

Studies on Combining Ability Analysis for Yield and Yield Related Traits in Tomato (*Solanum lycopersicum* L.)

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Abstract

An experiment on combining ability for yield and yield related traits of 50 F_1 hybrids of tomato derived from the crosses between 10 lines and 5 testers through line x tester technique was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during 2012-13 and 2013-14. The F_1 s and parents were grown in randomized block design with three replications. In most of the traits, over-dominance was predominant. The analysis of genetic variance for yield components showed that the main part of genetic variance was due to additive effect. Among the lines, EC 620533 was the promising line, EC 620534 the better general combiner and EC 620391, BBWR-10-3-17 and BBWR-11-1 the good general combiner. Among testers, Punjab Chhuhara was better general combiner for number of branches per plant and total number of fruits per plant followed by Arka Meghali and Palam Pink, which showed significant gca effect. Among crosses, BBWR-11-1 x Palam Pink was the better general combiner for the above traits.

Keywords: Combining ability; Fruit; Character; Desirable and yield components

Introduction

Tomato (*Lycopersicon esculentum* Mill.), a member of *Solanaceae* family, is the most widely grown vegetable of the World. India is the second largest tomato producer after China, accounting for about 11% of the world tomato production (Anonymous, 2012). It is gaining popularity among the consumers because of its higher content of antioxidants like vitamin C and lycopene. It has commercial value in the extraction of tomatine, a steroidal hormone, which is used as a substitute of diosgenin [1,2]. Its increasing consumption makes it a high value crop for generating income to the farmers. In tomato the galactosidases plays important role in softening of tomato by degrading the galactans enzyme Pressey; Steinhauser et al.

Tomato can be exploited for hybrid seed production because of its easy crossing and growing under varied climatic conditions, fruit containing large number of seeds and possessing high degree of heterosis for growth, yield and earliness. The choice of parents for hybridization needs to be based upon complete genetic information, the knowledge of heterosis and their combinations for the improvement of characters under consideration. Exploitation of hybrid vigour is one of the important means, by which, the crop yield can be increased. In view of the above facts, the efforts were made to develop F_1 hybrids for high yield, qualitative and quantitative traits.

Recent studies indicate that lycopene that gives the tomato its bright red colour on ripening, is a very effective natural antioxidant and quencher of free radicals [3] lycopene is especially efficient in neutralizing Reactive Oxygen Species (ROS). These properties of lycopene are due to its unique chemical structure, a very long chain of conjugated double bonds. Efforts are being made to increase its productivity by developing superior varieties. The components, i.e., gca and sca are defined by Sprague [4]. They stated that gca effects were due to additive type of gene action and sca effects were due to non-additive (dominant or epistatic) gene action. Several studies of combining ability for yield components are available in many species. Some researchers found the pre-dominancy of gca to be more important than that of sca [5,6], while others suggested that sca was more important [7-9].

Materials and Methods

The experimental material comprised 15 genetically divers genotypes (10 lines, 5 testers and 2 checks) was sown in nursery during 2012-13. The crosses were made in a line x tester fashion (Kempthorne, and the F_1 seed was extracted during 2013-14. Fifty F_1 crosses along with 15 parents and standard checks were sown in the nursery during 2013 and 2014, and the seedlings were transplanted in Randomized Block Design with three replications accommodating 14 plants in each treatment at 75x45 cm spacing. All the recommended cultural practices and plant protection measures were adopted to raise the crop successfully. Crosses were made manually by using the standard procedure of hand emasculation and pollination. F_1 s were evaluated along with their parents for various traits. Observations were recorded on number of flowers per cluster, number of flower clusters per plant, number of fruits per truss, total number of fruits per plant and total soluble solids. The mean values of all the above characters were subjected to statistical analysis and heterosis [10] were determined as increase or decrease of F_1 hybrids over standard check variety Hisar Arun.

Results and Discussion

The analysis of variance for combining ability (Table 1) showed the existence of significant variation for seven characters, indicating a wide range of variability among the genotypes. Highly significant variation due to gca as well as sca indicated the importance of additive as well as non-additive types of gene action of inheritance for all the traits. In combining ability analysis, the variances due to crosses were further partitioned into lines, testers and lines x tester interaction components (Table 1). The difference due to lines was found significant for all the

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characters except days to 50% fruit set. Variance for testers was noticed significant for four traits, while the line x tester interaction variance was found highly significant for five of the seven traits, suggesting the major role of lines and the line x tester interaction for majority of the characters.

