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Combining ability analysis for yield and quality traits in double cross F_1s of tomato (*Solanum lycopersicum* L.)

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Abstract

The present investigation was carried out in 25 double cross F_1 hybrids derived from 10 single cross hybrids for yield and its component traits along with one check AS-95. The investigation was undertaken at the new orchard of Main Agriculture Research Station, UAS, Dharwad. Crosses were made to determine general combining ability and specific combining ability of parents and crosses respectively using Line x Tester mating design. Combining ability revealed that predominance of non-additive gene action for all the characters under study. Line KSP-1326 and S-85 found to be good general combiner for fruit yield per plant and number of fruits per plant. NS-585 for average fruit weight and number of locules per fruit. MHAT-306 and Sindu for TSS. MHAT-306 for number of primary branches per plant and number of fruits per cluster. High per se performance with remarkable heterosis and significant SCA effects in desirable direction for yield per plant and its contributing traits were expressed by four major economic heterotic double crosses like KSP-1326 × S-85, MHAT-306 × NS-585, KSP-1326 × Sagara and Abhilash × Shankara. Hence, the selection of these parents will be framework for improving high yielding genotypes of tomato with desirable traits.

Keywords: tomato, DCF_1s, combining ability, yield, GCA, SCA

Introduction

Tomato (*Solanum lycopersicum* L.) with chromosome number 2n=2x=24, belongs to family solanaceae. It is one of most the popular and nutritious fruit vegetable, widely grown around the world and ranked second after potato. Globally, the area under tomato is 4.81 million hectares with production of 130 million tonnes (Anonymous, 2019) [2]. In India, it is grown in an area of 0.77 million hectares with a production of 19.39 million tonnes and the average productivity is about 21.2 tonnes per hectare. The important tomato growing states are Andhra Pradesh, Karnataka and Madhya Pradesh. In Karnataka, tomato is grown on an area of 0.06 million hectare with a production of about 2.13 million MT with a productivity of about 33.55 tonnes per hectare (Anonymous, 2019) [2].

The fruits are eaten raw or cooked. Large quantities of tomato are used to produce soup, juice, ketchup, puree, paste and powder. It is a rich source of vitamins, minerals, organic acids, sugars and lycopene. It is a good source of Fe and vitamin A, B and C. Edible portion of tomato contains energy 79 KJ, protein 0.76 g, fat 0.25 g, carbohydrate 3.20 g, total free sugars 1.82 g, glucose 0.18 g, Ca 8.90 mg, Fe 0.22 mg, Mg 11.86 mg, P 15.45 mg, K 167 mg, Na 11.86 mg, Zn 0.11 mg, vitamin C 22.8 mg, thiamin 0.04 mg, riboflavin 0.02 mg, vitamin B-6 0.08 mg, vitamin E 0.56 mg, lycopene 2481 µg, citric acid 288 mg, total ascorbic acid 25.27 mg, total saturated fatty acids 47.65 mg, total polyunsaturated 119 mg per 100 g (Longvah *et al*., 2017) [8]. Consumption of tomato and its products can significantly reduce the risk of developing colon, rectal and stomach cancer. Recent studies suggest that tomatoes contain the antioxidant lycopene, which markedly reduces the risk of prostate cancer (Kucuk, 2001) [7].

Global demand for tomato production is increasing tremendously due to its diverse utility in raw, cooked and processed form of food. This necessitates the continued supply of highly nutritious and better yielding improved cultivars to the producers, that to under the rapid changing agro-climatic conditions. Hence, there is continuous need to strengthen the crop improvement programmes in tomato and ultimately developing new varieties/hybrids satisfying to the present day needs of farmers and consumers as well. It is, therefore, essential to find out the combining ability of desirable genotypes to be involved in breeding programme for effective transfer of desirable genes in the resultant progenies. Hence, combining ability, which is important in the development of breeding procedures, is of notable use in crop hybridization, either to exploit heterosis or to combine the favorable fixable genes.

