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GENE ACTION AND COMBINING ABILITY ANALYSIS FOR YIELD AND QUALITY IMPROVEMENT IN TOMATO (*SOLANUM LYCOPERSICON* L.)

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Abstract

Combining ability and gene effects for yield and quality traits in tomato were studied by involving twenty four cross combinations obtained from crossing eight diverse lines with three testers in line x tester mating fashion. The analysis of variance revealed that the variance due to line x tester effects were highly significant for all the traits except lycopene content under study. Combining ability analysis revealed that magnitude of *sca* variance was greater than *gca* variance suggesting the predominance of non-additive gene action for yield per plant, pericarp thickness, TSS, titrable acidity, lycopene and shelf life. The degree of dominance revealed, over dominance is the cause of heterosis for these traits. Based on *gca* effects of parents, the lines LE-62 and LE-53 and the testers Arka Meghali and Arka Vikas were good general combiners for most of the traits under study. The crosses *viz*., EC-157568 x Arka Vikas, EC-163611 x Arka Alok, LE-62 x Arka Alok and LE-64 x Arka Vikas were found to be superior specific combiners for yield per plant. For quality traits, the cross EC-165749 x Arka Alok was also superior specific combiner for yield per plant, TSS, ascorbic acid and shelf life and the cross EC-157568 x Arka Alok was superior specific combiner for TSS, titrable acidity and lycopene.

Key words : *Solanum lycopersicon* L., Combining ability, Gene action, Quality, Tomato, Yield

Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most important vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries. The fruits are available year round and eaten raw or cooked. Tomato in large quantities is used to produce soup, juice, ketchup, puree, paste and powder; it supplies ascorbic acid and adds variety of colours and flavours to the food.

All fruit quality attributes were expressions of genotypic and environmental effect of interactions. Hence quality attributes have to be considered together for future genetic improvement of tomato quality. Total soluble solids (TSS) and ascorbic acid content have been recognized as the most desirable attributes in tomato for processing industry. Berry and Uddin (1991) observed that an increase of 1% TSS in fruits results to increase 20% recovery of processed products. High ascorbic acid content in addition to improving the nutrition also helps in the better retention of natural colour and flavour of the tomato products. The red pigment in tomato (lycopene) is now being considered as the "world's most powerful natural antioxidant" (Jones, 1999). Therefore, tomato is one of the most important 'protective foods' because of its special nutritive value. The shelf life is an important quality trait for marketing, transportation and domestic use. This trait is controlled by genetic factors as well as environmental factors such as temperature. Characters like whole fruit firmness, number of locules per fruit and pericarp thickness are the important parameters contributing towards shelf life besides biochemical changes (Bekov, 1968). However, pericarp thickness alone accounts for 64% of fruit firmness (Ahrens *et al.,* 1987). Hence, development of firm tomato is the basic need for longer shelf life.

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The ultimate objective in any crop improvement programme is to identify the best parent(s) and hybrid(s). Combining ability analysis is a common biometrical tool used in the breeding programme for testing the performance of lines in hybrid combinations and also for characterizing the nature and magnitude of gene action involved in the expression of traits. Line x Tester analysis is a useful tool for preliminary evaluation of genetic stock for use in hybridization programme with a view to identify good combiners, which may be used to build up a population with favourable and fixable genes for effective yield and quality improvement. Thus present investigation aimed to study the genetic architecture of quality traits for the development of high quality varieties/ hybrids for processing tomato.

Materials and Methods

The present study was conducted at Vegetable Research Station, Hyderabad, Dr. Y.S.R. Horticultural University during 2009-10. Eight genetically divers lines (EC-165749, EC-157568, EC-164838, EC-163611, LE-53, LE-56, LE-62 and LE-64) were crossed with three testers (Arka Alok, Arka Meghali and Arka Vikas) in line x tester mating design during *rabi* 2009. The resultant 24 F_1's were evaluated along with their parents and two standard checks (Lakshmi and US-618) during *Kharif* and *Rabi* 2010 in randomized block design, which was replicated thrice. Each entry was grown in one row with 10 plants in each row by adopting inter row spacing of 60 cm and intra row spacing of 45 cm. The observations were recorded on five randomly selected plants for *viz*., fruit yield per plant (kg/plant), number of locules per fruit, pericarp thickness (mm), TSS (^{0}Brix), titrable acidity (%), ascorbic acid (mg/100mg), lycopene (mg/100mg) and shelf life (days). The data were subjected to combining ability analysis following Kempthorne (1957).

