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Combining Ability Analysis of Fruit Yield and Quality Traits in Tomato (*Solanum lycopersicum* L.)

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Abstract

Combining ability analysis is essentially required to isolate exceptional resource material for heterosis breeding programme. In this experiment combining ability of important agronomic and quality traits were estimated in 6 tomato parents and 30 crosses between them, in order to identify better parents with high combining ability and new recombinants with high yield and superior quality. The comparative heterosis analysis was also done using a commercially demanding variety Abhinav, as a standard check. The results indicated the involvement of both additive and non additive genetic effects in the expression of traits under study, however, preponderance of non-additive gene action was observed. The parents AVTO-2 and NTL-50 were the best performer for comprehensive parameters including yield and the cross combination AVTO-2 x JTL-08-15 was the best high-yielding combiner. The information and the genetic material generated in this study can be used in the future tomato hybrid breeding programme to develop new superior varieties.

Key words : Combining ability, tomato and heterosis.

Tomato is a versatile and one of the most important vegetable crops, commercially grown across the length and the breadth of the country. The rising popularity of a vegetarian diet and awareness of consumers about the importance in a balance diet have opened up huge market for vegetables both domestic and global front. Tomato is an important source of minerals and vitamins A and C (Hari, 1997). Several processed products like paste, puree, soup, sauces, juices, ketchup, drinks, whole peeled tomatoes etc., are prepared on large scale and high acceptance as food ingredients have great demand for export (Singh et al., 2004). As tomato is an important raw material for multimillion food industries, to meet the ever increasing demand there is a need for development of improved genotypes best for higher yield and good nutritional quality. Developing ideal inbred line is an essential criterion to utilize heterosis for the improvement of yield and quality traits in field crops including tomato (Luo *et al*., 2013; Memon *et al*., 2015; Liu *et al*., 2021). Isolating parents based on their ability to give superior hybrid combinations is essential to obtain desired results in crop improvement programme (Golabadi *et al*., 2015). Combining ability analysis of the genetic material can be utilized to identify and select ideal parents and superior crosses based on their general and specific combining abilities, respectively. Thus, we designed this experiment to screen parental materials with good general performance and to develop and screen cross combinations with required and desired percentage of heterosis in tomato crop.

Materials and Methods

The experimental material for the study comprised of thirty seven entries including six parents (NTL-1, AVTO-2, NTL-50, JTL-08-15, JTL-12-10 and NTL-36), their 30 F_1s derived by crossing in all possible combinations including reciprocals and one standard check Abhinav, was laid out in a randomized block design with

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three replications at Navsari Agricultural University, Navsari-396450 (Gujarat). Each entry was sown in a single row plot of ten plants, spaced 90 x 45 cm. All the recommended agronomic practices and plant protection measures were adopted as and when required for raising a healthy crop. Five healthy plants were selected randomly to record the data on proposed characters. The combining ability analysis was done by following Model 1, Method 2 of Griffing (1956).

Results and Discussion

In the present investigation, analysis of variance for combining ability (Table 1) revealed that both GCA and SCA variances were highly significant for majority of the trais studied, further mean sum of squares for reciprocal were also found significant for all the characters except seed germination per cent, plant spread (East-West), plant spread (North-South), shelf life, acid : sugar ratio and pulp : skin ratio suggested that the importance of reciprocal cross differences for the said characters. Similar results were also reported by Chishti et al. (2008), Singh and Asati (2011), Yadav et al. (2013) and Amaefula et al. (2014) for fruit yield and other traits. This shows that both additive and non-additive variances were role to play in the expression of traits. Variance due to GCA was significant for all the characters except seed germination per cent, plant spread East-West, shelf life, acid : sugar ratio and pulp : skin ratio. Similarly, the SCA variance was also significant

Table 1. Analysis of variance for combining ability in respect of 18 characters of tomato