Days to 50% flowering

Among lines, the genotype EC 620533 showed the significantly positive gca, and among testers, none showed the significant gca effects and their difference (Table 2). Out of fifty crosses, none of the crosses exhibited significant sca effects, but among cross combinations, the cross Punjab Varkha Bahar-2 x Hisar Lalit (-2.56) followed by EC 620380 x Punjab Chhuhara (-2.29) showed higher sca effect for earliness. The cross EC 620380 x Palam Pink (2.94) and BBWR-11-1 x Arka Meghali (1.74), which showed positive sca effects favouring late flowering, were the poor specific cross combinations Anbu et al., [11] reported higher values for sca than gca for earliness, while Singh et al., [12] revealed both additive and non-additive variances for days to first flowering. They mentioned the tester Lalmani as the good general combiner for this character. Similarly, Gamed was reported as a good general combiner for early flowering. The findings of present study also corroborate the results of Cheema et al., Kumar et al. and Chauhan et al. [13-15] who identified a good general combiner and six early flowering cross combinations for days taken to 50% flowering.

Days to 50% fruit set

Among the crosses, the general and specific combining ability effects for days to 50% fruit set in parents and hybrids were not significant, hence, the results have not been interpreted in detail. Most of the hybrid combinations were late in 50% fruit set (Table 3). Similarly, all the lines except BBWR-10-3-17, EC 620383, EC 620380 and testers were also late in 50% fruit set in comparison of standard check Hisar Arun. Similar to present study Virdewala et al., Brahma et al. and Uppal et al. [16-18] also observed the hybrids early in flowering and maturity, while Tayel et al. [19] reported the hybrids late in flowering as compared to their parents.

Number of branches per plant

The significantly maximum positive gca effect was observed for line BBWR-11-1 (0.87*) and it was identified as the best general combiner for number of branches per plant (Table 4). The other good general combiner line was EC 620533. Among testers, Punjab Chhuhara was found a good general combiner for number of branches per plant. Only one line EC 620534 showed significantly negative gca effects, indicative for least branching habit. Out of fifty, some crosses showed significantly positive sca effects. The cross combination EC 620380 x Palam Pink (2.33*) recorded the significantly maximum positive sca effect. The results of present study find the support of Lonkar and Borikar [12,20], who reported complete dominance of low intensity of branches. Peter and Rai [21] and Kumar et al.

Sr. No.	Characters df	Mean Squares			
		Replication	Lines	Testers	Line x testers
1.	Days to 50% flowering	2.587	22.451*	1.757	5.834
2.	Days to 50% fruit set	1.140	19.073	19.357	14.471
3.	Number of branches per plant	0.287	2.681*	3.817*	4.517*
4.	Number of flowers per cluster	1.047	1.914*	1.523	6.857*
5.	Number of flower clusters per plant	0.447	4.638*	4.493*	6.730*
6.	Number of fruits per truss	0.127	6.756*	1.417*	4.561*
7.	Total number of fruits per plant	15.047*	70.149*	50.443*	47.347*

*, **P ≤ 0.05 and 0.01, respectively.

Table 1: ANOVA of the combining ability analysis for various characters in a line x tester set of tomato.

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-2.07	0.99	1.13	-0.14	1.59*	-0.07	1.13	-0.07	-1.21	-1.27
Palam Pink	0.19	2.94	-0.46	0.74	-1.32	0.27	0.27	-1.26	0.27	0.07	-1.52
Punjab Chhuhara	0.09	-2.29	0.30	0.50	-0.89	0.37	-0.29	-0.16	1.04	0.17	1.24
Arka Vikas	-0.37	-1.49	0.44	0.30	0.24	-0.16	0.50	0.30	-1.82	-2.02	3.70
Arka Meghali	0.19	-0.06	-1.12	-1.59	1.00	-0.06	-0.39	0.07	1.27	1.74	-0.86
Hisar Lalit	-0.10	0.90	0.84	0.04	0.97	-0.42	-0.09	1.04	-0.76	0.04	-2.56

SE gi = 2.25, SE gj = 2.15, C.D at 5% level of significance lines = 1.28, testers = 1.82, common lines = 4.46, common testers = 4.27

Table 2: General and specific combining ability effects for days to 50% flowering of parents and hybrids in a line x tester set of tomato.

