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Research Article

Line × tester analysis for yield and quality traits in Tomato

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Abstract Development of F_1 combinations for improvement of yield and quality, need identification of good specific and general combiners. The investigationwas carried out at Experimental Farm, Mata Gujri College, Fatehgarh Sahib during 2018-2019. Experimental materials comprised 15 F_1s from a line × tester mating design involving 8 parents and 1 check (Punjab Upma) with the objective of estimating heterosis and combining ability. Crosses 'EC-164863 × H-24' and 'EC-249504 × Azad T-5' had significant positive heterosis for total yield/plant. The general combining ability of parent 'EC-620395'exhibits positive significant effects for most traits followed by 'EC-914104' and 'EC-164863'. Of 15 three cross combinations 3 exhibited positive, significant, specific combining ability (SCA) effects for total yield/plant. The greatest SCA effect was for hybrid 'EC-620395 × H-24' followed by 'EC-165690 × H-24' for and 'EC-165690 × EC-914104' were specify that these crosses may be further used for commercially and 'EC-620395' 'EC-914104' 'EC-164863' tested for hybridization program.

Keywords: *Solanum lycopersicum*, combining ability, GCA, heterosis, SCA

Introduction

Tomato (*Solanum lycopersicum* L.) is an important component of Indian meal and produced for fresh market and processed into various forms such as juices, paste and puree (Tasisa *et al*., 2011). Tomato is moderate nutrition vegetable fruit and important source of vitamins and minerals (Hari, 2015).

Hybrid vigor, or out breeding enhancement, is the improved or increased function, of any biological quality in a F_1 hybrid. Heterosis can be defined as the superiority of F_1 hybrid over both parents for yield or some other character. An F_1 exhibits heterosis if its characters are enhanced due to mixing genetic contributions of its parents (Choudhary *et al*., 1965). Higher yield of hybrids could be due to high yielding parents selected for hybridization (Courtney and Peirce, 1979).

Combining ability are centered on predominant effects of general combing ability (GCA) on yield and yield components indicating the importance of additive gene action (Wos *et al*., 1999). Presence of significant GCA effects for yield traits indicates additive type gene action and specific combining ability (SCA) effects of non-additive gene action (Kumar *et al*., 2013). Line × tester analysis is powerful tools for estimating GCA of parents and crosses with high specific combining ability (Rashid *et al*., 2007).

Materials and methods

The investigation was carried out at the Experimental Farm, Mata Gujri College, Fatehgarh Sahib, Punjab, during October to March 2018-2019 at 246m above sea level. Twenty plant raised each cultivars/lines EC-165690, EC-164863, EC-164553, EC-249504, EC-620395, EC-914104, Azad T-5 and H-24 were crossed in a line (5) × testers (3) to obtain 15 cross combinations with a commercial check cv Punjab Upma. The F_1 seed along with parents and the commercial check were arranged in a randomized complete block design with 3 replications. Seedlings were produced by sowing seed under natural condition on 10 September, 2018 and transplanting of each parent and cross combination at the research farm was done on 5 October, 2018. There were fifteen plants of each entry in each replication in a plot with a spacing of 60 cm × 45 cm. Fertilizers were applied at the rate of 120 kg N, 80 kg P_2O_5 and 70 kg K_2O per hectare. Weeding and other cultural practices was also done manually.

Observations were recorded on 5 plants in each genotype for plant height, days to 50% flowering, number of primary branches/plant, number of fruit/plant, average fruit weight, fruit diameter, fruit shape index, number of fruits/cluster, fruit yield/plant, pericarp thickness, total soluble solid, ascorbic acid and titrable acidity.

For estimation of GCA and SCA variances and their effects, the 'line x tester' analysis follow the method of (Kempthorne 1957). Heterosis in F_1's were calculated as the difference of F_1 hybrid performance from the standard check (standard heterosis) and better parent (heterobeltiosis) using the formulae of Kempthorne (1957).The nature and magnitude of heterosis was computed as percent increase or decrease of mean values of hybridsover better parent and the standard check.

