

Combining Ability Analysis for Growth, Yield and Quality Traits in Tomato (*Solanum lycopersicon* L.)

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ABSTRACT

An experiment was carried out to study the combining ability effects for growth, yield and its attributing traits in tomato in a 9×9 diallel mating fashion excluding reciprocals to generate 36 hybrids by using 9 lycopene rich genotypes viz., 55P2, Kashi Hemanth, EC321425, 16P2, Arka Meghali, EC-528388, COHM7, 11P4 and COHMUD3. The F₁s and parents were grown in a Randomized complete block design with 2 replications. The magnitude of SCA variance is more than GCA variance for all the characters under study. The parent COHMUD3 is good general combiner for plant height at last harvest, number of branches at last harvest and number of fruits per cluster whereas, it was observed that genotype EC321425 was good general combiner for days to flowering, days to fifty per cent flowering, number of fruits per cluster, number of clusters per plant, number of fruits per cluster and number of fruits per plant.

Keywords: Tomato, Genotypes, Growth, Yield

INTRODUCTION

Tomato (*Solanum lycopersicum* L.; 2n=24) is one of the important and most widely grown versatile vegetable crops of both tropics and sub tropics. It is grown for its edible fruit, which can be consumed, either raw or cooked in the form of various processed products like juice, ketchup, sauce, pickle, pastes, puree and powder. It is an important commercial and dietary crop. Tomato cultivation has become increasingly popular since the mid-nineteenth

century due to the short duration of the crop and high yield. It occupies the most prestigious berth not only in the sophisticated, ultra-modern kitchen, but also equally in the kitchen of the poor man, because of diverse nutrition and value added products that can be prepared from it.

Combining ability is the ability of two parents to transmit favorable or unfavorable traits to their progeny.

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The improvement programme of tomato can be enhanced to considerable extent if some basic information relevant to the pattern and genetic variability is made available to the plant breeders. The inheritance pattern and combining ability studies are the basic themes to derive such information which can be used as guide lines in planning tomato breeding programmes for achieving short and long term objectives. Combining ability studies are more reliable as they provide useful information for the selection of parents in terms of performance of the hybrids and elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. Diallel cross analysis provides the estimates of genetic parameters regarding combining ability as well as a rapid overall picture of the dominance relationship of the parents studied using the first filial generations (F_1) with or without reciprocals, Diallel analysis involving parents give the additional information as presence or absence of average degree of dominance, distribution of dominant and recessive genes in the parents. Application of diallel technique in a self-pollinated crop like tomato for this purpose may be appropriate. Hence the study was undertaken to estimate the combining ability in terms of specific and general combining ability.

MATERIALS AND METHODS

The material for the present investigation comprised of nine tomato lines (*Solanum lycopersicum* L.) namely 55P2, Kashi Hemanth, EC321425, 16P2, Arka Meghali, EC-528388, COHM7, 11P4 and COHMUD3. The crosses were made in a 9×9 diallel mating fashion excluding reciprocals to generate 36 hybrids. All 36 F_1 hybrids along with their (nine) parents and commercial checks (Arka Rakshak and Arka Samrat) were evaluated in randomized complete block design with two replications at college of Horticulture, Bengaluru. The crop was raised with row to row and plant to plant spacing 1 x 0.75 m respectively. The observations were recorded on randomly selected five plants from parents and F_1 s. The observations were recorded on Plant height at last harvest (cm), Number of

branches at last harvest, Days to first flowering, Days to 50 per cent flowering, Number of fruits per cluster, Number of fruits per plant, Average fruit weight (g), Yield per plant (kg) and quality characters like Number of locules per fruit, Total soluble solids (TSS) ($^{\circ}$ B), Pericarp thickness (mm), Firmness (kg/cm^2), Lycopene content ($\text{mg}/100\text{g}$), Titratable acidity (%) and Ascorbic acid ($\text{mg}/100\text{g}$). The combining ability analysis was worked out as per method suggested by Griffing method-1 and method-2.

RESULT AND DISCUSSION

Analysis of variance for general combining ability (GCA) and specific combining ability reveals the presence of both additive and non-additive gene action in the characters studied, which is indicated by the significance of both the GCA and SCA variances. The magnitude of SCA variance is more than GCA variance for all the characters under study. This reveals predominance of additive gene effects in governing expression of all these characters (Jyothis, 2015 and Sureshkumara, 2016).

