

## Combining ability studies for maturity, growth, yield and quality traits in tomato (*Solanum lycopersicum* L.)

### Abstract

A study was conducted at Vegetable Research Farm, Vegetable Science Division, SKUAST- Kashmir, Shalimar, Indiato determine the general and specific combining abilities for maturity, growth, yield and quality traits in tomato by crossing 12 parents in a diallel Method II and Model I of Griffing mating design during *Kharif* season 2020. The F1 progenies of the sixty-six crosses (excluding reciprocals) were evaluated along with the twelve parents in Randomized Block Design during *Kharif* season 2021 at three locations. The observations were recorded on eighteen diverse traits. The analysis of variance for general combining ability (GCA) and specific combining ability (SCA) revealed significant mean squares due to GCA and SCA for all the traits under consideration. The mean squares due to  $gca \times$  environments and  $sca \times$  environments were found significant for most of the characters. None of the parents possessed significant and desirable GCA for all the traits. Different parents were found to reveal desirable general combining ability for different traits. Similarly, none of the crosses possessed significant and desirable specific combining ability for all the traits. However, different crosses were found to reveal desirable SCA for different traits.

**Key words:** Tomato, Genetic Improvement, General Combining Ability, Specific Combining Ability, Agronomic Traits

### Introduction

“Tomato (*Solanum lycopersicum* L. Syn. *Lycopersicon esculentum* Mill.) belongs to family Solanaceae with chromosome number  $2n = 24$ ” (Peralta *et al.*, 2005). “It is one of the most popular vegetables in India. Due to its increasing commercial and dietary values, wide adaptability, potential for growing under various cultivation conditions, relatively short life cycle, photoperiodic insensitivity, good productivity, and good capacity for seed production, it is becoming more and more well-liked on a global scale. Because of these characteristics and several other advantages like relatively small genome, the absence of gene duplication, the ease with which pollination and hybridization can be managed, the capacity for asexual propagation (grafting) and the ability to regenerate entire plants from various explants, it is used as a model plant for both basic and applied research projects” (Bai and Lindhot, 2007; Prema *et al.*, 2011; Venkadeswaran *et al.*, 2018).

Owing to the economic, nutritional and medicinal importance of the crop, a need-based crop development programme is necessary. Prior to beginning of any development programme through hybridization, it is necessary to understand the ability of different genotypes to combine. The choice of the best genotypes and the appropriate breeding technique for the creation of improved varieties and hybrids depend heavily on this knowledge. The general and specific combining ability of parents and their progeny can be assessed through a variety of various biometrical procedures. One of these methods is the

diallel analysis suggested by Griffing (1956a,b) and Hayman (1954a).

## Materials and Methods

Twelve diverse lines of tomato (*Solanum lycopersicum* L.) were crossed in a diallel fashion as per the Method II and Model I of Griffing (1956 a, b), to generate sixty-six crosses at Vegetable Research Farm of Division of Vegetable Science, SKUAST-Kashmir, Shalimar during Kharif 2020. These sixty-six crosses (excluding reciprocals) were evaluated along with the twelve parents in Randomized Block Design during Kharif season 2021 at three locations viz. E<sub>1</sub>: Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar; E<sub>2</sub>: Vegetable Seed Multiplication Farm, SKUAST-Kashmir, Shuhama and E<sub>3</sub>: Faculty of Agriculture, SKUAST-Kashmir, Wadura. The observations were recorded on eighteen diverse traits. The data thus generated was subjected to standard statistical procedures.

## Results and Discussion

The analysis of variance for general combining ability (GCA) and specific combining ability (SCA) (Table 1) revealed significant mean squares due to gca and sca for all the traits under consideration. The mean squares due to gca × environments were found significant for all characters except number of days to first flowering, number of days to first fruit set, number of days to first fruit harvest, number of primary branches plant<sup>-1</sup>, seed yield fruit<sup>-1</sup> and 100 seed weight. The mean squares due to sca × environments were found significant for all characters except number of days to first fruit set, number of days to first fruit harvest, number of primary branches plant<sup>-1</sup>, number of fruits cluster<sup>-1</sup>, plant height, average fruit weight, seed yield fruit<sup>-1</sup> and 100 seed weight. The above findings are in accordance with the findings of Dharva *et al.* (2018), Kumar *et al.* (2018), Rajkumar *et al.* (2018), Mishra *et al.* (2020), Veena *et al.* (2019), Bhajantri *et al.* (2022), Ummyiah *et al.* (2021) and Ummyiah *et al.* (2015a).