Results and discussion

The analysis of variance of combining ability for partitioning total genetic variance into gca (representing additive type of gene action) and sca, (a measure of non-additive gene action) was according to Griffing (1956). Variances due to gca and sca were significant for all characters studied except titrable acidity. Magnitudes of sca variance was higher than gca for all characters. The analysis of variance for combining ability (Table 1 and 2) exhibited the existence of significant variation in treatments for 13 characters, indicating a wide range of variability between the genotypes. Predominant additive gene effects were for total yield per plant, number of fruit/plant, average fruit weight and fruit shape index, non-additive genetic variance control pericarp thickness, TSS, titrable acidity and ascorbic acid (Garg*et al*., 2008 and Kumar *et al*., 2013). Involvement of additive and non-additive gene effects for fruit yield, average fruit weight and TSS has been reported (Agarwal *et al*., 2014). F_1 cross combinations, recorded with good specific combiner for average fruit weight and lycopene. General combiners for fruit yield and its contributing characters have been reported (Savale *et al*., 2017). They also found high sca effects for fruit yield, titrable acidity and non-reducing sugar per-cent. Good general combiners for fruit yield and its contributing characters have been reported (Dharva *et al*., 2018) and there are SCA effect for fruit yield and its yield contributing traits has been reported (El-Gabry, 2014).

A positive general combining ability (GCA) effect for total yield/plant occured in EC-164863 and H-24, plant height (EC-165690, and EC-164563), number of branches/plant (EC-620395, EC-914104), number of fruit/plant (H-24), average fruit weight (EC-620395, and EC-914104), fruit diameter (EC-249504, and EC-914104), fruit shape index (EC-165690), number of fruit/cluster (EC-165690), pericarp thickness (EC-164863), total soluble solid (EC-164863, EC-620395, and EC-914104), ascorbic acid (EC-249504) and titrable acidity (EC-249504, and EC-620395). Negative GCA effect for number of fruit/cluster was recorded in EC-164863, EC-164563 and EC-914104. The highest GCA effects for number of primary branches/plant, average fruit weight, total soluble solids and titrable acidity were recorded in EC-620395. Decreased performance for certain characters was indicated by negative combining ability, positive combining ability indicated increasing performance in certain characters.

The highest SCA estimated (Table 3) for plant height was in combiners EC-620395 × H-24 with high effect of EC-164863 × EC-914104 and EC-164563 × Azad T-5. For days to 50% flowering, highest positive SCA effect was in EC-164863 × H-24. The highest SCA for number of branches/plant was in EC-620395 × EC-914104 with high effect in EC-165690 × H-24. The highest SCA for number of fruits/plant was in EC-165690 ×EC-914104 and with high effect in EC-164563 × Azad T-5. The highest SCA effect for average fruit weight was in EC-165690 × Azad T-5 with high combiner EC-164563 × H-24. For fruit diameter estimated SCA was in EC-249504 × EC-914104. The highest SCA was in EC-620395 × H-24 for fruit shape index. Number of fruits/cluster had highest SCA in EC-620395 × H-24. The highest SCA estimated for total yield/plant in combiner EC-165690 × EC-914104 followed by EC-249504 × H-24 and EC-164563 × H-24. Highest estimated positive SCA effect was for pericarp thickness in EC-165690 × H-24 with high in combiner EC-620395 × H-24. Total soluble solid highest SCA was in EC-165690 × H-24, ascorbic acid had positive GCA in combinations EC-620395 × H-24 and EC-2549504 × Azad T-5.

Heterosis for yield and quality parameters varied (table 4 and 5). Better parent heterosis (BPH) was highest for total yield/plant in EC-620395 × H-24 and standard check heterosis (SCH) in EC-164563 × H-24, BPH for plant height in EC-165690 × H-24, BPH for days to 50% flowering in EC-164863 × Azad T-5 and SCH in EC-164563 × H-24, BPH and SCH for branches/plant in EC-620395 × EC-914104, number of fruits/plant in EC-164863 × H-24, fruit diameter in EC-249504 × EC-914104, number of fruit/cluster in EC-249504 × Azad T-5, pericarp thickness in EC-164863 × EC-914104, total soluble solid in EC-164863 × Azad T-5, titratable acidity in EC-249504 × Azad T-5, BPH for fruit shape index in EC-249504 × EC-914104 and SCH in EC-165690 × EC-914104, BPH for average fruit weight in EC-164863 × Azad T-5 and its SCH in EC-164863 × EC-914104. Significant heterosis over the better and the commercial check has been reported (Kumar *et al*., 2012).

Dominant gene action influenced the estimated heterotic and GCA effect, heterosis and GCA effects are positively associated (Yustiana, 2013). Additive and dominant gene action types play an important role in controlling yield and yield components in tomato, but additive gene action was more prominent to controlling yield and its attributing traits.In this research we have improved the yield of commercial varieties without any compromise on shelf-life by exploiting derived testers.Present study important for researcher/breeder because it is important vegetable crop and cultivated around the world andgenotypes including study can be used fordevelopment of crops suitable for their environment.