General combining ability (GCA)

From the studies on GCA effects and their relative performance, it was observed that, all the desirable characters were not present in any single parent. However, three parents viz., 16P2, Kashi Hemanth and COHM7 were good general combiners for yield per plant. Whereas, three parents Arka Meghali, 11P4 and EC528388 were general combiners for lycopene content as they have shown significant GCA effect in positive direction.

The parent COHMUD3 is a good general combiner for plant height at last harvest, number of branches at last harvest, number of fruits per cluster, TSS, fruit firmness and ascorbic acid and this parent is also good general combiner for number of locules per fruit as it have shown significant negative GCA effect. Parent 11P4 is a good general combiner for plant height at last harvest, number of branches, number of clusters per plant, number of locules per fruit, fruit firmness, lycopene and ascorbic acid content.

COHM7 showed good general combining ability for number of fruits per plant, average fruit weight, yield per plant, pericarp thickness and fruit firmness. Parent EC528388 is having good general combining ability for plant height at last harvest, number of clusters per plant, fruit firmness and lycopene content. Arka Meghali is a good general combiner for lycopene content and parent 16P2 is a having good general combining ability for average fruit weight, yield per plant, pericarp thickness, fruit firmness and ascorbic acid content.

Parent EC321425 has shown significant positive GCA for number of fruits per cluster, number of clusters per plant, number of fruits per plant, TSS and firmness while, this also had significant GCA effect for number of locules per fruit. Kashi Hemanth is a good general combiner for average fruit weight, yield per plant, pericarp thickness, fruit firmness and this is also the good general combiner for number of locules per fruit as it have shown significant negative GCA effect.

Parent 55P2 showed good general combining ability for number of fruits per cluster, number of clusters per plant and fruit firmness. Negative GCA effect is desirable for earliness and in the present study parent EC321425 have expressed significant negative GCA effect for (in desired direction) for days to first flowering and days to 50 per cent flowering. Similar findings were done by Mahendrakar (2004), Premalakshmi et al. (2006), Shalini (2009), Bharathkumar (2014), Jyothi (2015) and Sureshkumara (2016).

Specific combining ability (SCA)

Plant height and number of branches are the important growth parameters to support yield and its component traits. The estimate of SCA effect for these two traits revealed that crosses EC321425 × EC528388 for plant height and Kashi Hemanth × EC321425 for number of branches at last harvest had significant and higher magnitude of SCA effects. One of the parents in the cross EC321425 × EC528388 involves negative × positive general combiner parents and positive × negative general combiner parents in Kashi Hemanth ×

EC321425. It also gives clue that these characters possess non-additive type of gene interactions for both plant height (Pandey et al., 2006; Akram et al., 2013 and Tanvi et al., 2017) and number of branches at last harvest (Srivastava et al., 1998 and Izge and Garba, 2012).

Dominance gene effects for days to first flowering and days to fifty per cent flowering was observed to be predominant as evident from higher magnitude of dominance gene effects in the hybrid combination of COHM7 × COHMUD3 which indicate that decreasing alleles are more frequently dominant. Whereas, for days to 50 per cent flowering, the highest negative SCA effect is observed in cross 16P2 × EC528388 in which parents are positive × positive combiners, which indicates presence of non-additive type of gene action in the expression of trait (Adhi et al., 2013 and Vilas et al., 2015). Therefore, the breeding methodology which exploit dominance and dominance × dominance epistasis would be highly rewarding. Under these circumstances the appropriate selection methods would be those that take the advantage of specific combining ability (Mather and Jinks, 1983).

With respect to number of fruits per cluster and number of clusters per plant highest positive SCA effect is observed in cross 55P2 × EC321425 which includes positive × positive combiners, indicating the presence of additive × additive type of gene action in the expression of these traits (Ashwini, 2005). For number fruits per plant cross 11P4 × COHMUD3 had highest positive SCA effect and it has negative × negative combiners. Such a tendency is attributed to over dominance and epistasis.