Source of variation	DF	Seed germination (%)	Plant spread East-West (cm)	Plant spread North-South (cm)	No. of branches plant^{-1}	Days to 50% flowering	Days to first fruit harvest
GCA	5	21.14	11.42	57.61**	1.55**	35.72**	15.46**
SCA	15	12.32	18.90	14.66	1.43**	8.77**	12.46**
Error	70	9.95	29.25	17.00	0.18	3.50	4.60
σ2 GCA/σ2 SCA		0.39	0.14	-1.44	0.09	0.51	0.11
Source of variation	**DF**	**No. of locules**	**Shelf life (days)**	**Lycopene content (mg 100^{-1} gm)**	**Acid: Sugar ratio**	**pH of fruit**	**Pericarp thickness (mm)**
GCA	5	0.35**	0.16	15.47**	7.46	297.97**	0.38**
SCA	15	0.55**	0.31	4.31**	4.37	655.86**	0.29**
Error	70	0.01	0.20	0.00	3.52	19.55	0.10
σ2 GCA/σ2 SCA		0.05	-0.03	0.29	0.38	0.03	0.12
Source of variation	**DF**	**Pulp : Skin ratio**	**TSS (°Brix)**	**Fruit length (cm)**	**Fruit girth (cm)**	**Av. fruit weight (g)**	**Marketable fruit yield plant^{-1} (kg)**
GCA	5	0.84	0.68**	0.13**	0.43**	112.89**	1.37**
SCA	15	4.22	0.21**	0.31**	0.18**	120.98**	0.60**
Error	70	2.75	0.00	0.02	0.01	12.09	0.02
σ2 GCA/σ2 SCA		-0.10	0.26	0.03	0.20	0.07	0.19

**, * Significant at 1% and 5% respectively for all the traits except seed germination per cent, plant spread East-West, plant spread North-South, shelf life, acid : sugar ratio and pulp : skin ratio. The GCA variance and SCA variance ratio indicated that non-additive gene action was predominant for inheritance of all the traits.

The estimates of Va (additive) and Vd (non additive) variances were revealed that the additive variance was pre-dominant for the character plant spread (North-south). These types of findings were also reported by (Ghosh and Shyamal, 1994). Preponderance of non-additive type of variance was observed in seed germination per cent, plant spread (East-West), number of branches per plant, days to fifty per cent flowering, days to first fruit harvest, number of locules, shelf life, lycopene content, acid : sugar ratio, pH of fruit, pericarp thickness, pulp : skin ratio, TSS, fruit length, fruit girth, fruit weight, marketable fruitst and marketable fruit yield. These types of findings also reported by Pandey *et al*. (2006), Seeja *et al*. (2006), Rattan and Chadha (2009) and Sharma and Sharma (2010).

An overall appraisal of GCA effects (Table 2) revealed that AVTO-2 was found to be best general combiner for most of the traits. It was also good general combiners for quality parameters (TSS, pH, lycopene content and acid : sugar ratio) and yield attributing traits (fruit girth, average fruit weight and number of marketable fruits per plant) and that was resulted in yield too. The GCA effects of the other parents, in general, were found to be inconsistent for most of the characters but, in view of yield attributing and yield point, the parent NTL-50 for fruit girth, average fruit weight and number of fruits plant^{-1}; whereas, NTL-1 for number of fruits plant^{-1} only. In case of fruit quality, parent NTL-50 for TSS and lycopene content while, NTL-1 for pericarp thickness, total soluble solids, pH and lycopene content. On the contrary, parents *viz*., JTL-12-10 and NTL-36 were proved to be poor general combiners for majority of the traits under studied.

Table 2. Estimates of general combining ability (GCA) effects of parents in tomato

Parents / Characters	NTL-1	AVTO-2	NTL-50	JTL-08-15	JTL-12-10	NTL-36
Seed germination (per cent)	0.01	1.78*	-0.65	-2.04*	-0.09	1.00
Plant spread East-West (cm)	0.15	0.97	-1.37	-0.52	1.19	-0.41
Plant spread North-South (cm)	1.16	1.90	-0.33	-2.94**	-2.15	2.37*
Number of branches plant^{-1}	-0.08	-0.54**	-0.12	-0.04	0.37**	0.42**
Days to fifty per cent flowering	0.05	2.44**	1.22*	-1.30*	-2.38**	-0.02
Days to first fruit harvest	-0.58	1.27*	1.37*	-0.36	-1.56**	-0.14
Number of locules fruit^{-1}	0.02	0.18**	0.21**	-0.18**	-0.09*	-0.15**
Shelf life (days)	-0.05	0.01	0.14	0.09	-0.18	-0.00
Lycopene content (mg 100^{-1} gm)	0.22**	1.38**	0.85**	-1.73**	0.12**	-0.85**
Acid : Sugar ratio	0.01	1.05*	-0.39	-1.21*	-0.05	0.59
pH of fruit	3.99**	6.57**	-5.45**	0.10	-5.89**	0.68
Pericarp thickness (mm)	0.29**	-0.12	-0.11	-0.05	0.13	-0.14
Pulp : Skin ratio	0.16	0.26	-0.13	-0.15	-0.38	0.24
TSS (°Brix)	0.27**	0.19**	0.12**	-0.14**	-0.34**	-0.10**
Fruit length (cm)	0.05	0.04	-0.02	0.06	-0.20**	0.05
Fruit girth (cm)	-0.13**	0.25**	0.18**	-0.22**	-0.11**	0.03
Average fruit weight (g)	-3.00**	4.94**	2.07*	-0.24	-2.91**	-0.85
Number of marketable fruits plant^{-1}	2.72**	3.07**	1.77*	0.12	-4.85**	-2.84**
Marketable fruit yield plant^{-1} (kg)	0.03	0.50**	0.16**	0.01	-0.49**	-0.22**