Material and methods

Plant materials

The present investigation was undertaken at the new orchard of Main Agriculture Research Station, UAS, Dharwad. The research material was derived from 10 hybrids of tomato. The experimental material for present study comprised of 500 plants of 25 double cross F_1 genotypes of tomato. These 25-double cross F_1s were developed by crossing 5 SCF_1s × 5 SCF_1s in line × tester mating design for identifying heterotic with high sca effect performance resulting from crossing of genetically divergent genotypes (Kempthorne, 1957) [6].

Evaluation

The material generated was evaluated in *rabi* 2019 by laying out in the Completely Randomized Block Design (RBD) with 25 lines were replicated twice. In each row ten seedlings were transplanted for each entry in each replication. Totally 25 rows represented 25 entries. All the 500 plants along with one check planted with spacing 75 × 60 cm. Recommended practices were followed for successful cultivation.

The observations were recorded on five competitive plants taken at random in each entry over the replications on plant height (cm), number of primary branches per plant (no.), days to first flowering (days), days to 50% flowering (days), number of fruit clusters per plant (no.), number of fruits per cluster (no.), number of fruits per plant (no.), average weight of fruit (g), length of fruit (mm), fruit diameter (mm), fruit shape index, number of locules per fruit (no.), pericarp thickness (mm), TSS (°brix) and yield per plant (kg).

Analysis

The first step in line × tester analysis is first we need to perform analysis of variance for Randomized Block Design to test the significance of difference among different genotypes along with their parents and checks. The analysis of variance was done for all the parameters as per the method given by Kempthorne (1957) [6] and emphasized by Arunachalam (1974) [3].

Results and Discussion

The analysis of variance for line x tester analysis presented in Table 1. Analysis of variance carried out for fifteen characters in tomato double crosses, indicated that treatment differed significantly except for days to 50 per cent flowering, whereas replications showed non-significant effect for all the parameters studied.

Effect of GCA

Nature and magnitude of combining ability effects provide guideline in identifying the better parents and their utilization. The summery of the GCA effects of the parents (Table 2) indicated that none of the parents was a good general combiner for all the characters, suggesting that specific parents will have to be used for genetic improvement depending on the character under consideration. Following parents have good general combing ability for various traits: KSP-1326, S-85 and NS-585 for yield per plant; S-85 and KSP-1326 for number of fruits per plant; NS-585 followed by Sagara and KTH-354 for average fruit weight; Sindu, Sagara, KSP-1326 and MHAT-306 for pericarp thickness; NS-585 and KTH-354 for number of locules per fruit; MHAT-306 and Sindu for TSS; KTH-354, Shankara and NS-585 for plant height; NS-526, MHAT-306 and S-85 for number of primary branches per plant; MHAT-306 for number of fruits per cluster (Table-2). Thus, these parents could be utilized extensively in hybridization followed by selection to accelerate the pace of genetic improvement of yield and its component traits. This result is in accordance with the findings of Mohamed *et al.* (2012) [9], Shankar *et al.* (2013) [11], Savale and Patel (2017) [10] and Triveni *et al.* (2017) [12].

Effect of SCA

The specific combining ability effects represents dominance and epistatic gene effects which can be used as an index to determine the usefulness of a particular cross combination for exploitation through heterosis breeding and hybridization programme. Out of 25 DCF_1s, four major economic heterotic double crosses (KSP-1326 × S-85, MHAT-306 × NS-585, KSP-1326 × Sagara and Abhilash × Shankara) showed significant SCA effects in desirable direction for yield per plant. Cross KSP-1326 × S-85 involved parental combination of significant × significant positive general combiners. This was followed by MHAT-306 × NS-585 significant negative × significant positive general combiners, KSP-1326 × Sagara involved significant positive × non-significant general combiners. These crosses had one parent with significant positive GCA effect showing importance of interaction between the parents of these crosses. While Abhilash × Shankara (0.37**) involved significant negative × significant negative general combining parental combination (Table-3). Some form of recurrent selection or full sib selection was to be adopted under such conditions since both additive and non-additive components were important in the inheritance of the characters. This will lead to upgrading of genetic ceiling by accumulating favorable genes and simultaneously exploiting dominance variance. This result is in accordance with the findings of Katkar *et al.* (2012) [5], Shankar *et al.* (2013) [11], Basavaraj *et al.* (2015) [4] and Alam *et al.* (2017) [1].