Results and Discussion

The pooled results obtained in the present study (*Kharif* and *Rabi* 2010) pertaining to combining ability, gene action and ANOVA for yield and quality characters are discussed here under. Analysis of variance (table 1) for combining ability revealed that the variance due to lines effects were highly significant (@ P = 0.01) for yield per plant (kg), ascorbic acid content (mg/100g) and lycopene (mg/100g) whereas, mean squares due to testers were non significant for all traits under study except number of locules per fruit, which indicated the existence of substantial genetic diversity in the parents for those traits. While the variance due to line x tester effects were highly significant (@P = 0.01) for all traits under study except lycopene, representing specific combining ability and suggested manifestation of parental genetic variability in their crosses or possibility of better selection of cross combinations among 24 F_1 hybrids for these traits.

General combining ability

General combining ability refers to the average performance of a line in a series of cross combinations and it is attributable to additive (fixable) gene action. The estimates of *gca* effects provides a measure of general combining ability of each genotype, thus aids in selection of superior ones as parents for breeding programmes.

The line LE-53 registered significant highest *gca* effect for yield per plant, while LE-62 exhibited significant highest *gca* effects for pericarp thickness and lycopene content and number of locules per fruit (desirable negative highest). The highest significant *gca* effects for TSS and shelf life were recorded by EC-163611. The highest significant *gca* effects were exhibited by EC-165749 for titrable acidity and LE-56 for ascorbic acid.

Among testers, Arka Alok registered positively significant highest *gca* effect for pericarp thickness, whereas Arka Meghali exhibited highest significant *gca* effects for yield per plant, ascorbic acid and lycopene. The tester Arka Vikas recorded highest significant *gca* effects for number of locules per fruit, TSS, titrable acidity and shelf life.

Comprehensive assessment of parents by considering *gca* effects for 8 characters studied has resulted into identification of lines LE-62 and LE-53 as good general combiners for overall characters. Among testers, Arka Meghali and Arka Vikas were identified as good general combiners for overall characters. Hence, these can be utilized in commercial breeding programmes as good donors for yield and quality. The higher *per se* performance of the lines EC-165749 and LE-56 along with high *gca* estimates for titrable acidity and ascorbic acid, respectively suggesting that these two parents may be used in further breeding programme to improve yield and quality by adopting pedigree method.

Specific combining ability

The specific combining ability reveals the best cross combination among the genotypes which can be useful for developing hybrids with high vigour for the traits. Results revealed that was no cross combinations consistently good for all the traits. However, some of the crosses exhibited significant *sca* effects for more than one character.

The cross EC-157568 x Arka Vikas was found to exhibit highest *sca* effects in the desirable direction for

Table 1 : ANOVA for combining ability for yield and quality traits in tomato.

Source	df	Mean Sum of Squares							
		Yield per plant (kg)	No. of locules per fruit	Pericarp thickness (mm)	TSS (^{0}Brix)	Titrable acidity (%)	Ascorbic acid (mg100g^{-1})	Lycopene (mg100g^{-1})	Shelf life (days)
Replications	2	0.834**	0.384	0.002	0.001	0.026**	395.814**	0.051	0.849
Genotypes	34	1.858**	1.981**	1.813**	0.506**	0.054**	141.109**	17.311**	7.463**
Line Effect	7	2.656*	1.283	2.536	0.749	0.043	340.854**	15.565**	11.980
Tester Effect	2	0.146	2.702*	1.846	0.037	0.046	123.028	20.027	2.169
Line * Tester Eff.	14	0.873**	0.506**	1.006**	0.550**	0.050**	47.418**	9.720	4.917**
Error	68	0.014	0.179	0.065	0.049	0.004	0.042	0.173**	0.678
Total	104	0.633	0.772	0.635	0.197	0.021	53.771	5.773	2.900

*Significant at 5% level, ** Significant at 1% level.

Table 2 : Estimates of *gca* effects of lines and testers for fruit yield and quality traits in tomato.