The estimates of GCA effects further revealed that the parental line showing high GCA effects for marketable fruit yield per plant also exhibited high or average GCA effects for one or more yield components. The highest GCA effects for marketable fruit yield per plant in AVTO-2 and NTL-50 were linked with positive significantly higher GCA effects for number of marketable fruits per plant, average fruit weight, total soluble solid and fruit girth. Almost identical results have been reported by Brar *et al*. (2005), Ahmad *et al*. (2009) and Mali and Patel (2014).

In case of specific combining ability effects none of the hybrids exhibited favourable SCA effect for all the characters. These results are getting support from the findings of Brar et al. (2005), Ahmad *et al*. (2009), Yadav *et al*. (2013) and Amaefula *et al*. (2014). Among all the thirty hybrids, top specific combinations for marketable fruit yield per plant were AVTO-2 x JTL-08-15, JTL-08-15 x AVTO-2, NTL-36 x JTL-12-10, and NTL-1 x JTL-08-15 (Table 3). The best specific combination i.e. AVTO-2 x JTL-08-15 recorded desirable SCA effect for average fruit weight, number of marketable fruits per plant, number of locules, lycopene content and pH of fruit. The second best combination i.e. JTL-08-15 x AVTO-2 showed the desirable SCA effect for average fruit weight, number of marketable fruits plant^{-1}, lycopene content and total soluble solids. NTL-36 x JTL-12-10, the third best cross combination had recorded desirable SCA effect for number of marketable fruits plant^{-1} and total soluble solids. The fourth cross combination i.e. NTL-1 x JTL-08-15 had desirable significant SCA effect for fruit girth, average fruit weight, no. of branches plant^{-1}, lycopene content and total soluble solids.

Eleven out of thirty crosses were having superior and significant SCA effect for marketable fruit yield per plant. The highest per se was noted by the cross AVTO-2 x JTL-08-15, followed by NTL-1 X JTL-08-15, it was interesting to note that per se performance of hybrids for various traits was not correlated with their SCA effects. Out of top four crosses none of the cross have shown good x good GCA effect for marketable fruit yield per plant. AVTO-2 x JTL-08-15 and JTL-08-15 x AVTO-2, have involved one good and one average parents with GCA effect for marketable fruit yield per plant. The crosses showing high sca effects involving one good general combiner indicated additive x dominance type of gene interaction which could produce desirable transgressive segregants in subsequent generations. While the cross combination NTL-1 x JTL-08-15 have shown the combination of Average x Average parents and on the other hand the cross NTL-36 x JTL-12-10 have the combination of two poor parents, indicated the presence of over-dominance or epistasis which remain responsible for its highly significant SCA effect. The approach towards biparental mating leading to more segregation and recombination can give the desirable result for such crosses.

On the basis of combining ability the most promising parents for yield attributing traits were AVTO-2 and NTL-1 the most promising hybrids

Table 3. Top specific combinations for Marketable fruit yield per plant and their performance for other traits

Cross	Per se performance	SCA effect	GCA effect	Other traits showing desirable SCA effect
AVTO-2 x JTL-08-15	5.48	1.02 **	G x A	AFW, NMFP, MFYP, LC, NOL, pH
JTL-08-15 x AVTO-2	3.43	0.85**	A x G	AFW, NMFP, MFYP, LC, TSS,
NTL-36 x JTL-12-10	2.39	0.72**	P x P	NMFP, MFYP,TSS
NTL-1 x JTL-08-15	4.48	0.67**	A x A	FG, AFW, MFYP, NBPP, LC, TSS

were AVTO-2 x JTL-08-15, JTL-08-15 x AVTO-2, NTL-36 x JTL-12-10, and NTL-1 x JTL-08-15 these crosses could be exploited fully in future tomato breeding programme by adopting appropriate breeding technique for getting desirable recombinants from the segregating population in order to evolve high yielding hybrids of tomato. It was also observed that the significant SCA of the crosses for marketable fruit yield was largely depend on their SCA effect for componential characters like average fruit weight and number of marketable fruits per plant. So the approaches that can exploit both the additive and non additive gene effect simultaneously can be used effectively to obtain maximum yield and mating of selected plants in early segregating generations could help in developing desirable gene combinations for high yielding lines.

