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Research Note

Combining ability analysis for growth, yield and quality traits of tomato (*Solanum lycopersicon* (Mill.)Wettsd.) genotypes

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Abstract
Combining ability of thirteen lines for growth, yield and quality traits was conducted through a line × tester analysis. The analysis of variances mean sum of squares for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant differences for all the characters except fruit length and pericarp thickness. Mean sum of squares due to lines were found highly significant for plant height followed by ascorbic acid, number of fruits per plant, average fruit weight, number of fruits per cluster, fruit length, total fruit yield per plant, marketable fruit yield per plant and pericarp thickness. The estimate of variance of GCA and SCA and their ratio indicated preponderance of non-additive gene action for most of the traits. Based on the mean performance and *gca* effects, male parents H-86 and NDT-4 were found as good general combiner for fruit yield per plant and number of fruits per plant, while female parents Arka Ahuti, Arka Abha and Azad T-6 were better for fruit yield per plant.

Keywords
Solanum lycopersicon (Mill.)Wettsd., combining ability, fruit yield per plant

Tomato (*Solanum lycopersicon* (Mill.) Wettsd.), 2n=24) of nightshade or solanaceae family with primary centre of origin in Mexico-Peru-Equador region was once considered inedible but has evolved into globally leading popular vegetable. It is highly worked crop by the horticulturists and breeders. It has wide range of variation in terms of growth habit, morphological traits and uses making it a repository of glowing traits in its armory. It has determinate *vs* indeterminate types, cherry to table type, canning to juice type, smooth to ridged, acidic to sweet type, red to orange, yellow to striped colour fruits, etc., But whatever may be the type botanically these are same and crossable. Botanical nomenclature of tomato has seen a lot of debate, research work and change. It's nomenclature has changed from previously widely used *Lycopersicon esculentum* Miller in *Lycopersicon* genus to originally named *Solanum lycopersicum* L in *Solanum* genus (named in 1753 by Linnaeus; *lyco* = wolf, *persicum* = peach *i.e.,* wolf-peach). Tomato ranks second in importance next to potato in many countries including India (Bose and Som, 1993). It is used as fresh as well as processed vegetable. It is also very important for processing industry as it ranks first as processing vegetable crops in the world. Ripe tomato is widely used for the preparation of several processed items like paste, syrup, juice, soup, ketchup, drinks, whole peeled tomato and canned tomato etc, in the processing industry on large scale. Being very good appetizer, tomato is rich source of minerals, vitamins and organic acids. In addition to meet local demand, tomato has also been identified as potential vegetable for export by the APEDA. General combining ability study helps in making the choice of the parents and also helps in the isolation of suitable germplasm for further improvement. General combining ability is primarily a function of additive and additive × additive gene action. The *sca* effects represent non-additive gene action which is non-fixable. Specific combining ability effects helps in the identification of superior cross combinations for development of promising varieties/hybrids. The crosses showing high *sca* effects involving parents with high *gca* effects may give rise desirable segregants in future generation.

Experiment was conducted on sandy loam soil, at the Main Experiment Station, Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad (U.P.). Geographically, Kumarganj falls under humid sub-tropical climate and is located in between 24.47^0 and 26.56^0 N latitude and 82.12^0 and 83.98^0 E longitude at an altitude of 113 m gangetic alluvial plains of Eastern Uttar Pradesh. The physical and chemical properties of the soil are good and average fertility level and pH in the range of 7.5 to

8.5. The experimental plant material for present investigation was comprised of 36 F_1's developed by crossing nine lines (Arka Abha, Azad T-6, Arka Ahuti, Punjab Chhuhara, HS-7, Angoor Lata, NDT-5, NDT-3, and Arka Abhijeet) with four testers (CO-3, H-24, H-86 and NDT-4) during *rabi*, 2012-13. The experiment was conducted in Randomized Complete Block Design (RBD) with three replications to assess the performance of 36 F_1 hybrids and 13 parents (9 lines and 4 testers). Observations were recorded for five randomly selected plants in each replication. Genotype means were used for the analysis of variance (Panse and Sukhatme, 1967). The combining ability analysis was carried out following Kempthorne (1957). Data were recorded on five randomly selected plants for characters under study.