	Yield per plant (kg)	No. of locules per fruit	Pericarp thickness (mm)	TSS (^{0}Brix)	Titrable acidity (%)	Ascorbic acid (mg100g^{-1})	Lycopene (mg100g^{-1})	Shelf life (days)
Lines								
EC- 165749	-0.67**	-0.04**	-0.03**	-0.55**	0.13**	-5.44**	-1.11**	-1.33**
EC- 157568	-0.11**	-0.28**	0.38**	0.09**	-0.07**	-0.33**	-1.94**	-0.33**
EC- 164838	-0.59**	0.00**	-0.71**	0.10**	0.01**	1.22**	0.34**	1.05**
EC- 163611	-0.40**	0.02	-0.63**	0.43**	0.02**	-1.01**	0.02	1.44**
LE - 53	0.77**	0.42**	0.52**	0.12**	0.04**	-3.67**	1.55**	1.17**
LE - 56	0.24**	-0.18**	-0.34**	-0.12**	-0.09**	14.33**	-1.11**	0.33*
LE - 62	0.10**	-0.57**	0.74**	0.12**	-0.02**	-1.89**	1.76**	-1.33**
LE - 64	0.67**	0.62**	0.07**	-0.19**	-0.02**	-3.22**	0.49**	-0.99**
$SE_{(i)}$	0.04	0.14	0.09	0.07	0.02	0.07	0.14	0.28
Testers								
Arka Alok	0.02**	0.23**	0.24**	0.01*	0.00**	-1.22**	-0.78**	-0.02**
Arka Meghali	0.06**	0.15**	0.06**	-0.04**	-0.04**	2.61**	1.00**	-0.29**
Arka Vikas	-0.09**	-0.38**	-0.30**	0.03**	0.04**	-1.39**	-0.22**	0.31**
$SE_{(i)}$	0.02	0.09	0.05	0.05	0.01	0.04	0.08	0.17

* Significant at 5% level, ** Significant at 1% level.

yield per plant and pericarp thickness. The eight cross combinations *viz*., EL-157568 x Arka Vikas (0.85), EC-163611 x Arka Alok (0.60), LE-62 x Arka Alok (0.56), LE-64 x Arka Vikas (0.54), EC-165749 x Arka Alok (0.40), EC-164838 x Arka Vikas (0.33) and LE-53 x Arka Alok (0.26) recorded significant *sca* effects and high *per se* performance for the character yield per plant. The gene action involved in the crosses which recorded significant *sca* effects is dominant or epistatic in nature, which is non-fixable. Hence, heterosis breeding is recommended. The hybrid EC-164838 x Arka Vikas was best specific combination for titrable acidity and ascorbic acid. While the crosses EC-157568 x Arka Alok, LE-56 x Arka Meghali and EC-16364 x Arka Vikas were found to be the best specific combiners for TSS, lycopene and shelf life, respectively.

Some of the hybrids showed significant *sca* effects in desired direction along with yield per plant such as

Table 3 : Estimates of specific combining ability (*sca*) effects for yield and quality traits in tomato.