For both average fruit weight and yield per plant 16P2 × 11P4 had highest positive SCA effect and it has positive × negative combiners for both the traits which indicate the presence of additive × dominance type of gene action for expression of average fruit weight (Yashavantakumar, 2008 and Tanvi et al., 2017) and yield per plant (Yashavantakumar, 2008 and Tanvi et al.,

2017). The cross 16P2 × Arka Meghali showed highest negative SCA for number of locules per fruit which have positive × positive combiners. EC321425 × 11P4 have exhibited highest SCA effect for TSS and it have combinations of parents with positive × positive GCA effects. This indicates presence of additive × additive type of gene action in the expression of this character (Ashwini, 2005 and Tanvi et al., 2017).

55P2 × COHMUD3 exhibited highest positive SCA effect for pericarp thickness and it have negative × negative combiners indicating the predominance of over dominance and epistasis. For fruit firmness

16P2 × COHM7 exhibited highest positive SCA effect with positive × positive GCA effects indicating presence of additive × additive type of gene action. Kashi Hemanth × COHMUD3 showed highest positive SCA effect for lycopene content and it has negative × negative combiners which shows that it is governed by over dominance type of gene action. For ascorbic acid content cross Arka Meghali × EC528388 exhibited highest positive SCA effect with negative × negative combiners indicating the role of over dominance and epistasis in expression of this trait (Adhi et al., 2014).

Table 1: Estimates of GCA effects of growth parameters in 9 × 9 half diallele set of cross in tomato

Parents	X1	X2	X3	X4	X5	X6	X7	X8	X9
55P2	-2.699 **	-0.620 **	0.354	0.667	0.598 **	1.247 **	0.946	-6.030 **	-0.247 **
Kashi Hemanth	1.563	-0.175	0.081	-0.061	0.063	-0.889 **	0.242	20.339 **	1.016 **
EC321425	-5.005 **	-0.922 ***	-0.874 *	-1.242 *	0.566 **	1.595 **	10.382 **	-17.091 **	-0.889 **
16P2	-3.068 **	-0.422 *	1.263 **	1.530 **	-0.486 **	-0.639 **	0.454	22.394 **	1.123 **
Arka Meghali	0.254	0.048	-0.101	-0.833	-0.299 **	-0.986 **	-0.331	-5.700 **	-0.417 **
EC528388	3.879 **	0.164	0.263	1.121 *	-0.456 **	0.379 **	-0.725	-9.002 **	-0.442 **
COHM7	-9.359 **	-0.627 **	-0.192	-0.333	-0.081	-0.212 **	2.123 **	7.785 **	0.432 **
11P4	4.164 **	0.458 *	-0.374	-0.106	-0.059	0.291 **	-6.260 **	-7.045 **	-0.305 **
COHMUD3	10.270 **	2.097 **	-0.419	-0.742	0.154 *	-0.785 **	-6.830 **	-5.652 **	-0.269 **
SEm ±	0.97	0.19	0.43	0.46	0.06	0.04	0.62	0.59	0.04
CD @ 5 %	2.24	0.45	0.99	1.06	0.15	0.10	1.44	1.35	0.09

X1. Plant height at last harvest (cm)	X2. Number of branches at last harvest	X3. Days to flowering
X4. Days to 50 per cent flowering	X5. Number of fruits per cluster	X6. Number of clusters per plant
X7. Number of fruits per plant	X8. Average fruit weight (g)	X9. Yield per plant (kg/plant)

Table 2: Estimates of GCA effects of quality parameters in 9 × 9 half diallele set of cross in tomato

Parents	X10	X11	X12	X13	X14	X15
55P2	-0.383 **	-0.055	-0.024	0.032 **	-0.328 **	-1.210 **
Kashi Hemanth	-0.415 **	0.117	0.489 **	0.037 **	-0.211 *	-0.223
EC321425	-0.415 **	0.156 *	-0.458 **	0.032 **	-0.325 **	-1.721 **
16P2	0.808 **	-0.014	0.524 **	0.062 **	0.029	0.822 *
Arka Meghali	0.621 **	0.108	0.029	0.011	0.813 **	-1.778 **
EC528388	0.076	-0.141	-0.256 **	0.033 **	0.332 **	-1.595 **
COHM7	0.403 **	-0.401 **	0.147 *	0.046 **	0.048	0.688
11P4	-0.370 **	0.067	-0.203 **	0.071 **	0.351 **	2.256 **
COHMUD3	-0.324 *	0.163 *	-0.248 **	0.044 **	-0.708 **	2.761 **
SEm ±	0.12	0.07	0.06	0.01	0.08	0.37
CD @ 5 %	0.29	0.17	0.16	0.03	0.19	0.87