The general combining ability analysis (Table 2) showed that none of the parents possessed significant and desirable general combining ability for all the traits. However, different parents were found to reveal desirable general combining ability for different traits. The parents exhibiting significant and desirable GCA effects for most of the traits were SKAU-T-165690, SKAU-T-914091, SKAU-T-914108, SKAU-T-617047, SKAU-T-164334 and SKAU-T-914106 in individual and data pooled over environments. Hence, these parents could be selected for use in future crop improvement programmes and direct selection for higher values of yield plant<sup>-1</sup> can be made in advanced generations of their heterotic crosses. Similar findings with respect to GCA effects were also reported Jadav *et al.* (2017), Kaushik *et al.* (2018), Rajkumar *et al.* (2018), Veena *et al.* (2019), Ummyiah *et al.* (2015b) and Vekariya *et al.* (2019), Kumar *et al.* (2020), and Lone *et al.* (2022).

The specific combining ability analysis for different traits showed that none of the crosses possessed significant and desirable specific combining ability for all the traits. However, different crosses were found to reveal desirable specific combining ability for different traits. The crosses exhibiting significant and desirable SCA effects for most of the

traits were SKAU-T-02 × SKAU-T-164334, SKAU-T-914103 × SKAU-T-914091, SKAU-T-914113 × SKAU-T-165690, SKAU-T-165690 × SKAU-T-145057, SKAU-T-914108 × SKAU-T-914106 and SKAU-T-914103 × SKAU-T-165690 in individual and data pooled over environments. Hence, these crosses with desirable SCA for maximum traits, could be selected for use in future breeding programmes i.e., hybrid development. Similar findings with respect to SCA effects were also reported by Dharva *et al.* (2018), Kaushik *et al.* (2018), Rajkumar *et al.* (2018), Veena *et al.* (2019), Vekariya *et al.* (2019), Mishra *et al.* (2020), Liu *et al.* (2021), Ummiyah *et al.* 2015(c) and Arora *et al.* (2022).

These desirable specific cross combinations resulted out of crosses between the parents with high × high, high × low, low × high, low × low, high × average, average × low or low × average general combining ability (Table 3). The perusal of results indicated that superior crosses for different traits involved all types of combiners, which was reported by several workers in most of the crop species. Dass *et al.* (1997) concluded that good cross combination is not always as a result of high × high general combiners. The superiority of crosses involving high × low or average × low combiners as parents could be explained on the basis of interaction between positive alleles from good/average combiners and negative alleles from the poor combiners as parents (Dubey, 1975).

## Conclusion

The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding. The superior cross combination involving low × low general combiners could result from over dominance and epistasis (Rehman *et al.*, 1981). The crosses could be exploited for isolation of pure lines through pedigree method of breeding involving progeny testing, since that non-additive component is predominant.

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UNDER PEER REVIEW

**Table 1(a): Analysis of variance for combining ability for maturity, growth, yield and quality traits in Tomato (*Solanum lycopersicum*L.) [Pooled data over environments]**

Source of variation	d.f	Number of days to first flowering	Number of days to first fruit set	Number of days to first fruit harvest	No. of pickings	No. of fruits cluster <sup>-1</sup>	No. of fruits plant <sup>-1</sup>	Fruit length (cm)	Fruit diameter (cm)	No. of locules fruit <sup>-1</sup>
environments	2	795.97**	839.63**	730.69**	89.19**	14.52**	1484.69**	14.04**	15.11**	15.24**
gca	11	23.52**	56.00**	211.40**	13.68**	0.98**	893.28**	3.83**	4.68**	3.83**
sca	66	22.54**	28.25	67.38**	13.51**	0.48**	645.05**	2.38**	2.78**	2.77**
gca x environments	22	0.31	0.19	0.39	0.26**	0.11**	6.27**	0.06**	0.03*	0.03*
sca x environments	132	0.41*	0.22	0.26	0.33**	0.03	5.04**	0.04**	0.03*	0.03**
Error	154	--	--	--	--	--	--	--	--	--
Pooled	462	0.30	0.28	0.31	0.06	0.03	0.65			