S. no.	Crosses	Yield per plant (kg)	No. of Locules per fruit	Pericarp thickness (mm)	TSS (^{0}Brix)	Titrable acidity (%)	Ascorbic acid (mg 100g^{-1})	Lycopene (mg 100g^{-1})	Shelf life (days)
1.	EC – 165749 x Arka Alok	0.40**	0.26	0.70**	0.64**	0.01	5.44**	-0.32	1.02*
2.	EC - 165749 x Arka Meghali	0.03	-0.70 **	-0.31*	-0.23	0.12**	-3.72**	-0.80**	0.29
3.	EC – 165749 x Arka Vikas	-0.42**	0.44	-0.39*	-0.41**	-0.13**	-1.72**	1.12**	-1.31**
4.	EC – 157568 x Arka Alok	-0.86**	-0.21	-0.61**	-0.46**	0.11**	3.67**	2.01**	1.02*
5.	EC – 157568 x Arka Meghali	0.00	0.10	-0.52**	-0.20	0.02	-2.17**	-1.15**	0.29
6.	EC – 157568 x Arka Vikas	0.85**	0.11	1.13**	0.66**	-0.13**	-1.50**	-0.86**	-1.31**
7.	EC – 164838 x Arka Alok	-0.35**	-0.42	-0.26	-0.07	-0.03	-3.89**	-2.54**	-0.87
8.	EC – 164838 x Arka Meghali	0.02	0.12	0.30*	0.09	-0.12**	-1.72**	1.14**	-0.10
9.	EC – 164838 x Arka Vikas	0.33**	0.30	-0.04	-0.02	0.16**	5.61**	1.40**	0.97*
10.	EC – 163611 x Arka Alok	0.60**	0.22	0.20	-0.37**	0.12**	1.68**	0.22	1.24*
11.	EC – 163611 x Arka Meghali	-0.24**	-0.36	-0.01	-0.08	-0.20**	-0.16	-1.04**	0.51
12.	EC – 163611 x Arka Vikas	-0.36**	0.14	-0.19	0.45**	0.08*	-1.52**	0.82**	-1.76**
13.	LE – 53 x Arka Alok	0.26**	-0.18	0.06	0.61**	0.00	1.00**	-1.38**	-0.48
14.	LE – 53 x Arka Meghali	-0.07	0.14	0.04	-0.20	0.04	-1.50**	-0.30	0.29
15.	LE – 53 x Arka Vikas	-0.19**	0.04	-0.10	-0.41**	-0.04	0.50**	1.68**	0.19
16.	LE – 56 x Arka Alok	-0.05	0.09	0.78**	-0.01	0.00	1.00**	-1.08**	-1.64**
17.	LE – 56 x Arka Meghali	0.18*	-0.10	-0.23	0.04	-0.09*	-0.83**	2.60**	0.62
18.	LE – 56 x Arka Vikas	-0.13	0.01	-0.54**	-0.03	0.09*	-0.16	-1.52**	1.02*
19.	LE – 62 x Arka Alok	0.56**	0.11	-0.47**	-0.02	-0.13**	-3.45**	1.71**	0.02
20.	LE – 62 x Arka Meghali	0.06	0.22	0.19	0.23	0.11**	4.72**	0.45	-1.71**
21.	LE – 62 x Arka Vikas	-0.62**	-0.34	0.28	-0.21	0.02	-1.27**	-2.16**	1.69**
22.	LE – 64 x Arka Alok	-0.57**	0.12	-0.40**	-0.31*	-0.07	-5.45**	1.38**	-0.32
23.	LE – 64 x Arka Meghali	0.03	0.57*	0.55**	0.34**	0.11**	5.39**	-0.90**	-0.19
24.	LE – 64 x Arka Vikas	0.54**	-0.69**	-0.15	-0.03	-0.04	0.06	-0.48	0.51
	S.Ed	0.07	0.24	0.15	0.13	0.04	0.12	0.24	0.48
	CD @ 5% level	0.14	0.49	0.30	0.26	0.08	0.24	0.48	0.96
	CD @ 1% level	0.18	0.66	0.40	0.34	0.10	0.32	0.65	1.28

* Significant at 5% level, ** Significant at 1 % level.

EC-157568 x Arka Vikas for pericarp thickness and TSS, EC-163611 x Arka Alok for titrable acidity, ascorbic acid and shelf life, LE-62 x Arka Alok for lycopene, LE-64 x Arka Vikas for number of locules per fruit and EC-165749 x Arka Alok for pericarp thickness, TSS, ascorbic acid and shelf life.

Gene action

The variance due to *gca* and *sca* were found to be significant for all the traits except TSS and titrable acidity revealing the presence of both additive and non-additive type of gene action for the inheritance of yield and quality traits. In case of TSS and titrable acidity, *sca* variance alone was significant indicating that only non-additive genetic component is involved in the inheritance of this character (table 4).

The additive variance was larger than its counter part non-additive variance for number of locules per fruit, the estimates of average degree of dominance had also confirmed the additive gene action for this trait. Similar results were reported by Dhaliwal *et al*. (2000). Hence,

Table 4 : Estimates of variance components and degree of dominance for yield and quality traits in tomato.

