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

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### Abstract

Thirty crosses were done in tomato using ten genotypes as lines and three genotypes as testers in line × tester mating design. All the crosses along with parents were evaluated for combining ability and heterosis for quality traits and yield. H-86 was the good general combiner for titrable acidity, ascorbic acid, lycopene and shelf life, Azad T-5 was the good general combiner for TSS. Best specific combiner for TSS and fruit yield was Fla 7171 × Sel-7. A perusal of GCA/SCA variances revealed that SCA variances were of higher magnitude than GCA variances for yield, ascorbic acid and titrable acidity. It shows the preponderance of non-additive gene action governing these traits. For the fruit shape index, TSS, lycopene and shelf life, the GCA variance was of higher magnitude than the SCA variance, indicating the predominant role of additive gene action. The ratio of  $\sigma^2_{gca} / \sigma^2_{sca}$  is less than unity for all characters except fruit shape index, titrable acidity and ascorbic acid which also indicated the preponderance of non additive genetic variance. Best heterotic combination, for fruit yield and TSS was Fla 7171 × Sel-7, for fruit shape index was H-24 × Azad T-5, for ascorbic acid was Kashi Amrit × Kashi Sharad, for lycopene was H-86 × Azad T-5 and for shelf life was Floradade × Azad T-5. High heritability (>60%) combined with high genetic advance (>20%) was observed for shelf life, fruit yield, lycopene, TSS which indicates that these traits can be improved by simple selection.

**Keywords:** Crosses, combining ability, heterosis, variances, heritability, genetic advance

### Introduction

Tomato is an indispensable vegetable, holding prominent position as a source of vitamins A and C, and for its variety of processed products like sauce, ketch up, juice, puree etc. Total soluble solids (TSS), ascorbic acid and titrable acidity are the most important quality traits which enhance the utility of tomato. To break productivity barriers and to evolve varieties having a built-in high yield potential, hybridization is successful to a considerable extent. In a hybridization programme, selection of the parents on the basis of *per se* performance alone is not a sound procedure since superior lines identified on the basis of *per se* performance may yield poor recombinants in the segregating generations. Therefore, parents should be selected on the basis of their combining ability (Garg *et al.*, 2008) [5]. There are several techniques for the evaluation of varieties or strains in the terms of their combining ability and line × tester analysis is one of them. This technique was developed by Kempthorne in 1957 [9]. It is a good approach for screening the germplasm on the basis of combining ability effects and variances. Hybrids are preferred over pure line varieties in tomato on account of their superiority in marketable fruit yield, component traits and fruit quality. The pace with which the commercial F<sub>1</sub> hybrids of tomato are gaining popularity, it is demanding now to obtain such hybrids in public sector also, which have excellent quality and yield stability. The combining ability is the measure of nature of gene action. General combining ability variances largely involve additive gene action, while specific combining ability variances indicate presence of non-additive gene action which offers good scope for exploitation of heterosis.

### Materials and Methods

The present investigation was conducted with a view of generating information on hybrid vigour, combining ability and genetic parameters for quality traits and yield in tomato.

The experiment was conducted at the Horticulture Research Farm of Banaras Hindu University during *winter season-2013* and *rainy season-2014*. Based on the genetic diversity studies thirteen tomato genotypes were selected of which Floradade, Punjab Upma, H-86, Fla 7171, H-24, Kashi Amrit, CO-3, DT-2, Pant T-3 and NDTV-60 were designated as female lines. Kashi Sharad, Azad T-5 and Sel-7 were designated as testers. During *winter season-2013*, 10 elite lines and 3 testers were planted in the crossing block and crosses were done in L×T mating design. Lines were used as females and testers as males. Crossing is done by hand emasculation in evening followed by hand pollination in next morning. After fruit maturity F<sub>1</sub> seeds from each cross were collected separately and used for evaluation in next season. During *rainy season-2014*, the 30 F<sub>1</sub>s along with parents and standard check was sown in Randomized Block Design with 3 replications at 60 cm × 50 cm spacing. A plant population of 30 was maintained per treatment. Data for various quality components and yield in tomato was collected from the F<sub>1</sub>s, parents and standard check. *Per se* performance of the F<sub>1</sub>s and parents was assessed and magnitude of heterosis, heterobeltiosis, standard heterosis, combining ability, additive and dominance gene action was estimated