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-0.34	-0.14	1.73	1.06	0.59	-2.41	-0.07	0.39	0.13	-0.94
Palam Pink	0.76	2.77	2.24	0.04	-1.29	1.17	-0.82	0.84	1.04	-1.02	-4.96
Punjab Chhuhara	0.42	-0.22	-0.76	-0.29	0.70	-0.16	2.17	-0.82	-0.62	-2.02	2.04
Arka Vikas	0.16	0.37	-0.16	-1.69	2.30	-2.22	3.44	-2.89	1.30	-1.09	0.64
Arka Meghali	-1.34	-2.79	0.34	1.47	-0.19	-0.72	-0.72	0.94	-3.86	3.40	2.14
Hisar Lalit	-0.00	-0.12	-1.66	0.47	-1.52	1.94	-4.06	1.94	2.14	0.74	0.14

SE gi = 5.38, SE gj = 5.16, C.D at 5% level of significance lines = 3.08, testers = 4.36, common lines = 10.69, common testers = 10.23

Table 3: General and specific combining ability effects for days to 50% fruit set of parents and hybrids in a line x tester set of tomato

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-0.20	-0.07	0.00	-0.13	0.60*	-0.60*	-0.20	-0.13	0.87*	-0.13
Palam Pink	-0.20	2.33*	-0.13	1.13*	-1.40*	-1.46*	-0.26	1.66*	-2.06*	1.26*	-1.06*
Punjab Chhuhara	0.53*	-0.73	1.80*	-0.26	-1.80*	0.13	0.20	-1.73*	1.20*	0.53	0.86*
Arka Vikas	0.20	-0.06	-0.53	0.40	0.86*	1.13*	0.33	-0.06	-1.46*	-1.13*	0.53
Arka Meghali	-0.23	-0.96*	-1.43*	-0.83	1.63*	-0.43	-0.23	-0.30	2.30*	-0.03	0.30
Hisar Lalit	-0.30	-0.56	0.30	-0.43	0.70	0.63	0.16	0.43	0.03	-0.63	-0.63

SE gi = 0.45, SE gj = 0.43, C.D at 5% level of significance lines = 0.25, testers = 0.36, common lines = 0.89, common testers = 0.85

Table 4: General and specific combining ability effects for number of branches per plant of parents and hybrids in a line x tester set of tomato.

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-0.29	-0.03	-0.16	0.24	-0.69*	0.31	0.31	0.51*	-0.23	0.04
Palam Pink	-0.12	-1.74*	2.32*	1.79*	-1.27	-0.00	-0.67	-0.67	-1.54*	1.19	0.59
Punjab Chhuhara	0.30	-1.84*	-1.10	0.69	1.62*	0.22	0.56	0.56	0.36	0.42	-1.50*
Arka Vikas	-0.19	1.66*	-1.94*	-1.80*	0.12	1.39*	-1.27	-1.60*	1.52*	1.59*	0.32
Arka Meghali	0.17	2.29*	-0.30	1.16	-2.57*	-0.97	1.02	0.69	-0.17	-1.77*	0.62
Hisar Lalit	-0.16	-0.373	1.02	-1.84*	2.09*	-0.64	0.36	1.02	-0.17	-1.44*	-0.04

SE gi = 0.70, SE gj = 0.67, C.D at 5% level of significance lines = 0.40, testers = 0.57, common lines = 1.40, common testers = 1.34

Table 5: General and specific combining ability effects for number of flowers per cluster of parents and hybrids in a line x tester set of tomato.