Analysis of variances (Table 1) for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant differences for all the characters except fruit length and pericarp thickness. Variances due to lines were highly significant for plant height followed by ascorbic acid, number of fruits per plant, average fruit weight, number of fruits per cluster, fruit length, total fruit yield per plant, marketable fruit yield per plant and pericarp thickness. Whereas variances due to testers were also highly significant for plant height. Similar finding was also reported by Dharmatti *et al.* (1999), Pandey (2006), Singh *et al.* (2006) and Saidi *et al.* (2008). The significant and positive *gca* effects for fruit yield per plant were exhibited by four lines. Three lines which in order of merit for good general combining ability were Arka Ahuti, Arka Abha and Azad T-6 among lines and along with two testers H-86 and NDT-4 for fruit yield per plant. On the basis of *gca* effects and mean performance, lines Azad T-6 was found good combiner for days to 50 % flowering, average fruit weight, pericarp thickness, number of locules per fruit, number of fruits per plant, marketable fruit yield per plant, total fruit yield per plant. Thus, lines Arka Abha and Azad T-6 among lines and NDT-4 among testers emerged as the most useful parent as these parents were found good general combiner along with high *per se* performance (Table 2) for most of the traits studied. Hence, these parents may also be recommended for exploitation in hybridization programme aimed at improving the yield components for which they were good general combiner. These results corroborated with the findings of Singh *et al.* (2006), Veer *et al.* (2006), Hannan *et al.* (2007), Prabuddha *et al.* (2008) and Sherpa *et al.* (2014). Out of thirty six crosses studied two crosses *viz.***,** Arka Abha × NDT-4, and Azad T-6 × CO-3 showed significant and positive *sca* effects for fruit yield per plant as well as some other yield components (Table 3). The cross Arka Abha × NDT-4 was found most promising as it had highly significant *sca* effects for fruit yield per plant along with average fruit weight. While the cross Azad T-6 × CO-3 was found significant and positive *sca* effects for average fruit weight, ascorbic acid, marketable fruit yield per plant. Relationship between positive and significant *sca* effects of crosses with its corresponding *gca* effects of their parents for the characters under study and also advocated by previous workers in tomato (Joshi and Thakur, 2005; Mahendrakar *et al.,* 2005; Veer *et al.,* 2006; Srivastava *et al.*, 2013; Yadav *et al.*, 2013 and Sherpa *et al.,* 2014).

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Table 1. Analysis of variance for combining ability following line × tester mating design for 14 characters in tomato

Sources of variation	*df*	Days to 50 % flowering	Plant height (cm)	Number of primary branches / plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (gm)	Pericarp thickness (cm)	Number of locules / fruit	Total soluble solids	Ascorbic acid (mg/100g)	Number of fruits / cluster	Number of fruits / plant	Marketable fruit yield / plant (kg)	Total fruit yield / plant (kg)
Replications	2	2.231	3.296	0.126	0.379	0.801	16.042	0.711	0.257	0.165	16.322	0.391	4.764	0.026	0.132
Lines	8	5.579	5540.582**	0.489	1.268*	2.330	351.034*	0.888**	0.596	0.982	1490.487**	1.763*	354.621**	0.905**	1.174**
Testers	3	4.706	10934.510**	0.281	0.821	1.151	176.345	0.292	0.459	0.215	218.692	0.403	19.528	0.219	0.262
Lines × Testers	24	6.282**	764.531**	0.258**	0.502	1.996*	119.736**	0.229	0.818**	0.783*	112.887**	0.613*	29.431*	0.220**	0.213**
Error	70	2.193	42.761	0.081	0.318	1.044	10.087	0.210	0.113	0.113	6.365	0.275	11.765	0.030	0.026

Table 2. Estimates of general combining ability (*gca*) effects of parents (lines and testers) for characters in tomato