The double cross F_1 hybrid combinations with maximum significant SCA effect for different traits are KSP-1326 × S-85, MHAT-306 × NS-585, KSP-1326 × Sagara and Abhilash × Shankara for yield per plant, MHAT-306 × S-85 and KSP-1326 × Sagara for number of fruits per plant, MHAT-306 × NS-585 for average fruit weight and KTH-354 × Shankara for number of locules per fruit, MHAT-306 × NS-585 for TSS, KSP-1326 × Sagara followed by MHAT-306 × Sindu (0.66**) for pericarp thickness (Table-3).

Table 1: Mean sum of squares of lines, testers and line × tester interaction with respect to 15 characters in tomato for double cross hybrids

Sl. No.	Source of variation / Characters	Replication	Crosses	Line effect	Tester effect	Line × tester effect	Error
	Degrees of freedom	1	24	4	4	16	24
1.	Plant height (cm)	0.058	20.55**	11.70	10.59	25.25 **	0.18
2.	Number of primary branches per plant	4.50	5.50 **	13.23 *	2.23	4.39**	0.29
3.	Days to first flowering	5.12	4.53 **	2.08	4.58	5.13 **	0.28
4.	Days to 50 percent flowering	12.50	6.04 **	0.68	9.28	6.58**	0.01
5.	Number of clusters per plant	1.62	8.44 **	7.88	20.08*	5.68 **	0.45
6.	Number of fruits per cluster	0.08	0.29 **	0.25	0.15	0.33 **	0.03

7.	Number of fruits per plant	38.72	73.59**	63.08	65.78	78.18**	4.22
8.	Average weight of fruit (g)	0.5	213.96**	109.92	373.05	200.20 **	0.26
9.	Fruit diameter (mm)	3.09	68.71 **	28.61	46.36	84.32**	0.02
10.	Average fruit length (mm)	2.69	51.26 **	54.16	50.70	50.67**	0.02
11.	Fruit shape index (%)	0.00	0.02 **	0.01	0.00	0.02**	0.01
12.	Total soluble solids (TSS)	0.28	0.55 **	1.00	0.20	0.53 **	00.02
13.	Number of locules per fruit	0.5	1.16 **	0.88	1.33	1.19**	0.33
14.	Pericarp thickness (mm)	0.09	0.48**	0.31	0.8	0.44**	0.01
15.	Total yield per plant (Kg)	0.23	0.48**	0.41	0.71	0.45 **	0.01

*Significant at 5%, **Significant at 1%

Table 2: General combining ability (gca) effect for 14 characters in double cross F_1 hybrids of tomato

Parents	PH	NB	D1ST	C/P	F/C	NF/P	AFW	DIAM	L	FSI	TSS	NOL	PT	Y/P
NS-526	-0.51**	1.46**	0.54**	-1.04**	-0.1	-3.54**	2.67**	1.05**	-2.87	-0.07**	0.08*	0.16	-0.13**	-0.16**
KSP-1326	-0.34	-1.44**	0.34*	0.56*	0.1	3.46**	1.02	1.47**	2.18	0.01**	-0.01	-0.04	0.18**	0.32**
MHAT-306	-0.75**	0.56**	0.04	-0.64*	0.20**	0.66	-3.19**	0.25**	1.28	0.02**	0.38**	-0.04	0.12**	-0.12*
KTH-354	1.91**	-0.84**	-0.46**	-0.04	-	-0.54	3.30**	-2.84**	-2.13	0.01**	-0.49**	0.36**	-0.23**	0.07
Abhilash	-0.31	0.26	-0.46**	1.16**	-0.2**	-0.04	-3.82**	0.04	1.55	0.02**	0.02	-0.44**	0.06**	-0.12*
Shankara	1.16**	0.06	-0.26	-0.44	0.1	0.46	-5.02**	2.43**	2.98	0.01**	-0.15**	0.16	-0.15**	-0.16**
Sindu	-0.9**	-0.74**	0.94**	-1.44**	0.1	-2.34**	-6.62**	1.43**	-0.13	-0.03**	0.22**	-0.24	0.29**	-0.37**
S-85	-1.25**	0.56**	0.34*	2.36**	-0.2**	4.16**	-0.46	-1.27**	-2.62	-0.02**	-0.07	-0.14	0.05**	0.23**
Sagara	0.37*	-0.04	-0.86**	-0.44	-	-1.74*	4.22**	0.35**	1.38	0.03**	-0.01	-0.34	0.21**	0.07
NS-585	0.62**	0.16	-0.16	-0.04	-	-0.54	7.87**	-2.96**	-1.59	0.01**	0.00	0.56**	-0.40**	0.23**
CD 95% GCA (Line)	0.346	0.368	0.303	0.47	0.10	1.44	1.45	0.09	0.07	0.00**	0.07	0.35	0.00**	0.10
CD 95% GCA (Tester)	0.346	0.368	0.303	0.47	0.10	1.44	1.45	0.09	0.07	0.00**	0.07	0.35	0.00**	0.10