### Results and Discussion

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. It is an established fact that dominance is a component of non-additive genetic variance (breeding value). Breeders use these variance components to infer the gene action and to assess the genetic potentialities of the parents in hybrid combination. Analysis of variance for combining ability reveals the presence of both additivity and non-additivity for all characters studied. The variance due to SCA was higher in magnitude than GCA for all the traits. Further, the values of  $\sigma^2_{GCA}$  to  $\sigma^2_{SCA}$  ratio for all the traits supports the predominance of non-additive gene effects in governing the expression of all these characters. These results are in conformity with the findings of Dhaliwal *et al.* (2004)<sup>[4]</sup> and Kumar *et al.* (2015)<sup>[14]</sup>. Top four best general combiners in parents and specific combiners in crosses were given in Table 1.

Among lines H-86 was observed to be the good general combiner (Table 1) for quality parameters *viz.*, TSS, titrable acidity, ascorbic acid, lycopene and shelf life. No cross had good specific combining ability for all quality traits. For the quality traits TSS, lycopene, shelf life additive effects were predominant as the variance ratio is more than unity. For titrable acidity and ascorbic acid variance ratio is less than unity indicating the preponderance of dominance gene effects. Similar results were obtained by Garg *et al.* (2008)<sup>[5]</sup> for TSS, Akhtar and Hazra (2013)<sup>[3]</sup> for TSS and lycopene, Kumar *et al.* (2013b)<sup>[12]</sup> for titrable acidity and ascorbic acid. Fruit shape specifications in tomato vary with end use of the fruits. Round fruits are generally preferred for fresh market. So, polar to equatorial diameter ratio should be less than unity. Pre-dominance of additive effect of genes were observed for this trait as the variance ratio was greater than unity. The significant positive *gca* was observed in parents H-24 and Fla 7171 while the cross Floradade × Azad T-5 showed highest significant *sca* effects. The results are in conformity with the findings of Garg *et al.* (2008)<sup>[5]</sup>, Sharma and Sharma (2010)<sup>[17]</sup> and Kapur (2011)<sup>[8]</sup>.

Every breeding programme is aimed at achieving high fruit yield along with superior quality. The Kashi Amrit, Fla 7171 and Floradade were observed to be good general combiners for fruit yield. Hybrids, Punjab Upma × Azad T-5, Fla 7171 × Sel-7 and Kashi Amrit × Sel-7 exhibited high *sca* effects. The combining ability analysis revealed the preponderance of non-additive gene action for the expression of this trait. Similar results were observed by Saidi *et al.* (2008), Dordevic *et al.* (2010), Sharma and Sharma (2010)<sup>[17]</sup>, Dhaliwal and Cheema (2011), Kapur (2011)<sup>[8]</sup>, Katkar *et al.* (2012), Saleem *et al.* (2013), Shankar *et al.* (2013), Agarwal *et al.* (2014)<sup>[1]</sup>.

The ratio of  $\sigma^2_{gca} / \sigma^2_{sca}$  is less than unity for all characters except fruit shape index, titrable acidity and ascorbic acid which also indicated the preponderance of non additive genetic variance. It suggested greater importance of non-additive gene action in their expression and indicated better prospects for the exploitation of non-additive genetic variation for fruit yield and quality traits through hybrid breeding. When *gca* is high and *sca* is low than expected response of additive gene action. On the other hand *gca* low and *sca* variance is higher, expected response of non-additive gene action. In case of line × tester analysis, additive genetic variance is equal to *gca* variance and dominance variance is equal to *sca* variance.

The study revealed the marked differences in nature and magnitude of heterosis between F<sub>1</sub> hybrids for all the traits. The manifestation of heterosis was appreciable in both nature and magnitude for the crosses and also over the standard check. In the present study, a wide range of heterosis was noted in the crosses in respect of yield and quality traits indicating the presence of diversity in the parents. Top four best crosses based on heterobeltiosis and standard heterosis were presented in Table 2.

Heterosis is directly proportional to the existence of non-additive genetic variance in a population. If *sca* variance, which is a measure of non-additive genetic variance, along with observed heterosis is high for a character, such cross can be utilized for commercial exploitation of heterosis. In the present study the condition was found in different crosses for different characters (Table 2).