\*, \*\* Significant at 5 and 1 per cent levels, respectively

**Table 1(b): Analysis of variance for combining ability formaturity, growth, yield and quality traits in Tomato (*Solanum lycopersicum*L.) [Pooled data over environments]**

Source of variation	d.f	Pericarp thickness (mm)	No. of primary branches plant <sup>-1</sup>	Plant height (cm)	Average fruit weight (g)	Fruit yield plant <sup>-1</sup> (kg)	Fruit yield hectare <sup>-1</sup> (q)	Seed yield fruit <sup>-1</sup> (g)	Seed yield plant <sup>-1</sup> (g)	100 Seed weight
environments	2	19.98**	28.84**	516.74**	1724.07**	4.59**	631967.71**	16.02**	47.72**	0.18**
gca	11	6.33**	1.65**	584.22**	1366.07**	0.97**	134265.13**	15.94**	20.97**	1.20**
sca	66	4.64**	0.37**	871.15**	791.07**	0.85**	117545.17**	15.97**	13.76**	0.40**
gca x environments	22	0.10**	0.03	5.97**	4.40**	0.01**	2529.13**	0.03	0.24**	0.02
sca x environments	132	0.07**	0.01	1.54	1.25	0.01**	1982.03**	0.01	0.16**	0.09
Error	154	--	--	--	--	--	--	--	--	--
Pooled	462	0.02	0.02	2.48		296.86		0.07	0.02	0.01

\*, \*\* Significant at 5 and 1 per cent levels, respectively

**Table 2(a): Estimation of general combining ability effects of parents for maturity, growth, yield and quality traits in Tomato (*Solanum lycopersicum*L.)**

Parents	Number of days to first flowering	Number of days to first fruit set	Number of days to first fruit harvest	No. of pickings	Number of fruits cluster <sup>-1</sup>	Number of fruits plant <sup>-1</sup>	Fruit length (cm)	Fruit diameter (cm)	No. of locules fruit <sup>-1</sup>
SKAU-T-01	1.252**	0.581**	1.756**	0.364**	0.088*	-5.672**	0.743**	0.784**	0.549**
SKAU-T-914103	-0.537**	-0.858**	-2.511**	1.270**	0.358**	10.909**	-0.068*	-0.144**	-0.148**
SKAU-T-914113	-0.802**	-2.201**	-5.238**	0.281**	0.049	1.783**	-0.119**	-0.294**	0.027
SKAU-T-620438	0.150	0.303**	0.076	0.032	0.073**	-1.008**	-0.118**	-0.153**	-0.146**
SKAU-T-165690	-0.670**	-0.138	-1.385**	0.060	0.054*	0.831**	0.170**	0.264**	0.469**
SKAU-T-914108	-0.677**	-0.465**	0.495**	-0.140	0.147**	3.762**	0.144**	0.231**	0.221**
SKAU-T-02	-0.181*	-0.364**	-2.819**	-0.473**	-0.083**	-2.622**	-0.070*	-0.051	-0.348**
SKAU-T-914106	-0.215**	-1.311**	-0.192*	0.168*	0.167**	4.284**	-0.005	0.087**	0.219**
SKAU-T-617047	-0.790**	-1.626**	-0.649**	-0.050	0.014	1.638**	0.511**	0.541**	0.446**
SKAU-T-914091	-0.256**	-0.006	-1.932**	0.469**	0.115**	1.308**	0.133**	0.168**	0.095**
SKAU-T-145057	1.401**	1.942**	1.593**	-1.065**	-0.218**	-5.776**	-0.226**	-0.124**	-0.107**
SKAU-T-164334	0.046	0.396**	1.303**	0.356**	-0.013	0.869**	0.191**	0.109**	0.054
<b>SE± (g<sub>i</sub>)</b>	<b>0.08149</b>	<b>0.07943</b>	<b>0.08312</b>	<b>0.08381</b>	<b>0.03101</b>	<b>0.11920</b>	<b>0.03089</b>	<b>0.02656</b>	<b>0.02750</b>
<b>SE±(g<sub>i</sub>-g<sub>j</sub>)</b>	<b>0.12036</b>	<b>0.11733</b>	<b>0.12278</b>	<b>0.12380</b>	<b>0.04581</b>	<b>0.17607</b>	<b>0.04563</b>	<b>0.03923</b>	<b>0.04063</b>
<b>C.Dat 5%</b>	<b>0.23653</b>	<b>0.23056</b>	<b>0.24127</b>	<b>0.18447</b>	<b>0.06825</b>	<b>0.34600</b>	<b>0.06799</b>	<b>0.05845</b>	<b>0.06054</b>