*Significant at 5%, **Significant at 1%

PH- Plant height (cm) NB- Number of primary branches DIST- Days to first flowering
C/P- Number of fruit clusters per plant F/C- Number of fruits per cluster F/P- Number of fruits per plant AWF-Average weight of fruit (g)
DIAM- Fruit diameter (mm) FL- Fruit length (mm) FSI- Fruit shape index (%) TSS- Total soluble solids (TSS)
NLO- Number of locules per fruit PT- Pericarp thickness (mm) Y/P- Total yield per plant (Kg)

Table 3: Specific combining ability (sca) effect for 14 characters in double cross F_1 hybrids of tomato

Crosses	PH	NB	D1ST	C/P	F/C	NF/P	AFW	DIAM	FL	FSI	TSS	NLO	PT	Y/P
NS-526 X Shankara	2.31**	0.24	1.06**	0.64		1.64	3.52*	1.98**	0.41**	-0.019**	0.47**	-0.86*	0.25**	0.27*
NS-526 X Sindu	0.37	-2.46**	-0.14	-0.36	0.5**	5.94**	-1.37	-5.31**	-1.26**	0.06**	-0.10	0.54	-0.29**	0.35**
NS-526 X S-85	-0.28	1.74**	-1.54**	-0.16	-0.7**	-8.06**	5.46**	-0.90**	7.62**	0.154**	-0.10**	-0.56	0.30**	-0.34**
NS-526 X Sagara	-0.05	2.34**	0.66	-0.36	0.1	-0.66	4.77**	5.46**	-3.88**	-0.152**	-0.56**	1.14**	-0.51**	0.033
NS-526 X NS-585	-2.35**	-1.86**	-0.04	0.24	0.1	1.14	-12.37**	-1.21**	-2.90**	-0.04**	0.31**	-0.26	0.24**	-0.32**
KSP-1326 X Shankara	-1.86**	-0.86*	-2.74**	-0.96	0.3*	1.14	-3.82*	-3.93**	-2.64**	0.015**	0.17	0.34	-0.22**	-0.131
KSP-1326 X Sindu	-1.8**	-0.06	0.06	-2.96**	-0.2	-10.06**	8.27**	3.66**	8.67**	0.08**	0.39**	-0.76	0.48**	-0.46**
KSP-1326 X S-85	3.6**	0.64	0.66	1.24*	0.1	4.44**	8.61**	4.97**	1.76**	-0.047**	-0.008	1.14	-0.68**	0.66**
KSP-1326 X Sagara	-6.27**	0.24	0.86*	3.04**	-0.1	7.34**	-4.32*	5.74**	-0.94**	-0.11**	0.43**	-0.66	0.76**	0.48**
KSP-1326 X NS-585	6.33**	0.04	1.16**	-0.36	-0.1	-2.86	-8.72**	-10.43**	-6.86**	0.06**	-0.98**	-0.06	-0.34**	-0.54**
MHAT-306 X Shankara	-2.45**	0.14	0.56	1.24*	-0.3*	0.44	-6.10**	-4.31**	0.55**	0.074**	-0.62**	0.34	-0.04**	-0.12
MHAT-306 X Sindu	-0.49	-0.06	1.36**	1.24*	-0.3*	-1.26	-5.008**	6.78**	-1.52**	-0.12**	0.19*	-0.76	0.66**	-0.161
MHAT-306 X S-85	-1.19**	-0.36	1.96**	-1.56**	1**	8.74**	-12.01**	1.47**	0.46**	-0.03**	0.19*	0.14	-0.22**	0.025
MHAT-306X Sagara	3.39**	-0.76	-0.84*	-0.76	-0.2	-4.86**	1.64	-9.33**	-1.54**	0.14**	-0.36**	-0.16	-0.27**	-0.26*
MHAT-306 X NS-585	0.74	1.04*	-3.04**	-0.16	-0.2	-3.06	21.49**	5.38**	2.03**	-0.05**	0.61**	0.44	-0.11**	0.52**
KTH-354 X Shankara	4.89**	0.54	0.06	-2.36**	-0.1	-8.86**	5.39**	3.98**	0.27**	-0.05**	-0.048	0.94**	-0.23**	-0.39**