Maximum heterosis for TSS was observed for Fla 7171 × Sel-7 and NDTV 60 × Azad T-5 over better parent and standard check respectively. More TSS increases the amount of finished product. The results are in accordance with Rattan (2007)<sup>[16]</sup>, Kumar *et al.* (2013a)<sup>[15]</sup> Solieman *et al.* (2013)<sup>[18]</sup>, Kumar *et al.* (2016)<sup>[11]</sup> and Agarwal *et al.* (2017)<sup>[2]</sup>. High acidity is a desirable character for cooking quality. Best heterotic combination was NDTV 60 × Azad T-5 over both better parent and standard check. The results confounded with the findings of Kumar *et al.* (2013a)<sup>[15]</sup>.

The crosses Kashi Amrit × Kashi Sharad and Kashi Amrit × Azad T-5 showed highest heterosis over better parent and standard check respectively for ascorbic acid content. Kashi Sharad was observed to be the best tester for ascorbic acid. Similar findings were reported by Kumar *et al.* (2013a)<sup>[15]</sup> and Solieman *et al.* (2013)<sup>[18]</sup>. Best heterotic combination over better parent and standard check for lycopene was H-86 × Azad T-5. High lycopene content is a desirable character. Kumar *et al.* (2012)<sup>[13]</sup> had also reported the similar results. Shelf life is one of the most important traits for any vegetable. Maximum heterosis for this trait over better parent and standard check was observed for Kashi Amrit × Kashi Sharad and Floradade × Azad T-5 respectively. The results are in accordance with Joshi *et al.* (2005)<sup>[7]</sup>.

Floradade  $\times$  Azad T-5 is the best cross based on heterosis and sca for fruit shape index which has also fruit shape index less than one indicates the getting of round fruits which is a desirable trait for cooking preference. So, for getting large fruits Sel-7 is the best tester and for getting round fruits H-24 is the best tester. Similar findings were observed by Rattan (2007)<sup>[16]</sup> and Kumar *et al.* (2013a)<sup>[15]</sup>.

The fruit yield was maximum for the cross Fla 7171  $\times$  Sel-7 over both better parent and standard check. Other crosses that recorded maximum heterosis over standard check were Kashi Amrit  $\times$  Sel-7 and Kashi Amrit  $\times$  Kashi Sharad. The best tester to increase fruit yield was Sel-7 followed by Kashi Sharad. The findings are in conformity with Rattan (2007)<sup>[16]</sup>, Kumar *et al.* (2012)<sup>[13]</sup>, Solieman *et al.* (2013)<sup>[18]</sup> Agarwal (2014)<sup>[11]</sup>, Jose *et al.* (2016)<sup>[6]</sup>, Kumar *et al.* (2016)<sup>[11]</sup> and Agarwal *et al.* (2017)<sup>[12]</sup>.

Best heterotic combination, for fruit yield and TSS was Fla 7171  $\times$  Sel-7, for fruit shape index was H-24  $\times$  Azad T-5, for ascorbic acid was Kashi Amrit  $\times$  Kashi Sharad, for lycopene was H-86  $\times$  Azad T-5 and for shelf life was Floradade  $\times$  Azad T-5. Good general combiners for titrable acidity, ascorbic acid, lycopene and shelf life was H-86, for TSS was Azad T-5. Best specific combiner for TSS and fruit yield was Fla 7171  $\times$  Sel-7. A perusal of GCA/SCA variances revealed that SCA variances were of higher magnitude than GCA variances for all the characters except fruit shape index, TSS, lycopene and shelf life. It shows the preponderance of non-additive