S. No.	Lines	Days to 50 % flowering	Plant height (cm)	Number of primary branches / plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Pericarp thickness (cm)	Number of locules /fruit	Total soluble solids	Ascorbic acid (mg/100g)	Number of fruits / cluster	Number of fruits / plant	Marketable fruit yield / plant (kg)	Total fruit yield / plant (kg)
1.	Arka Abha	-1.227**	-10.719**	0.028	0.283	0.117	8.123**	-0.561**	0.097	-0.179	-8.502**	0.233	5.241**	0.520**	0.215**
2.	Azad T-6	0.356	-17.469**	-0.089	-0.175	-0.388	2.060*	0.170	0.147	0.515**	-5.390**	0.208	5.075**	0.253**	0.323**
3.	Arka Ahuiti	1.190**	-8.385**	-0.256**	-0.089	-0.373	-2.711**	0.050	-0.269**	0.341*	-4.543**	-0.583**	8.075**	0.166**	0.269**
4.	Punjab chuhra	-0.144	-14.469**	-0.289**	0.498**	0.582	-6.461**	0.212	0.089	-0.135	1.910*	0.150	-0.259	-0.237**	0.066
5.	HS-7	-0.394	25.265**	-0.056	-0.459**	-0.183	-7.627**	-0.001	-0.261**	-0.107	18.998**	-0.175	1.296	-0.235**	-0.441**
6.	Angoor Lata	0.440	20.398**	0.044	-0.419**	-0.579	-3.294**	-0.106	0.264**	-0.175	-8.460**	-0.350	-5.610**	-0.301**	-0.571**
7.	NDT-5	-0.477	37.581**	0.053	0.101	0.571	3.706**	-0.203	-0.153	-0.080	-13.043**	0.033	-1.592	0.086	-0.079
8.	NDT-3	0.273	-18.185**	0.253**	-0.027	0.430	0.581	0.379**	-0.203*	-0.370*	3.020**	0.713**	-4.175**	-0.135*	0.058
9.	Arka Abhijeet	-0.019	-14.019**	0.311**	0.286	-0.178	5.623**	0.060	0.289**	0.192	16.009**	-0.229	-8.050**	-0.117*	0.160**
	SE (gi) lines	**0.404**	**1.795**	**0.076**	**0.157**	**0.299**	**0.917**	**0.128**	**0.096**	**0.166**	**0.788**	**0.179**	**0.945**	**0.052**	**0.047**
	SE (gi – gj)	**0.571**	**2.539**	**0.108**	**0.221**	**0.423**	**1.297**	**0.181**	**0.136**	**0.235**	**1.116**	**0.254**	**1.336**	**0.074**	**0.068**
Testers															
1.	CO-3	0.227	-13.285**	-14.176**	-0.241*	-0.257	-3.100**	-0.146	0.137*	-0.115	-3.206**	0.169	0.391	-0.102**	-0.078*
2.	H-24	-0.625*	-6.396**	-5.967**	0.154	0.054	-0.951	0.000	-0.100	0.069	0.946	-0.042	0.404	-0.021	-0.091**
3.	H-86	0.171	-10.207**	-11.051**	-0.009	-0.037	1.363*	0.086	-0.122	0.072	-1.169*	-0.008	-1.274*	0.007	0.098**
4.	NDT-4	0.227	29.889**	31.194**	0.097	0.240	2.688**	0.060	0.085	-0.026	3.429**	-0.119	0.479	0.116**	0.071*
	SE (gi) testers	**0.269**	**1.197**	**1.267**	**0.104**	**0.199**	**0.917**	**0.085**	**0.064**	**0.111**	**0.526**	**0.119**	**0.630**	**0.034**	**0.032**
	SE (gi – gj)	**0.381**	**1.693**	**1.792**	**0.147**	**0.282**	**0.864**	**0.120**	**0.091**	**0.156**	**0.744**	**0.169**	**0.891**	**0.049**	**0.045**

*, ** significant at 5 and 1 per cent levels, respectively

Table 3. Estimates of specific combining ability (*sca*) effects of crosses for 14 characters in tomato