\*, \*\* Significant at 5 and 1 per cent levels, respectively

**Table 2(b): Estimation of general combining ability effects of parents for maturity, growth, yield and quality traits in Tomato (*Solanum lycopersicum*L.)**

Parents	Pericarp thickness (mm)	No. of primary branches plant <sup>-1</sup>	Plant height (cm)	Average fruit weight (g)	Fruit yield plant <sup>-1</sup> (kg)	Fruit yield hectare <sup>-1</sup> (q)	Seed yield fruit <sup>-1</sup> (g)	Seed yield plant <sup>-1</sup> (g)	100 Seed weight (g)
SKAU-T-01	0.857**	0.090**	3.408**	6.816**	-0.024	-9.029**	-0.004**	-0.984**	0.035**
SKAU-T-914103	-0.296**	0.403**	6.086**	-6.961**	-0.032	-12.104**	-0.009**	0.933**	0.004**
SKAU-T-914113	-0.126**	0.210**	-1.545**	-4.760**	-0.084**	-30.981**	0.002**	0.304**	0.011**
SKAU-T-620438	-0.112**	0.157**	-1.651**	-5.083**	-0.116**	-43.007**	-0.004**	-0.315**	0.002**
SKAU-T-165690	0.302**	0.004	3.084**	4.202**	0.147**	54.254**	0.009**	0.469**	0.012**
SKAU-T-914108	0.247**	0.044*	4.387**	8.071**	0.258**	96.163**	0.007**	1.279**	0.004**
SKAU-T-02	-0.273**	-0.123**	-1.057**	1.580**	0.004	1.691	0.003**	0.451**	-0.011**
SKAU-T-914106	0.583**	-0.237**	1.473**	1.490**	0.044*	16.122**	-0.001	-0.520**	0.024**
SKAU-T-617047	0.460**	0.042	4.557**	9.988**	0.230**	85.386**	0.005**	0.035	-0.022**
SKAU-T-914091	-0.010	0.222**	0.852**	1.132**	0.142**	52.260**	0.001*	0.196**	-0.016**
SKAU-T-145057	-0.176**	-0.217**	-6.649**	-1.386**	-0.197**	-73.229**	-0.003**	-1.040**	-0.003**
SKAU-T-164334	-0.043	0.150**	-1.224**	4.889**	0.177**	65.492**	0.010**	0.295*	0.014**
<b>SE± (g<sub>i</sub>)</b>	<b>0.04100</b>	<b>0.02210</b>	<b>0.23312</b>	<b>0.19636</b>	<b>0.01810</b>	<b>2.54544</b>	<b>0.00040</b>	<b>0.06183</b>	<b>0.00066</b>
<b>SE±(g<sub>i</sub>-g<sub>j</sub>)</b>	<b>0.06056</b>	<b>0.03264</b>	<b>0.34434</b>	<b>0.29004</b>	<b>0.02680</b>	<b>3.75986</b>	<b>0.00069</b>	<b>0.09138</b>	<b>0.00098</b>
<b>C.Dat 5%</b>	<b>0.09024</b>	<b>0.04863</b>	<b>0.67666</b>	<b>0.56996</b>	<b>0.03985</b>	<b>7.38855</b>	<b>0.00103</b>	<b>0.13609</b>	<b>0.00146</b>