gene action governing these traits. For the fruit shape index, TSS, lycopene and shelf life, the GCA variance was of higher magnitude than the SCA variance, indicating the predominant role of additive gene action. Non-additive gene effects were found to be more pronounced for their contributions to the genetic variability than that due to the additive gene effects, since the estimated SCA variance showed higher values than those of GCA variance for most of the studied characters. Keeping in view the GCA and SCA effects and variances as well as additive ( $\sigma^2A$ ) and dominant ( $\sigma^2D$ ) components of variance, it would be worthwhile to affect genetic improvement in tomato by exploitation of hybrid vigour for almost all the traits which had high dominant ( $\sigma^2D$ ) components of variances to that of additive components of variance ( $\sigma^2A$ ). The results are in conformity with Dhaliwal *et al.* (2004)<sup>[4]</sup> and Kumar *et al.* (2015)<sup>[14]</sup>. High heritability (>60%) combined with high genetic advance (>20%) was observed (Table 3) for shelf life, fruit yield, lycopene and TSS. High heritability (>60%) combined with medium genetic advance (10-20%) was observed for titrable acidity and ascorbic acid. High heritability combined with high genetic advance indicates that these traits can be improved by simple selection. The results are in accordance with the findings of Ghosh *et al.* (2010), Singh *et al.* (2011), Manna and Paul (2012), Pandiarana *et al.* (2014) and Khan *et al.* (2014)<sup>[10]</sup>.

**Table 1:** Top four crosses based on *per se* performance, gca and sca

S. No	Character	<i>Per se</i> performance	General combining ability	Specific combining ability
1.	TSS ( $^{\circ}$ Brix)	NDTVR 60 $\times$ Azad T-5 (5.80) CO-3 $\times$ Azad T-5 (5.53) H-86 $\times$ Kashi Sharad (5.47) Punjab Upma $\times$ Azad T-5 (5.33)	NDTVR 60 (0.52) Azad T-5 (0.49) H-86 (0.27) Punjab Upma (0.23)	Fla 7171 $\times$ Sel-7 (0.41) Floradade $\times$ Sel-7 (0.37) H-86 $\times$ Kashi Sharad (0.36) H-24 $\times$ Sel-7 (0.27)
2.	Titrable acidity (%)	NDTVR 60 $\times$ Azad T-5 (0.68) H-24 $\times$ Azad T-5 (0.67) Fla 7171 $\times$ Kashi Sharad (0.63) H-86 $\times$ Kashi Sharad (0.63)	H-24 (0.06) NDTVR 60 (0.04) H-86 (0.04) Kashi Sharad (0.03)	CO-3 v Sel-7 (0.08) DT-2 $\times$ Kashi Sharad (0.06) NDTVR 60 $\times$ Azad T-5 (0.05)
3.	Ascorbic acid (mg/100g)	Kashi Amrit $\times$ Azad T-5 (28.19) H-86 $\times$ Azad T-5 (27.87) Kashi Amrit $\times$ Kashi Sharad (27.86) Pant T-3 V Azad T-5 (27.83)	Kashi Amrit (1.35) Azad T-5 (1.13) H-86 (1.10)	NDTVR 60 $\times$ Kashi Sharad (1.24) Punjab Upma $\times$ Sel-7 (0.95) Pant T-3 $\times$ Azad T-5 (0.83)
4.	Lycopene (mg/100g)	H-86 $\times$ Azad T-5 (5.03) NDTVR 60 $\times$ Kashi Sharad (4.98) CO-3 $\times$ Azad T-5 (4.70) NNDTVR 60 $\times$ Azad T-5 (4.54)	NDTVR 60 (0.52) Azad T-5 (0.40) H-86 (0.36)	Floradade $\times$ Sel-7 (0.43) H-86 $\times$ Azad T-5 (0.40) Punjab Upma $\times$ Sel-7 (0.35)
5.	Shelf life (days)	Floradade $\times$ Azad T-5 (11.67) Punjab Upma $\times$ Azad T-5 (8.33) Kashi Amrit $\times$ Azad T-5 (8.33) Pant T-3 $\times$ Azad T-5 (7.83)	Floradade (2.21) Azad T-5 (1.34) Punjab Upma (0.66)	Floradade $\times$ Azad T-5 (1.66)
6.	Fruit shape index	H-24 $\times$ Sel-7 (0.94) CO-3 $\times$ Sel-7 (0.94) Fla 7171 $\times$ Kashi Sharad (0.93) DT-2 $\times$ Kashi Sharad (0.93)	Pant T-3 (-0.07) Kashi Amrit (-0.05) Punjab Upma (-0.05)	Floradade $\times$ Azad T-5 (0.05)
7.	Fruit Yield (kg/plant)	Fla 7171 $\times$ Sel-7 (3.71) Kashi Amrit $\times$ Sel-7 (3.68) Kashi Amrit $\times$ Kashi Sharad (3.27) Floradade $\times$ Sel-7 (3.24)	Kashi Amrit (0.79) Fla 7171 (0.70) Floradade (0.43)	Punjab Upma $\times$ Azad T-5 (0.54) Fla 7171 $\times$ Sel-7 (0.41) Kashi Amrit $\times$ Sel-7 (0.29) CO-3 $\times$ Azad T-5 (0.26)