X10. Number of locules per fruit	X11. Total soluble solids (⁰ B)	X12. Pericarp thickness (mm)
X13. Firmness (kg/cm ²)	X14. Lycopene content (mg/100g)	X15. Ascorbic acid (mg/100g)

Table 3: Estimates of SCA effects of growth and yield parameters in 9 × 9 half diallele set of cross in tomato

Sl. No.	Crosses/ Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9
1	55P2 × Kashi Hemanth	4.17	-0.37	-3.64 *	-3.37 *	-0.72 **	3.49 **	5.99 **	-18.53 **	-0.94 **
2	55P2 × EC321425	-0.84	0.55	0.81	-0.19	2.55 **	6.21 **	-11.90 **	-7.08 **	-0.60 **
3	55P2 × 16P2	9.92 **	-0.37	-1.33	-1.46	1.39 **	-5.32 **	7.96 **	13.76 **	1.01 **
4	55P2 × Arka Meghali	0.27	-1.08	2.04	1.40	-1.33 **	-0.80 **	4.26 *	-5.14 **	-0.27 *
5	55P2 × EC528388	-6.09	-2.56 **	-1.83	-3.55 *	-1.14 **	-5.17 **	2.88	-10.36 **	-0.65 **
6	55P2 × COHM7	15.38 **	0.91	0.63	2.90	-0.25	1.42 **	5.64 **	13.17 **	0.79 **
7	55P2 × 11P4	-15.37 **	-0.09	0.81	0.17	1.56 **	-0.08	-2.87	-6.66 **	-0.55 **
8	55P2 × COHMUD3	9.18 **	1.37 *	1.35	1.31	-0.60 **	3.32 **	11.86 **	19.06 **	1.04 **
9	Kashi Hemanth × EC321425	11.65 **	3.84 **	4.08 **	4.54 **	1.37 **	5.15 **	-2.23	6.41 **	0.53 **
10	Kashi Hemanth × 16P2	15.71 **	-0.39	1.44	0.76	-0.41	-1.21 **	8.85 **	-6.69 **	0.10
11	Kashi Hemanth × Arka Meghali	-5.43	-1.83 **	-2.19	-0.88	0.12	0.33 *	6.62 **	-24.03 **	-1.09 **
12	Kashi Hemanth × EC528388	-15.34 **	0.49	-2.55	-3.83 *	-0.39	-1.23 **	8.20 **	-10.56 **	-0.45 **
13	Kashi Hemanth × COHM7	0.17	-1.39 *	-1.6	-2.37	1.54 **	0.16	7.52 **	20.88 **	1.57 **
14	Kashi Hemanth × 11P4	2.45	-0.13	-1.91	-2.10	-0.91 **	-1.95 **	-4.35 *	4.88 *	0.46 **
15	Kashi Hemanth × COHMUD3	16.12 **	3.41 **	3.13 *	3.54 *	1.12 **	-1.21 **	-1.6	13.44 **	1.02 **
16	EC321425 × 16P2	0.23	-0.32	-1.6	-2.55	-0.26	-2.50 **	-4.77 *	-17.54 **	-0.84 **