\*, \*\* Significant at 5 and 1 per cent levels, respectively

**Table 3a: Best specific cross combinations for different traits on the basis of sca and gca of parents involved in Tomato (*Solanum lycopersicum*L.) (based on pooled analysis)**

S. No.	Traits	Crosses	sca effect	gca effect of parents	S. No.	Traits	Crosses	sca effect	gca effect of parents
1.	Number of days to first flowering	SKAU-T-02 × SKAU-T-164334 SKAU-T-914113 × SKAU-T-165690 SKAU-T-165690 x SKAU-T-145057 SKAU-T-914113 x SKAU-T-145057 SKAU-T-02 x SKAU-T-914091	-6.130** -4.326** -2.730** -2.531** -2.361**	A × L H × H H x L H x L A x H	6.	No. of fruits plant <sup>-1</sup>	SKAU-T-914113 × SKAU-T-145057 SKAU-T-620438 × SKAU-T-617047 SKAU-T-914108 x SKAU-T-914091 SKAU-T-02 x SKAU-T-914091 SKAU-T-02 x SKAU-T-164334	37.674** 16.874** 15.345** 12.551** 7.573**	H × L L × H H x H L x H L x H
2.	Number of days to first fruit set	SKAU-T-02 x SKAU-T-164334 SKAU-T-914113x SKAU-T-165690 SKAU-T-914106 x SKAU-T-617047 SKAU-T-914103 x SKAU-T-617047 SKAU-T-02 x SKAU-T-914091	-7.764** -6.199** -4.431** -4.328** -2.651**	L x H H x L H x H H x H L x L	7.	Fruit length (cm)	SKAU-T-914113 x SKAU-T-620438 SKAU-T-914103x SKAU-T-914091 SKAU-T-914113x SKAU-T-165690 SKAU-T-165690 x SKAU-T-145057 SKAU-T-914106 x SKAU-T-617047	4.438** 2.245** 1.820** 1.693** 1.596**	L x L L x H L x H H x L L x H
3.	Number of days to first fruit harvest	SKAU-T-02 x SKAU-T-164334 SKAU-T-914113x SKAU-T-165690 SKAU-T-914103x SKAU-T-165690 SKAU-T-914113 x SKAU-T-145057 SKAU-T-620438 x SKAU-T-617047	-10.579** -10.078** -9.272** -7.656** -6.772**	L x H H x H H x H H x L L x H	8.	Fruit diameter (cm)	SKAU-T-914103x SKAU-T-914091 SKAU-T-914113x SKAU-T-165690 SKAU-T-02 x SKAU-T-164334 SKAU-T-165690 x SKAU-T-145057 SKAU-T-914106 x SKAU-T-617047	2.489** 2.453** 1.911** 1.659** 1.317**	L x H L x H L x H H x L H x H
4.	No. of pickings	SKAU-T-02 x SKAU-T-164334 SKAU-T-02 x SKAU-T-914091 SKAU-T-620438 x SKAU-T-617047 SKAU-T-914113 x SKAU-T-145057 SKAU-T-01 x SKAU-T-617047	4.602** 4.170** 4.079** 2.349** 2.131**	L x H L x H L x L H x L H x L	9.	No. of locules fruit <sup>-1</sup>	SKAU-T-02 x SKAU-T-164334 SKAU-T-914103 x SKAU-T-617047 SKAU-T-914113x SKAU-T-165690 SKAU-T-914103x SKAU-T-914091 SKAU-T-914108 x SKAU-T-914106	2.629** 1.573** 1.520** 1.389** 0.956**	L x L L x H L x H L x H H x H
5.	No. of fruits cluster <sup>-1</sup>	SKAU-T-914103 x SKAU-T-617047 SKAU-T-914108 x SKAU-T-914091 SKAU-T-02 x SKAU-T-164334 SKAU-T-620438 x SKAU-T-617047 SKAU-T-914113x SKAU-T-165690	0.922** 0.687** 0.640** 0.596** 0.526**	H x L H x H L x L H x L L x A	10.	Pericarp thickness (mm)	SKAU-T-02 x SKAU-T-164334 SKAU-T-914103x SKAU-T-914091 SKAU-T-914106 x SKAU-T-617047 SKAU-T-914103 x SKAU-T-914108 SKAU-T-914113x SKAU-T-165690	3.076** 2.619** 1.480** 1.387** 1.227**	L x L L x L H x H L x H L x H