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Table 1. ANOVA for combining ability, estimates of components of variance and their ratio for various characters in Tomato

Source of variation	d. f.	Days to 50% flowering	Number branches/plant	Number fruit/cluster	Number fruit/plant	Average fruit weight	Fruit diameter	Fruit shape index
Replication	2	3.35	0.45	1.252	13.00	48.89	0.379	0.003
Treatment	22	67.79**	3.403**	1.185**	34.649**	92.861**	1.431**	0.083**
GCA (Line)	4	167.02**	1.42**	0.93**	8.59**	40.36**	1.23**	0.12**
GCA (Tester)	2	20.31**	5.21**	0.65**	77.02**	31.23**	1.48**	0.03**
SCA (Line x Tester)	8	26.90**	1.54**	1.12**	17.40**	64.66**	1.45**	0.03**
Error	44	0.96	0.46	0.02	2.66	6.15	0.001	0.001
σ^2 GCA		5.564	0.148	-0.028	2.117	-2.405	-0.008	0.004
σ^2 SCA		8.64	0.36	0.366	4.91	19.50	0.48	0.008

Conti………..

Source of variation	d. f.	Plant height	Total yield/plant	Pericarp thickness	Total soluble solid	Ascorbic acid	Titratable acidity
Replication	2	15.79	0.210	0.711	0.63	5.03	0.001
Treatment	22	419.47**	1.203**	3.267**	1.148**	12.742**	0.017**
GCA (Line)	4	413.40**	0.10**	2.23**	1.34**	15.64**	0.061**
GCA (Tester)	2	60.30**	0.43**	0.59**	1.05**	7.86**	0.000
SCA (Line x Tester)	8	275.53**	0.16**	5.98**	1.16**	6.55**	0.005
Error	44	6.78	0.03	0.002	0.003	2.84	0.003
σ^2 GCA		-3.224	0.008	-0.381	0.003	0.433	0.002
σ^2 SCA		89.58	0.043	1.993	0.386	1.237	0.001

*, ** significant at 5% and 1% level, respectively

GCA=General Combining Ability, SCA=Specific Combining Ability

Table 3.Estimation of GCA effect for various characters in Tomato.

Parents	Days to 50% Flowering	No. of Primary Branches/ Plant	No. of Fruits/Cluster	No.of Fruits /Plant	Average Fruit Weight (gm)	Fruit Diameter (cm)	Fruit Shape Index	Plant Height (cm)	Total Yield/Plant (kg)	Pericarp Thickness (cm)	Total Soluble Solid (° Brix)	Ascorbic Acid (mg/100 g)	Titratable Acidity (%)
EC-165690	-0.57	-0.04	0.42**	0.79	-3.67**	-0.35**	0.12**	3.61**	-0.09	-0.11	-0.45**	0.69	-0.052**
EC-164863	-1.36	-0.42*	-0.26**	1.23	0.74	0.26	0.08	-9.65**	0.15**	0.55**	0.32**	-2.01**	-0.108**
EC-164563	-5.54**	-0.33	-0.38**	-0.78	0.67	-0.44**	0.02	8.31**	-0.05	-0.01	-0.39**	0.20	0.000
EC-249504	1.15	0.26	0.11	-1.02	0.45	0.39**	-0.06	0.61	-0.07	0.32	0.21	1.50**	0.088**
EC-620395	6.33**	0.53**	0.11	-0.23	1.82**	0.14	-0.17**	-2.86	0.06	-0.75**	0.31**	-0.39	0.072**
EC-914104	1.26	0.42*	0.15	-2.01**	1.65**	0.32**	0.02	0.74	-0.13**	0.16	0.27**	-0.16	-0.005
Azad T-5	-0.21	0.26	0.09	-0.45	-0.60	-0.02	-0.05	1.53	-0.07	0.07	-0.02	-0.63	-0.001
H-24	-1.04	-0.67**	-0.24**	2.46**	-1.05	-0.30	0.04	-2.27	0.19**	-0.22	-0.26	0.79	0.006
SE lines	0.293	0.203	0.046	0.486	0.739	0.008	0.012	0.776	0.054	0.014	0.010	0.503	0.015
SE (tester)	0.207	0.143	0.032	0.344	0.523	0.006	0.009	0.549	0.038	0.010	0.007	0.355	0.011

*, ** significant at 5% and 1% level, respectively.

Table 3.Estimation of SCA effect for various characters in Tomato.