17	EC321425 × Arka Meghali	7.19 *	0.22	-3.24 *	-2.69	-0.35	-4.15 **	-8.43 **	-3.97 *	-0.22
18	EC321425 × EC528388	26.45 **	0.94	-0.60	-0.14	-0.04	1.68 **	-5.40 *	5.95 **	0.20
19	EC321425 × COHM7	-4.38	-0.95	0.35	0.31	-1.52 **	0.26	-4.24 *	16.97 **	0.99 **
20	EC321425 × 11P4	11.58 **	0.46	-0.96	0.58	-0.95 **	1.57 **	0.85	-9.89 **	-0.77 **
21	EC321425 × COHMUD3	-23.79 **	-2.09 **	-0.92	-0.28	-0.67 **	-6.35 **	-6.90 **	-8.63 **	-0.65 **
22	16P2 × Arka Meghali	13.65 **	0.04	-3.37 *	-3.96 *	0.56 *	1.08 **	6.27 **	-27.02 **	-1.25 **
23	16P2 × EC528388	-12.92 **	-2.23 **	-2.74	-4.42 **	0.21	0.38 **	6.52 **	1.94	0.32 *
24	16P2 × COHM7	-3.57	-1.29	2.72	3.04 *	-0.52 *	-0.89 **	2.47	27.69 **	1.60 **
25	16P2 × 11P4	-5.99	-0.52	-2.10	-2.69	0.10	-0.53 **	0.78	32.49 **	1.87 **
26	16P2 × COHMUD3	-4.61	-1.26	0.44	-0.05	-0.25	-1.46 **	-1.81	-23.44 **	-1.18 **
27	Arka Meghali × EC528388	20.89 **	-0.73	-0.87	-1.55	0.72 **	2.86 **	9.63 **	27.33 **	1.69 **
28	Arka Meghali × COHM7	-4.84	-0.44	-2.42	-2.10	0.313	-2.35 **	8.62 **	-14.42 **	-0.68 **
29	Arka Meghali × 11P4	15.29 **	2.49 **	0.76	0.67	0.03	-3.85 **	1.90	10.01 **	0.63 **
30	Arka Meghali × COHMUD3	-12.18 **	-0.15	2.31	2.31	0.39	1.23 **	-6.57 **	-3.48	-0.13
31	EC528388 × COHM7	-15.40 **	-1.55 *	-0.78	-0.55	-0.14	-1.71 ***	4.51 *	-17.12 **	-1.02 **
32	EC528388 × 11P4	-0.89	0.22	2.40	1.22	0.94 **	-2.88 **	-2.03	3.06	0.04
33	EC528388 × COHMUD3	-0.09	-1.60 *	3.44 *	3.85 *	0.27	1.36 **	-2.96	6.92 **	0.32 *
34	COHM7 × 11P4	19.65 **	1.68 *	2.85 *	1.17	0.97 **	2.04 **	1.61	-7.80 **	-0.47 **
35	COHM7 × COHMUD3	15.14 **	3.36 **	-4.10 **	-4.19 **	-0.25	-1.89 **	-4.81 *	-5.93 **	-0.31 *
36	11P4 × COHMUD3	-9.13 **	-2.47 **	-2.92 *	-2.92	-1.13 ***	1.95 **	14.68 **	-7.25 **	-0.55 **
	SEm ±	3.12	0.63	1.38	1.48	0.21	0.13	2.00	1.88	0.12
	CD @ 5 %	6.35	1.29	2.80	3.02	0.44	0.28	4.06	3.83	0.25