**Table 3b: Best specific cross combinations for different traits on the basis of sca and gca of parents involved in Tomato (*Solanum lycopersicum*L.) (based on pooled analysis)**

S. No.	Traits	Crosses	sca effect	gca effect of parents	S. No.	Traits	Crosses	sca effect	gca effect of parents
11.	No. of primary branches plant <sup>-1</sup>	SKAU-T-914103× SKAU-T-165690 SKAU-T-914108 x SKAU-T-914106 SKAU-T-02 x SKAU-T-164334 SKAU-T-914106 x SKAU-T-617047 SKAU-T-914103x SKAU-T-914091	0.655** 0.655** 0.622** 0.591** 0.481**	H × L A x L L x H L x L H x H	15.	Fruit yield hectare <sup>-1</sup> (q)	SKAU-T-914113x SKAU-T-165690 SKAU-T-02 x SKAU-T-164334 SKAU-T-914103x SKAU-T-914091 SKAU-T-914108 x SKAU-T-914106 SKAU-T-165690 x SKAU-T-145057	483.644** 479.138** 445.200** 417.305** 392.574**	L × H L x H L x H H x H H x L
12.	Plant height (cm)	SKAU-T-914113 x SKAU-T-145057 SKAU-T-02 x SKAU-T-164334 SKAU-T-620438 x SKAU-T-617047 SKAU-T-01 x SKAU-T-617047 SKAU-T-914103x SKAU-T-165690	34.640** 26.949** 18.473** 16.792** 16.279**	L x L L x L L x H H x H H x H	16.	Seed yield fruit <sup>-1</sup> (g)	SKAU-T-02 x SKAU-T-164334 SKAU-T-620438 x SKAU-T-617047 SKAU-T-914103x SKAU-T-914091 SKAU-T-914108 x SKAU-T-914091 SKAU-T-914103 x SKAU-T-914108 SKAU-T-914108 x SKAU-T-164334	0.058** 0.044** 0.036** 0.030** 0.027** 0.027**	H x H L x H L x A H x A L x H H x H
13.	Average fruit weight (g)	SKAU-T-914113x SKAU-T-165690 SKAU-T-914103x SKAU-T-914091 SKAU-T-02 x SKAU-T-164334 SKAU-T-165690 x SKAU-T-145057 SKAU-T-914108 x SKAU-T-914106	50.958** 40.041** 37.410** 28.484** 27.407**	L x H L x H H x H H x L H x H	17.	Seed yield plant <sup>-1</sup> (g)	SKAU-T-914113 x SKAU-T-145057 SKAU-T-620438 x SKAU-T-617047 SKAU-T-02 x SKAU-T-164334 SKAU-T-914108 x SKAU-T-914106 SKAU-T-914113x SKAU-T-165690	4.443** 4.213** 3.769** 3.421** 1.967**	H x L L x L H x A H x L H x H
14.	Fruit yield plant <sup>-1</sup> (kg)	SKAU-T-914113x SKAU-T-165690 SKAU-T-02 x SKAU-T-164334 SKAU-T-914103x SKAU-T-914091 SKAU-T-914108 x SKAU-T-914106 SKAU-T-165690 x SKAU-T-145057	1.297** 1.283** 1.198** 1.123** 1.061**	L x H L x H L x H H x A H x L	18.	100 seed weight (g)	SKAU-T-914103x SKAU-T-914091 SKAU-T-914103 x SKAU-T-617047 SKAU-T-620438 x SKAU-T-617047 SKAU-T-165690 x SKAU-T-145057 SKAU-T-914113x SKAU-T-165690	0.073** 0.072** 0.054** 0.053** 0.041**	H x L H x L H x L H x L H x H

H: High, L: Low and A: Average