Cross combination	Days to 50% flowering	Number branches/ Plant	Number fruit/cluster	Number fruit /plant	Average fruit weight (g)	Fruit diameter (cm)	Fruit shape index	Plant height (cm)	Total yield/plant (kg)	Pericarp thickness (mm)	Total soluble solid (° Brix)	Ascorbic acid (mg/100 g)
EC-165690 × EC-914104	-3.15**	-0.26	-0.19	3.83**	-2.28	-0.52	0.03	2.00	0.27**	-0.62	-0.97**	0.31
EC-165690 × Azad T-5	2.92**	-0.53	-0.37	-2.64**	7.10**	0.47	-0.01	-5.21	0.06	-0.93	0.22	0.68
EC-165690 × H-24	0.24	0.79*	0.56	-1.19	-4.82**	0.05	-0.02	3.21	-0.33**	1.56**	0.76**	-0.99
EC-164863 × EC-914104	0.56	-0.51	0.05	0.44	2.18	0.56**	-0.06	12.02**	0.15	1.11	0.26	-0.23
EC-164863 × Azad T-5	-4.09**	0.77	0.51	-0.52	0.84	-0.82**	0.07	-0.17	-0.01	0.40	0.25	0.02
EC-164863 × H-24	3.53**	-0.27	-0.56**	0.08	-3.02	0.26	-0.01	-11.85**	-0.14	-1.51**	-0.51**	0.21
EC-164563 × EC-914104	0.74	-0.05	0.71**	-3.37**	2.29	-0.65**	0.05	-5.48	-0.24**	-0.92	0.66**	0.11
EC-164563 × Azad T-5	0.21	0.47	-0.37	2.99**	-6.43**	0.63	0.06	9.80**	0.00	0.97	-0.35	-0.63
EC-164563 × H-24	-0.96	-0.42	-0.34	0.38	4.14**	0.02	-0.10**	-4.32	0.23**	-0.04	-0.31	0.52
EC-249504 × EC-914104	2.53**	-0.18	-0.05	-0.76	-1.96	0.68**	0.09**	0.08	-0.16	1.08	0.39	0.36
EC-249504 × Azad T-5	1.12**	0.17	0.43	-0.37	-1.12	-0.77**	-0.11**	-0.01	-0.09	0.40	-0.37	1.63*
EC-249504 × H-24	-3.65**	0.02	-0.38	1.14	3.08	0.10	0.02	-0.07	0.24**	-1.48**	-0.02	-2.00**
EC-620395 × EC-914104	-0.69	0.99**	-0.52**	-0.14	-0.24	-0.07	-0.11**	-8.62**	-0.02	-0.65	-0.34	-0.56
EC-620395 × Azad T-5	-0.16	-0.87**	-0.21	0.55	-0.38	0.49	-0.01	-4.42	0.03	-0.83	0.26	-1.71**
EC-620395 × H-24	0.85*	-0.12	0.73**	-0.41	0.62	-0.43	0.12**	13.03**	-0.01	1.48**	0.0	2.27**
SE (sij)	0.414	0.287	0.065	0.688	1.045	0.012	0.018	1.098	0.076	0.019	0.014	0.711

*, ** significant at 5% and 1% level, respectively

Table 4. Estimation of Better Parent Heterosis (BPH) and Standard Check Heterosis (SCH) for different yield characters in Tomato

Cross combination	Days to 50% flowering		Number branches/plant		Number fruit/cluster		Number fruit/plant		Average fruit weight (g)		Fruit diameter (cm)		Fruit shape index	
	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH
EC-165690 × EC-914104	-12.94	-7.19	9.00	15.36	15.99	4.09	8.84	11.65**	0.02	4.45	0.96	-3.37	24.69**	42.84**
EC-165690 × Azad T-5	0.82	7.48	4.48	10.59	10.71	-0.64	7.39	-0.22	7.86	12.64**	8.16	8.43	13.58	30.12
EC-165690 × H-24	-9.69	-3.72	-13.02	14.92	23.73**	11.05**	20.36**	10.32	-5.75*	-1.57	-0.19	-4.48	21.30	38.92**
EC-164863 × EC-914104	-10.80	2.13	11.82	8.53	10.36	-4.54	1.90	4.52	11.28**	14.64**	43.27**	27.60**	25.95**	28.63
EC-164863 × Azad T-5	-32.83**	-17.43	24.51**	20.84**	19.37	3.25	14.04	5.97	15.90**	10.51	-4.35	-4.11	25.66**	34.99**
EC-164863 × H-24	-5.90	4.26	-24.96**	-0.85	-12.16**	-24.02**	26.12**	14.44**	9.39	5.56	24.22**	10.64	31.62**	35.42**
EC-164563 × EC-914104	-11.98	-10.64	2.91	14.59	11.63	5.98	-13.18**	-9.54**	0.60	14.69**	-7.55**	-7.43**	36.59**	33.30**
EC-164563 × Azad T-5	-18.26**	-17.02**	6.37	18.45	-11.77**	-16.23**	5.19	9.60	-10.47**	2.07	9.63	9.90	17.76	26.51
EC-164563 × H-24	-24.55**	-23.40**	-25.52**	-1.59	-17.92**	-22.07**	5.89	10.33	-0.25	13.72**	-6.81	-6.69**	15.81	19.09
EC-249504 × EC-914104	21.10**	16.43**	18.51	19.59**	24.64**	0.53	-6.24	-3.82*	5.55	9.54	52.37**	32.16**	45.42**	29.06
EC-249504 × Azad T-5	11.54	7.24	20.51**	21.62**	34.94**	8.84**	6.18	0.90	3.99	7.92	-1.10	-0.85	-6.25**	0.74
EC-249504 × H-24	-7.05	-10.64	-16.97**	9.71	4.06	-13.36**	17.42	11.58**	8.15	12.24**	28.80**	9.96	19.93	23.33
EC-620395 × EC-914104	7.14	22.66**	36.42**	35.51**	13.53	-8.44	-2.91	-0.40	9.78	13.09**	4.75	13.96	0.37	-3.50**
EC-620395 × Azad T-5	-6.43	19.68**	13.92	13.16	19.57	-3.57	13.03	5.03	7.16	10.34	8.42	17.96**	-6.91**	0.00
EC-620395 × H-24	8.52	20.22**	-15.86	11.17	30.03**	8.26**	20.94**	9.74	7.78	10.99	-12.03**	-4.30	19.24	22.69