S. No.	Crosses	Days to 50 % flowering	Plant height (cm)	Number of primary branches / plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (gm)	Pericarp thickness (cm)	Number of locules / fruit	Total soluble solids	Ascorbic acid (mg/100g)	Number of fruits / cluster	Number of fruits / plant	Marketable fruit yield / plant (kg)	Total fruit yield / plant (kg)
1	Arka Abha X Co-3	-0.14	-1.21	0.14	-0.50	-0.77	-10.57**	0.01	-0.35	-0.03	-0.50	-0.64		-0.49**	0.05
2	Arka Abha X H-24	0.04	-4.77	0.40*	0.15	0.40	-5.72**	0.22	0.06	-0.29	-9.32**	0.50	0.68	-0.22*	0.19
3	Arka Abha X H-86	1.91*	6.37	-0.15	0.22	0.22	4.97**	-0.08	0.11	0.55	-4.87**	0.40	-0.64	0.16	-0.12
4	Arka Abha X NDT-4	-1.81*	-0.39	-0.38*	0.13	0.15	11.31**	-0.16	0.17	-0.22	14.70**	-0.26	1.27	0.55**	-0.12
5	Azad T-6 X Co-3	-0.73	-7.46*	0.35*	-0.03	-0.35	9.16**	-0.04	-0.06	0.17	10.34**	0.31	-0.47	0.36**	-0.16
6	Azad T-6 X H-24	-0.88	-15.02**	-0.11	0.24	0.78	9.01**	0.03	-0.36	-0.58	-1.81	-0.04	-5.15**	0.15	-0.10
7	Azad T-6 X H-86	0.66	-1.88	-0.24	-0.47	-0.19	-5.30**	0.22	0.70***	0.19	-3.28*	-0.27	6.19**	0.01	0.09
8	Azad T-6 X NDT-4	0.94	24.36**	0.00	0.26	-0.24	-12.88**	-0.21	-0.28	0.23	-5.25**	0.00	-0.56	-0.51**	0.17
9	Arka Ahuti X Co-3	0.44	-6.88	0.29	-0.05	-0.04	0.27	0.08	0.42*	0.29	-1.79	0.57	0.53	0.01	0.01
10	Arka Ahuti X H-24	1.63*	-9.10*	0.02	-0.23	-0.30	2.78	-0.29	-0.44*	-0.48	-0.28	-0.25	-0.49	0.10	-0.13
11	Arka Ahuti X H-86	0.50	-2.96	-0.10	0.06	0.14	5.47**	-0.18	-0.22	-0.06	4.84**	-0.25	1.19	0.28**	0.33**
12	Arka Ahuti X NDT-4	-2.56**	18.94**	-0.20	0.21	0.20	-8.52	0.38	0.24	0.24	-2.76	-0.07	-1.23	-0.39**	-0.21*
13	Pb.chuhhra X Co-3	-1.56	10.20**	-0.25	0.71*	1.26	0.35	0.32	0.20	0.06	2.42	-0.39	1.53	0.05	-0.01
14	Pb.chuhhra X H-24	-0.38	2.98	-0.31*	0.42	0.88	0.53	0.17	0.57**	-0.12	-1.73	-0.18	0.51	0.03	0.00
15	Pb.chuhhra X H-86	0.83	4.46	0.56***	-0.05	-0.60	-0.11	0.02	-0.31	0.18	3.53*	0.48	-1.14	-0.03	0.30**
16	Pb.chuhhra X NDT-4	1.11	-17.64**	0.00	-1.08**	-1.53*	-0.77	-0.51*	-0.45*	-0.13	-4.22**	0.09	-0.90	-0.06	-0.29**
17	HS-7 X C0-3	0.02	2.47	-0.18	-0.45	-1.63	2.18	0.02	-0.49*	-0.68*	-0.34	-0.14	0.64	0.09	-0.22*
18	HS-7 X H-24	-0.79	13.58**	0.39*	-0.41	-0.96	1.03	-0.07	-0.08	0.64	2.68	0.41	-0.99	0.01	0.41