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References

Ahmad, S., Quamruzzaman, A. K. M. and Uddin, M. N. 2009. Combining ability estimates of tomato (*Solanum lycopersicum* L.) in late summer. SAARC J. Agri., 7(1): 43-56.

Amaefula C., Christian U. and Godson, E. N. 2014. Hybrid vigour and genetic control of some quantitative traits of tomato (*Solanum lycopersicum* L.). Open J. of Genetics, 4: 30-39.

Brar, P. S., Singh, M. and Gupta, R. K. 2005. Combining ability study in tomato under high temperature conditions. Haryana J. Hort. Sci., 34(1-2): 107-108.

Chishti, S. A. S., Khan, A. A., Sadia, B. and Khan, I. A. 2008. Analysis of combining ability for yield, yield components and quality characters in Tomato. J. Agri. Res., 46(4): 325-331.

Ghosh, P. K. and Syamal, M. M. 1994. Diallel analysis for combining ability in tomato. South Indian Hort., 42(3): 204-205.

Golabadi, M., Golkar, P., Eghtedary, A. R. Combining ability analysis of fruit yield and morphological traits in greenhouse cucumber (*Cucumis sativus* L.). 2015. Can. J. Plant Sci. 95: 377-385.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci., 9: 463-493.

Hari, H. R. 1997. Vegetable breeding principles and practices, Kalyani Publ. India.

Liu, Z., Jiang, J., Ren, A., Xu, X., Zhang, H., Zhao, T., Jiang, X., Sun, Y., Li, J. and Yang, H. 2021. Heterosis and combining ability analysis of fruit yield, early maturity, and quality in tomato. Agronomy, 11: 807. https://doi.org/10.3390/agronomy 11040807.

Luo, D., Xu, H., Liu, Z., Guo, J., Li, H., Chen, L., Fang, C., Zhang, Q., Bai, M. and Yao, N.A. 2013. Detrimental mitochondrial-nuclear interaction causes cytoplasmic male sterility in rice. Nat. Genet., 45: 573-577.

Mali, B. and Patel, A. I. 2014. Heterosis study in Tomato (*Lycopersicon esculentum* Mill.). Trends in Biosci., 7(4): 250-253.

Memon, S., Baloch, M.J., Baloch, G. M., Jatoi, W. A. 2015. Combining ability through line × tester analysis for phenological, seed yield, and oil traits in sunflower (*Helianthus annuus* L.). Euphytica, 204: 199-209.

Pandey, S. K., Dixit, J., Pathak, V. N. and Singh, P. K. 2006. Line x tester analysis for yield and quality characters in tomato. Veg. Sci., 33(1): 13-17.

Rattan, P. and Chadha, S. 2009. Gene action for yield & its contributing characters. Biological Forum-An International J., 1(2): 8-10.

Seeja, G., Chandramony, D. and Saraswathy, P. 2006. Gene action studies of yield and yield components in intervarietal hybrids of tomato (*Lycopersicon esculentum* Mill.). Indian J. Agric. Res., 40(4): 306-309.

Sharma, D. and Sharma, H. R. 2010. Combining ability analysis for yield and other horticultural traits in tomato. Indian J. Hort., 67(3): 402-405.

Singh, A. K. and Asati, B. S. 2011. Combining ability and heterosis studies in tomato under bacterial wilt condition. Bangladesh J. Agril. Res., 36(2): 313-318.

Singh, N. P., Bharadwaj, A. K., Kumar, A. and Singh, K. M. 2004. Modern technology on vegetable production. Int. Book Distributing Co. Lucknow, pp. 84-98.

Yadav, S. K., Singh, B. K., Baranwal, D. K. and Solankey, S. S. 2013. Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum* L.). Glob. J. C., Soil Sci. and Plant Breed., 1(1): 59-65.