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	0.15	-0.05	0.62*	-0.71*	0.29	0.02	0.82*	-0.11	-1.05*	0.02
Palam Pink	0.38	-1.25	0.28	0.61	-0.72	-0.38	-0.12	0.74	2.34*	-2.05*	0.54
Punjab Chhuhara	-0.24	1.04	-0.42	0.58	-1.75*	0.91	0.51	0.71	-0.35	-1.08	-0.15
Arka Vikas	0.42	-1.95*	0.91	0.24	-0.75	-0.08	0.18	0.04	0.31	1.24	-0.15
Arka Meghali	-0.11	1.58*	0.78	-3.88*	0.44	1.11	0.04	0.58	-0.15	-0.22	-0.28
Hisar Lalit	-0.44	0.58	-1.55*	2.44*	2.78*	-1.55*	-0.62	-2.08*	-2.15*	2.11*	0.04

SE gi = 0.67, SE gj = 0.64, C.D at 5% level of significance lines = 0.38, testers = 0.54, common lines = 1.33, common testers = 1.28

Table 6: General and specific combining ability effects for number of flower clusters per plant of parents and hybrids in a line x tester set of tomato.

[22] recorded additive gene action more important than the non-additive gene action for number of branches per plant.

Number of flowers per cluster

Only one line showed significantly positive gca effects for this trait. The line BBWR-10-3-18 (0.51*) with significantly positive gca effect was rated as good general combiner for number of flowers per cluster (Table 5). However, none of the testers was found a good general combiner but Punjab Chhuhara and Arka Meghali showed positive effect. Out of fifty crosses, only the cross combination EC 620383 x Palam Pink (2.32*) registered the significantly highest sca effects followed by EC 620380 x Arka Meghali (2.29*), EC 620445 x Hisar Lalit (2.09*), EC 620391 x Palam Pink (1.79*), EC 620380 x Arka Vikas (1.66*), BBWR-11-1 x Arka Vikas (1.59*), BBWR-10-3-18 x Arka Vikas (1.52*) and EC 620533 x Arka Vikas (1.39*). Thus, these were rated as average specific combinations. Similar results were shown by Gul et al. (2010), Angadi et al. (2012) and Saeed et al. (2014) for number of flowers per cluster [22-24].

Number of flower clusters per plant

Among lines, a total of two genotypes showed significantly positive gca effects but four genotypes had negative gca effects. The line BBWR-10-3-17 showed the significantly highest positive gca effect and was marked as the best general combiner for number of flowers per plant (Table 6), which was also a good combiner for this trait. The line EC 620391 showed significantly positive gca effect but was rated as

average general combiner. None of the testers was found to be a good general combiner. Among hybrids, the cross combination EC 620445 x Hisar Lalit (2.78*), EC 620391 x Hisar Lalit (2.44*), BBWR-10-3-18 x Palam Pink (2.34*) and BBWR-11-1 x Hisar Lalit (2.11) exhibited the significantly positive sca effect, thus, rated as good specific cross combinations. This study also followed the trend of Kumar et al., Saeed et al. and Angadi et al. [22-25], who recorded high gca/additive gene action for number of flower clusters per plant.

Number of fruits per truss

Among lines, the significantly higher positive gca effect was observed for the line BBWR-10-3-17 (0.67*), which was the best general combiner (Table 7) followed by EC 620533 (0.47*), EC 620391 (0.40*) and EC 620445 (0.40*), which were noted as the good general combiners. None of the testers was found to be good general combiner for this trait. The line EC 620534 was the poor general combiner as it depicted the significantly maximum negative gca effect (-1.40*). The cross EC 620380 x Arka Meghali exhibited the significantly maximum positive sca effect (1.93*) closely followed by EC 620534 x Arka Vikas (1.70*), EC 620383 x Palam Pink (1.50*) and EC 620533 x Arka Vikas (1.50*). These three crosses were judged average specific combinations for number of fruits per truss. The above results are in conformity with the findings of Kanthaswamy et al. [26] and Bhatt et al. [27].

Total number of fruits per plant

The significantly highest positive gca effect was observed for line

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-0.60*	0.27*	0.40*	0.40*	0.47*	-1.40*	0.67*	0.27	0.27	-0.73*
Palam Pink		-0.36	-0.96	1.50*	1.36*	-0.96	-1.36*	-0.16	-1.23*	0.50	1.50*
Punjab Chhuhara		0.00	-1.66*	0.13	0.33	-0.33	0.93*	0.80	0.40	0.13	-1.86*
Arka Vikas		0.10	-0.10	-0.96*	-1.10*	0.90	1.50*	1.70*	-0.36	1.03*	-1.63*
Arka Meghali		0.06	1.93*	-1.26*	-0.06	0.93	-0.13	-0.60	0.66	-2.26*	1.06*
Hisar Lalit		0.20	0.80	0.60	-0.53	-0.53	-0.93	-1.73*	0.53	0.600	0.93

SE gi = 0.48, SE gj = 0.46, C.D at 5% level of significance lines = 0.27, testers = 0.39, common lines = 0.95, common testers = 0.91

Table 7: General and specific combining ability effects for number of fruits per truss of parents and hybrids in a line x tester set of tomato.