19	HS-7 X H-86	1.41	13.32**	-0.07	0.13	0.86	-0.95	0.01	0.57**	-0.41	-0.37	0.24	0.47	-0.01	-0.39**
20	HS-7 X NDT-4	-0.64	-29.37**	-0.13	0.73*	1.72**	-2.27	0.03	0.00	0.45	-1.97	-0.51	-0.12	-0.09	0.19*
21	A.Lata X C0-3	0.86	2.40	-0.05	0.06	0.16	2.18	-0.12	0.89**	-0.12	4.46**	0.37	-0.19	0.09	-0.16
22	A.Lata X H-24	-1.63*	24.78**	-0.31*	0.08	0.03	-0.97	-0.30	0.59**	0.45	-1.36	-0.02	5.19	0.13	-0.24*
23	A.Lata X H-86	-0.75	2.26	0.13	0.01	0.22	2.05	-0.15	-0.65**	0.20	-0.91	-0.15	-3.18	-0.05	0.07
24	A.Lata X NDT-4	1.52	-29.44**	0.23	-0.16	-0.42	-3.27	0.57*	-0.83**	-0.52	-2.18	-0.21	-1.82	-0.17	0.33**
25	NDT-5 X Co-3	0.11	5.09	-0.36*	-0.07	0.59	-5.15**	-0.29	-0.40*	-0.17	1.71	-0.01	1.19	-0.14	0.30**
26	NDT-5 X H-24	0.63	10.93**	0.08	-0.01	-0.12	-1.97	0.03	0.17	1.00**	-1.11	-0.23	-0.82	-0.10	-0.46**
27	NDT-5 X H-86	-1.84*	-8.33*	-0.18	0.01	-0.31	0.05	0.38	-0.30	-0.39	2.67	-0.47	-5.81**	-0.25*	-0.14
28	NDT-5 X NDT-4	1.11	-7.69*	0.46*	0.07	-0.16	7.06**	-0.12	0.52**	-0.45	-3.26*	0.71	5.44**	0.49**	0.31**
29	NDT-3 X Co-3	0.36	-0.61	-0.12	0.17	0.16	0.97	-0.17	-0.38	0.70*	-11.02**	-0.19	0.44	0.08	0.15
30	NDT-3 X H-24	-0.79	-13.17**	-0.06	0.10	-0.05	-2.84	0.37	-0.28	-0.67*	6.27**	0.45	1.76	-0.02	0.18
31	NDT-3 X H-86	-0.59	-7.69*	-0.05	0.10	-0.01	-3.66	-0.06	-0.19	-0.08	-2.34	0.20	2.77	-0.02	-0.02
32	NDT-3 X NDT-4	1.02	21.48**	0.22	-0.38	-0.10	5.52**	-0.13	0.84**	0.06	7.09**	-0.47	-4.98*	-0.04	-0.31**
33	NDGCT-1 X Co-3.	0.65	-3.98	0.19	0.15	0.61	0.60	0.18	0.16	-0.22	-5.26**	0.12	-2.35	-0.04	0.05
34	NDGCT-1 X H-24	2.17**	-10.20**	-0.08	-0.36	-0.66	-1.88	-0.17	-0.23	0.06	6.67**	-0.64	-0.70	-0.08	0.15
35	NDGCT-1 X H-86.	-2.13*	-5.56	0.10	-0.01	-0.32	-2.53	-0.15	0.29	-0.17	0.74	-0.19	0.15	-0.09	-0.14
36	NDGCT-1 X NDT-4	-0.69	19.74**	-0.20	0.22	0.38	3.81*	0.14	-0.22	0.33	-2.15	0.71	2.90	0.21*	-0.07
	SE (S_{ij})	**0.81**	**3.59**	**0.15**	**0.31**	**0.60**	**1.83**	**0.25**	**0.19**	**0.33**	**1.58**	**0.36**	**1.89**	**0.10**	**0.09**
	SE ($S_{ij} - S_{kl}$)	**1.14**	**5.08**	**0.21**	**0.44**	**0.85**	**2.60**	**0.36**	**0.27**	**0.46**	**2.23**	**0.51**	**2.67**	**0.15**	**0.13**

*, ** significant at 5 and 1 per cent levels, respectively