**Table 2:** Top four best crosses based on better parent and standard heterosis

S. No.	Character	Better parent heterosis	Standard heterosis
1.	TSS (°Brix)	Fla 7171 × Sel-7 (10.71) H-86 × Kashi Sharad (7.89) Floradade × Sel-7 (7.76) CO-3 × Azad T-5 (3.75)	NDTVR 60 × Azad T-5 (41.46) CO-3 × Azad T-5 (34.88) H-86 × Kashi Sharad (33.41) Punjab Upma × Azad T-5 (30.00)
2.	Titration acidity (%)	NDTVR 60 × Azad T-5 (15.17) H-24 × Azad T-5 (9.89) Kashi Amrit × Kashi Sharad (6.11) Fla 7171 × Kashi Sharad (5.56)	NDTVR 60 × Azad T-5 (30.77) H-24 × Azad T-5 (28.85) Kashi Amrit × Kashi Sharad (23.08) H-86 × Azad T-5 (23.08) H-24 × Kashi Sharad (23.08)
3.	Ascorbic acid (mg/100g)	Kashi Amrit × Kashi Sharad (10.03) Kashi Amrit × Azad T-5 (7.62) Fla 7171 × Kashi Sharad (6.28) Pant T-3 × Azad T-5 (6.25)	Kashi Amrit × Azad T-5 (15.49) H-86 × Azad T-5 (14.17) Kashi Amrit × Kashi Sharad (14.13) Pant T-3 × Azad T-5 (14.01)
4.	Lycopene (mg/100g)	H-86 × Azad T-5 (47.99) NDTVR 60 × Kashi Sharad (47.15) Floradade × Sel-7 (44.90) CO-3 × Azad T-5 (37.87)	H-86 × Azad T-5 (44.13) NDTVR 60 × Kashi Sharad (42.69) CO-3 × Azad T-5 (34.67) Punjab Upma × Azad T-5 (28.08)
5.	Shelf life (days)	Kashi Amrit × Kashi Sharad (10.00)	Floradade × Azad T-5 (84.36) Punjab Upma × Azad T-5 (31.60) Kashi Amrit × Azad T-5 (31.60) Pant T-3 × Azad T-5 (23.70)
6.	Fruit shape index	Kashi Amrit × Kashi Sharad (-12.77) Pant T-3 × Sel-7 (-12.68) Punjab Upma × Kashi Sharad (-11.68) Floradade × Sel-7 (11.59)	Pant T-3 × Azad T-5 (-15.93) Kashi Amrit × Kashi Sharad (-11.48) Punjab Upma × Azad T-5 (-11.11) Pant T-3 × Sel-7 (-10.74)
7.	Fruit Yield (kg/plant)	Fla 7171 × Sel-7 (52.05) CO-3 × Azad T-5 (51.86) Floradade × Sel-7 (46.76) H-24 × Azad T-5 (43.67)	Fla 7171 × Sel-7 (28.82) Kashi Amrit × Sel-7 (27.78) Kashi Amrit × Kashi Sharad (13.54) Floradade × Sel-7 (12.85)

**Table 3:** Heritability and genetic advance for quality traits and yield in tomato

	TSS (°Brix)	Titration acidity (%)	Ascorbic acid (mg/100g)	Lycopene (mg/100g)
Heritability (%)	95.73	78.93	89.29	90.21
Genetic advance	1.23	0.11	3.53	1.49
Genetic advance as percent mean (GAM)	26.41	18.58	13.94	40.13

  

	Shelf life (days)	Fruit shape index	Fruit yield (kg/plant)
Heritability (%)	83.14	72.18	93.01
Genetic advance	3.39	0.08	1.16
Genetic advance as percent mean (GAM)	52.02	9.47	49.52

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