Testers	Lines	EC 620380	EC 620383	EC 620391	EC 620445	EC 620533	EC 620534	BBWR-10-3-17	BBWR-10-3-18	BBWR-11-1	Punjab Varkha Bahar-2
	GCA	-2.62*	0.31	0.58	-2.09*	-1.15*	-1.55*	1.45*	-1.42*	4.11*	2.38*
Palam Pink		1.41	-2.81	-1.08	4.32*	-0.34	2.05	-2.54	-5.54*	5.98*	1.78
Punjab Chhuhara		-1.68*	-0.04	2.35	-5.58*	6.08*	-1.18	-4.44*	3.88*	-3.24	-0.78
Arka Vikas		0.94	-3.01	0.05	-0.54	-1.88	5.85*	-0.74	2.58	1.12	-0.74
Arka Meghali		-0.95	-3.11	-3.71	6.02*	0.02	-1.91	4.82*	-2.51	-2.64	0.48
Hisar Lalit		0.28	8.98*	2.38	-4.21*	-3.88*	-4.81*	2.92	1.58	-1.21	-0.74

SE gi = 1.96, SE gj = 1.87, C.D at 5% level of significance lines = 1.12, testers = 1.58, common lines = 3.88, common testers = 3.72

Table 8: General and specific combining ability effects for total number of fruits per plant of parents and hybrids in a line x tester set of tomato.

BBWR-11-1 (4.11*), which was the best general combiner (Table 8) followed by Punjab Varkha Bahar-2 (2.38*). None of the testers was found to be good general combiner for this trait. The line EC 620380 was the poor general combiner as it depicted significantly maximum negative gca effect (-2.62*). The cross EC 620380 x Hisar Lalit exhibited the significantly maximum positive sca effect (8.98*). These three crosses were judged average specific combinations for number of fruits per plant. The above results are in conformity with the findings of Anbu et al. [11] and Singh et al. [12] who obtained larger values for sca than gca. Similarly, [28] reported two good general combiner lines and one tester for fruit number Lonkar and Borikar [12] and Singh et al. [20] judged two male sterile lines as the good general combiners. Whereas, Gamed was also noted as good general combiner for this trait (Kumar et al., Brahma et al., Rao et al., Singh et al., Kumari et al., Angadi et al., Farzane et al., Saleem et al.) [12,17,22,29-35] as it recorded the pronounced dominance effect for increased number of fruits per plant. All these results indicated good scope for utilizing such parents and combinations to improve the number of fruits per plant in tomato. The significantly highest positive sca effect was recorded in cross EC 620533 x Arka Meghali (4.96**). The cross EC 620445 x Arka Meghali (-6.04**) with highest negative sca effect was marked as the poorest cross combination for this trait.

The best lines, testers and cross combinations showing significant gca and sca those are among the lines, EC 620533 was the promising line with respect to days to 50% flowering, number of branches per plant, number of flower clusters per plant and total number of fruits per plant.

The line EC 620534 was better general combiner for number of branches per plant, number of fruits per truss and total number of fruits per plant. Similarly, the line EC 620391 was found good general combiner for number of flower clusters per plant and number of fruits per truss. Similarly, the line BBWR-10-3-17 was found good general combiner for number of flower clusters per plant, number of fruits per truss and total number of fruits per plant. The line BBWR-11-1 was found good general combiner for number of branches per plant, number of flower clusters per plant, total number of fruits per plant [36-41]. Similarly, among testers, Punjab Chhuhara was better general combiner for number of branches per plant and total number of fruits

per plant followed by Arka Meghali showing significant gca effect. Among crosses, BBWR-11-1 x Palam Pink was the better general combiner for total number of fruits per plant.

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