Pusa Ruby	1.09	2.78	311.29	0.01
	H-24 × NF-31	0.80	3.61	176.39	
	DVRT-1 × Punjab Chhuhara	0.08	1.14	109.69	
	DVRT-1 × NF-31	-1.20	1.27	144.89	
	Agata × NF-31	0.84	3.37	1.45	
Lycopene content (mg/100 g fresh)	DVRT-1 × Pusa Ruby	1.42	2.96	488.47	0.01
	H-24 × NF-31	0.89	3.53	366.98	
	Agata × NF-31	0.55	2.76	-6.21	
	H-24 × Hissar Arun	1.00	2.95	-5.79	