S. no.	Character	$\sigma^2 gca$	$\sigma^2 sca$	$\sigma^2 gca / \sigma^2 sca$	σ^2A	σ^2D	σ^2A / σ^2D	Degree of dominance
1.	Yield / plant (kg)	0.08*	0.29**	0.28	0.17	0.29	0.59	1.30
2.	No. of locules/ fruit	0.11**	0.11**	1.00	0.22	0.11	2.02	0.70
3.	Pericarp thickness (mm)	0.13**	0.31**	0.42	0.26	0.31	0.82	1.10
4.	TSS (^{0}Brix)	0.02	0.17**	0.12	0.04	0.17	0.25	2.00
5.	Titrable Acidity (%)	0.00	0.02**	0	0.00	0.02	0.32	1.77
6.	Ascorbic acid (mg/100g)	14.05**	15.79**	0.89	28.11	15.79	1.78	0.75
7.	Lycopene (mg/100g)	1.07*	3.18**	0.34	2.14	3.18	0.67	1.22
8.	Shelf life (days)	0.39*	1.41**	0.28	0.78	1.41	0.55	1.35

*Significant at 5% level, **Significant at 1 % level.

significant advancement could be achieved in the segregating generations using simple selection procedures or conventional breeding methods such as pedigree and bulk selection.

Non additive genetic variance had greater estimates than additive genetic variance and the ratio of additive variance and non additive genetic variance is less than unity, establishing the predominance of non additive gene action in the inheritance of these traits *viz.,* TSS, titrable acidity and lycopene (Mondal *et al.,* 2009), pericarp thickness and shelf life (Joshi *et al*., 2005) and yield per plant (Singh *et al*., 2010). The presence of non-additive gene action for these traits requires maintenance of heterozygosity in the population. Hence, it is necessary to follow modified breeding methods such as bi-parental cross or triple test cross design or any other form of recurrent selection method in early generations, which is more useful for exploitation of non-additive gene action in order to recover transgressive segregates by breaking linkages, releasing concealed variability, improving the concentration of favourable genes and changing linkage equilibrium, otherwise heterosis breeding would be a main breeding method in improvement of these traits.

While, the greater values of additive variance than non-additive variance and greater *sca* variance than *gca* variance revealed the involvement of both additive and non additive gene action in the inheritance of ascorbic acid. Patil and Bojappa (1986) also observed both additive and non additive gene action for this trait. There is a possibility of deriving high performing pure lines for this trait because longer proportion of non-additive effects in self pollinated crops seems to be due to additive x additive epistatic effect. Hence, reciprocal recurrent selection or bi parental mating is useful for improvement of ascorbic acid content since, it exploits both the components of genetic variance.

In conclusion, the present investigation suggests that heterosis breeding can be used efficiently to improve tomato yield together with good quality for processing purpose.

References

Ahrens, M.J., D.J. Huber and J.W. Scoot (1987). Firmness and mealiness of selected Florida grown tomato cultivars. *Proceedings of Florida State Horticultural Society*, **101:** 39-41.

Bekov, R.K. (1968). Initial material and breeding tomato varieties for mechanical harvesting. *Autoreferate Dess Moscow*, pp. 21.

Berry, S.Z. and M.R. Uddin (1991). Breeding tomato for quality and processing attributes. p. 196-206. In: *Genetic Improvement of Tomato*, G. Kalloo (eds.). Springer-Verlag Inc.

Dhaliwal, M.S., S. Singh and D.S. Cheema (2000). Estimating combining ability effects of the genetic male sterile lines of tomato for their use in hybrid breeding. *J. of Gen. and Plant Breeding.*, **54:** 199-205.

Jones, J.B. (1999). Tomato plant culture. In: *The field, green house and house garden.* p. 199. CRC Press, LLC 2000, Boca Raton, Florida.

Joshi, A., M.C. Thakur and U.K. Kohli (2005). Heterosis and combining ability for shelf life, whole fruit firmness and related traits in tomato. *Indian J. of Hort.*, **62(1):** 33-36.

Kempthorne, O. (1957). *An Introduction to genetic Statistic*. John Wiley and Sons, Inc. New York. pp: 208-223.

Mondal, C., S. Sarkar and P. Hazra (2009). Line x Tester analysis of combining ability in tomato (*Lycopersicon esculentum* Mill.). *J. of Crop and Weed*, **5(1):** 53-57.

Patil, A.A and K.M. Bojappa (1986). Combining ability for certain quality traits in tomato (*Lycopersicon esculentum* Mill.). *Prog. Hort.,* **18:** 73-76.

Singh, B., S. Kaul., D. Kumar and V. Kumar (2010). Combining ability for yield and its contributing characters in tomato. *Indian J. of Hort.*, **67(1) :** 50-55.