KTH-354 X Sindu	-1.05**	1.34**	-1.14**	1.64**	-0.1	2.94	5.49**	-2.41**	-1.10**	0.01**	-0.72**	0.84**	-0.65**	0.38**
KTH-354 X S-85	-3.5**	-0.96*	0.46	-0.16	0.2	2.44	-1.51	3.99**	-6.31**	-0.18**	0.47**	-0.76	0.51**	0.14
KTH-354 X Sagara	1.53**	-2.36**	0.66	0.64		2.34	3.14	-3.33**	6.77**	0.18**	0.21*	-0.56	0.22**	0.22
KTH-354 X NS-585	-1.87**	1.44**	-0.04	0.24		1.14	-12.50**	-2.21**	0.35**	0.04**	0.09	-0.46	0.14**	-0.34**
Abhilash X Shankara	-2.89**	-0.06	1.06**	1.44**	0.1	5.64**	1.02	2.29**	1.38**	-0.01**	0.03	-0.76	0.24**	0.37**
Abhilash X Sindu	2.97**	1.24**	-0.14	0.44	0.1	2.44	-7.37**	-2.70**	-4.79**	-0.04**	0.25	0.14	-0.19**	-0.11
Abhilash X S-85	1.37**	-1.06*	-1.54**	0.64	-0.6**	-7.56**	-0.53	-9.54**	-3.55**	0.11**	-0.54	0.04	0.08**	-0.48**
Abhilash X Sagara	1.4**	0.54	-1.34**	-2.56**	0.2	-4.16*	-5.22**	1.47**	-0.41**	-0.04**	0.29	0.24	-0.19**	-0.47
5 Line * 5 Tester	-2.85**	-0.66	1.96**	0.04	0.2	3.64*	12.12**	8.49**	7.36**	-0.01**	-0.02	0.34	0.06**	0.69
CD 95% SCA	0.77	0.82	0.67	1.06	0.24	3.23	3.24	0.20**	0.17	0.01	0.17	0.78	0.01	0.22

*Significant at 5%, **Significant at 1%

PH- Plant height (cm) NB- Number of primary branches DIST- Days to first flowering
C/P- Number of fruit clusters per plant F/C- Number of fruits per cluster F/P- Number of fruits per plant AWF-Average weight of fruit (g)
DIAM- Fruit diameter (mm) FL- Fruit length (mm) FSI- Fruit shape index (%) TSS- Total soluble solids (TSS)
NLO- Number of locules per fruit PT- Pericarp thickness (mm) Y/P- Total yield per plant (Kg)

Conclusions

The combining ability analysis gives an indication of the variance due to GCA and SCA which represent a relative measure of additive and non-additive gene actions, respectively. Most of the yield components are known to be under polygenic control, so plant breeder would need a close genetic characterization of as many parents as possible through phenotypic measurements. The combining ability effects, general (GCA) and specific (SCA) are some realistic parameters to serve this purpose.

It was concluding that, the lines KSP-1326 (0.32**), S-85 and NS-585 were identified as top GCA combiners while, the cross combinations KSP-1326 × S-85, MHAT-306 × NS-585, and KSP-1326 × Sagara were identified as top SCA combiners for multiple traits in tomato for fruit yield and its contributing characters.

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