X1. Plant height at last harvest (cm)	X2. Number of branches at last harvest	X3. Days to flowering
X4. Days to 50 per cent flowering	X5. Number of fruits per cluster	X6. Number of clusters per plant
X7. Number of fruits per plant	X8. Average fruit weight (g)	X9. Yield per plant (kg/plant)

Table 4: Estimates of SCA effects of quality parameters in 9 × 9 half diallele set of cross in tomato

Sl. No.	Crosses/ Hybrids	X10	X11	X12	X13	X14	X15
1	55P2 × Kashi Hemanth	-0.11	-0.76 **	-0.09	0.03	0.27	-1.14
2	55P2 × EC321425	-1.11 *	-0.85 **	-1.142 **	-0.03	1.48 **	5.89 **
3	55P2 × 16P2	2.82 **	-0.63 *	-0.72 **	0.03	0.05	-1.15
4	55P2 × Arka Meghali	0.85 *	1.25 **	-0.98 **	0.09 *	0.53	0.55
5	55P2 × EC528388	-0.60	-1.44 **	0.02	0.06	0.88 **	-2.68 *
6	55P2 × COHM7	0.07	0.16	0.65 **	-0.06	0.86 **	-2.95 *
7	55P2 × 11P4	-1.15 **	-0.21	0.019	0.08 *	0.66 *	5.37 **
8	55P2 × COHMUD3	-0.70	-0.65 **	1.79 **	-0.073	-0.65 *	-3.55 **
9	Kashi Hemanth × EC321425	-0.08	-0.62 *	-0.14	-0.06	-3.11 **	-3.64 **
10	Kashi Hemanth × 16P2	-0.80	0.85 **	1.42**	-0.04	-1.62 **	-0.61
11	Kashi Hemanth × Arka Meghali	-0.11	1.18 **	-1.75 **	0.11 **	1.61 **	-4.54 **
12	Kashi Hemanth × EC528388	-0.57	0.33	-0.76 **	-0.16 **	2.01 **	-1.94
13	Kashi Hemanth × COHM7	0.10	0.24	0.09	-0.13 **	-0.36	2.56 *
14	Kashi Hemanth × 11P4	0.88 *	0.27	0.29	0.19 **	0.44	3.57 **
15	Kashi Hemanth × COHMUD3	-0.17	-0.33	1.56 **	0.22 **	2.67 **	3.13 *
16	EC321425 × 16P2	-1.29 **	0.26	-1.04 **	0.01	1.77 **	-3.57 **
17	EC321425 × Arka Meghali	1.89 **	1.59 **	-0.25	-0.14 **	0.85 **	1.89
18	EC321425 × EC528388	0.93 *	0.54 *	1.30 **	-0.12 **	-0.40	-2.16
19	EC321425 × COHM7	0.10	0.25	0.82 **	0.07	2.40 **	3.88 **
20	EC321425 × 11P4	-0.12	1.63 **	-0.29	0.09 *	-2.11 **	-0.22
21	EC321425 × COHMUD3	-0.17	0.99 **	0.16	-0.02	0.36	4.63 **
22	16P2 × Arka Meghali	-2.33 **	-0.14	-0.94 **	-0.03	0.54	-3.23 *
23	16P2 × EC528388	-1.79 **	0.21	-0.12	-0.10 **	1.73 **	-2.80 *
24	16P2 × COHM7	2.88 **	0.02	1.47 **	0.27 **	0.31	-0.37
25	16P2 × 11P4	-0.34	-1.55 **	1.01 **	-0.15 **	1.54 **	2.98 *
26	16P2 × COHMUD3	-0.39	0.51 *	-0.01	-0.11 **	-2.19 **	2.91 *
27	Arka Meghali × EC528388	0.396	-1.36 **	0.71 **	-0.08 *	1.11 **	6.29 **
28	Arka Meghali × COHM7	-1.93 **	-0.45	-0.25	0.04	1.48 **	0.08
29	Arka Meghali × 11P4	2.34 **	-0.37	0.43	-0.07	-0.65 *	-0.59
30	Arka Meghali × COHMUD3	-0.20	-0.17	-0.07	0.02	-0.35	-0.13
31	EC528388 × COHM7	0.11	-1.01 **	-0.74 **	0.07	-1.04 **	3.04 *
32	EC528388 × 11P4	0.39	0.53 *	-0.11	-0.20 **	0.14	0.05
33	EC528388 × COHMUD3	-1.16 **	0.93 **	-0.57 *	0.23 **	-2.70 **	5.54 **
34	COHM7 × 11P4	-1.44 **	0.34	-0.13	0.02	-0.84 **	1.87
35	COHM7 × COHMUD3	0.51	0.24	-0.73 **	-0.01	-1.74 **	-0.06
36	11P4 × COHMUD3	0.79	-1.28 **	-1.06 **	-0.10 **	0.23	1.23
	SEm ±	0.40	0.23	0.22	0.03	0.27	1.20
	CD @ 5 %	0.83	0.49	0.45	0.07	0.55	2.45

X10. Number of locules per fruit	X11. Total soluble solids (^o B)	X12. Pericarp thickness (mm)
X13. Firmness (kg/cm ²)	X14. Lycopene content (mg/100g)	X15. Ascorbic acid (mg/100g)

CONCLUSION

In general crosses involving positive × positive combination, genetic interaction might be of additive × additive type. The category of positive × positive GCA effects played an

important role in the expression of favourable and significant SCA effects. Thus, choice of parents based on combining ability is a sound proposition (Sharma et al., 1996). Thus, they may be further improved upon through

conventional selections methods like pedigree or recurrent selection.

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