*, ** significant at 5% and 1% level, respectively

Table 5. Estimation of Better Parent Heterosis (BPH) and Standard Check Heterosis (SCH) for different yield and quality characters in Tomato

Cross combination	Plant height (cm)		Total yield/plant (kg)		Pericarp thickness (mm)		Total soluble solid (° Brix)		Ascorbic acid (mg/100g)		Titratable acidity (%)	
	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH
EC-165690 × EC-914104	9.82	-7.43	19.60	16.39	-22.46	-14.29	-24.41**	-10.61**	8.11**	12.14	-19.82**	-21.56**
EC-165690 × Azad T-5	-0.06	-12.80	40.98**	12.14	-28.62**	-22.45	-10.18	6.20	2.61	11.73	-12.91	-12.44
EC-165690 × H-24	13.16**	-8.93	36.44**	8.53	-0.06	22.45	-5.51	11.73	6.72	10.70	-15.53	-17.25
EC-164863 × EC-914104	6.60	-10.14	23.03	19.72	9.94**	34.69**	9.97	26.63**	-10.44**	-1.03	-20.50**	-20.90**
EC-164863 × Azad T-5	-7.96	-19.68**	52.66**	17.03	-3.39	18.37	14.43**	21.10**	-11.25**	-1.92	-31.87**	-31.51**
EC-164863 × H-24	-16.33**	-32.66**	59.49**	20.64**	-40.03**	-26.53**	-3.17	2.48	-5.34	4.61	-26.67**	-27.03**
EC-164563 × EC-914104	-11.26	-9.75	6.47	3.61	-26.15	-18.37	-4.13	21.10**	2.66	9.30	-14.33	-10.45
EC-164563 × Azad T-5	1.99	3.72	16.04	11.86	8.95**	18.37	-23.34**	-3.17	-4.14	4.38	-17.50	-13.76
EC-164563 × H-24	-12.78**	-11.30	30.07**	25.36**	-25.04	-8.16	-26.29**	-6.89**	7.84**	14.82**	-5.39	-1.16
EC-249504 × EC-914104	4.13	-11.55	7.99	5.08	5.67**	29.33**	4.22	27.13**	7.48**	15.63**	-0.42	5.14
EC-249504 × Azad T-5	2.05	-10.96	25.40	8.81	-7.12	13.67	-11.81	7.58	9.18**	18.88**	-3.14	2.32
EC-249504 × H-24	1.02	-14.20	44.18**	25.08**	-43.37**	-30.61**	-10.08	9.68	2.15	9.90	4.82**	10.61**
EC-620395 × EC-914104	-14.90**	-21.74**	15.60	12.50	-34.71**	-27.82	0.27	15.46	-5.42	4.20	-10.39	1.00
EC-620395 × Azad T-5	-10.34	-17.55**	50.97**	15.75	-38.76**	-33.47**	8.20**	21.23**	-11.38**	-2.37	-0.49	12.27**
EC-620395 × H-24	2.10	-6.12	60.83**	21.67**	-12.05	7.76	1.22	13.41	8.51**	19.54**	-13.82	-2.82

*, ** significant at 5% and 1% level, respectively