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Development of superior F_1 hybrids for commercial exploitation in tomato, *Solanum lycopersicum* L

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ABSTRACT

Heterosis for yield and quality in tomato was studied through line × tester analysis of 24 F_1 hybrids derived by crossing eight lines namely EC-165749, EC-157568, EC-164838, EC-163611, LE-53, LE-56, LE-62 and LE-64 with three testers (Arka Alok, Arka Meghali and Arka Vikas). The resultant 24 F_1s were evaluated along with their parents and two standard checks (Lakshmi and US-618) for yield and quality characters. Studies on heterosis revealed that majority of the hybrids exhibited relative heterosis, heterobeltiosis, standard heterosis in desirable direction. The hybrids exhibited high per se performance and also showed high standard heterosis. The cross LE-62 × Arka Vikas registered high negative standard heterosis (ie for earliness) for days to 50 per cent flowering. The potential crosses like LE-64 × Arka Vikas, LE-53 × Arka Alok, LE-53 × Arka Meghali, LE-64 × Arka Meghali and LE-62 × Arka Alok exhibited high standard heterosis and high per se performance for yield per plant which offers scope of commercial exploitation through heterosis breeding. Among promising hybrids for yield per plant the crosses LE-53 × Arka Alok for TSS and titrable acidity, LE-53 × Arka Meghali for titrable acidity and lycopene content and LE-64 × Arka Meghali for titrable acidity and ascorbic acid showed significant standard heterosis. Hence these are appreciable for processing purpose.

Keywords: Heterosis; quality; tomato; yield

INTRODUCTION

Tomato (*Solanum lycopersicum* 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. Of the various genetic approaches to break the yield barriers in tomato heterosis breeding is the most powerful one. Exploitation of heterosis is a quick and convenient way of combining desirable characters to develop hybrids with high yield potential, earliness and quality characters. Heterotic crosses are indicative of productive transgressive segregates. The extent of heterosis gives an idea of genetic control and may help in deciding whether the hybrids are of economic value and worthy for exploitation. A considerable degree of heterosis has been documented and utilized in tomato for various characters ever since the first official report by Hedrick and Booth (1907). Though tomato is a self pollinated crop in which degree of heterosis was theoretically considered less however unusual high heterosis was observed in tomato. Hence the present study was carried out to facilitate the selection of promising cross combinations and to work out magnitude of exploitable heterosis for yield and certain quality traits.

MATERIAL and METHODS

Eight lines EC-165749, EC-157568, EC-164838, EC-163611, LE-53, LE-56, LE-62 and LE-64 and three testers viz Arka Alok, Arka Meghali and Arka Vikas were crossed in Line × Tester mating design during 2009 Rabi. The resulting 24 F_1s along with 11 parents and commercial checks (Lakshmi and US-618) were evaluated in Randomized Block Design with 3 replications at Vegetable Research Station, Rajendranagar, Hyderabad, AP during Kharif and Rabi 2010. Observations were recorded from 10 randomly selected plants for yield and yield contributing and quality characters. The statistical analysis was carried out using the model of Line × Tester developed by Kempthorne (1957). The magnitude of heterosis was estimated for yield and yield contributing and quality characters in 24 F_1s and expressed as increase or decrease over mid parent value (Relative heterosis, h_1) over better parent (heterobeltiosis, h_2) and over best commercial check US-618 (Standard heterosis, h_3) for different characters.

RESULTS and DISCUSSION

Heterosis is expressed as per cent increase of F_1 hybrid over the mid parent value that is the average value of both the parents. In majority cases of practical plant breeding the superiority of F_1 over mid parent is of no use since it does not offer the hybrid any advantage over the better parent. Therefore heterosis is estimated over the better parent which is often called as heterobeltiosis. In many cases the superior parent of hybrid may be inferior to the best commercial variety or hybrid. In such cases it will be desirable to estimate heterosis in relation to the best commercial variety or F_1 hybrid of the crop. Such an estimate is known as standard heterosis or useful or economic heterosis.

The pooled results obtained in the present study (Kharif and Rabi 2010) pertaining to heterotic behaviour, ANOVA and per se performance for yield and yield components and quality characters are discussed hereunder. The analysis of variance (Table 1) reveals that the treatments (parents and crosses) and parents alone showed significant differences for the characters studied indicating great deal of diversity among them. Line and testers exhibited significant difference for all the characters but testers with exception to plant height, pericarp thickness, TSS and titrable acidity. Variance due to parents vs crosses was also highly significant for all characters except fruit length, TSS and titrable acidity. It clearly indicates expression of certain measure of heterosis was contributed by all selected parents in the crosses.

The range per se performance and relative heterosis (h_1), heterobeltiosis (h_2) and standard heterosis (h_3) were found to be highly variable among different crosses for all characters in the present study (Table 2). Overall performance of superior crosses based on per se performance and heterosis (h_1, h_2 and h_3) for all characters is presented in Table 3. With regard to days to 50 per cent flowering heterosis in negative direction is considered as desirable since earliness is preferred over late flowering in different situations. The cross LE-62 × Arka Vikas registered highest standard heterosis for days to 50 per cent flowering (-10.64%) and number of primary branches per plant (38.22%). Out of 24 only 4 and 11 crosses registered significant standard heterosis for respective characters. Similar results were obtained by Padma et al (2002) for days to 50 per cent flowering and Dharmatti (1995) for number of primary branches per plant. The crosses LE-53 × Arka Alok (25.66%) and EC-164838 × Arka Alok (92.86%) recorded highest standard heterosis for number of flowers per cluster and number of fruits per cluster respectively. Ten and 19 crosses out of 24 exhibited positive and significant standard heterosis for respective characters. Similarly significant positive standard heterosis for these characters was reported by Patil (1997).

The cross LE-64 × Arka Alok for fruit length (13.70%) and average fruit weight (29.22%) recorded highest significant standard heterosis respectively. None of the crosses recorded significantly positive standard heterosis and heterobeltiosis for fruit width but LE-64 × Arka Alok (7.78%) recorded highest relative heterosis. Out of 24 crosses 4 and 13 crosses recorded positively significant standard heterosis for fruit length and average fruit weight respectively. These results are in accordance with the findings of Padma et al (2002) for fruit length, Kumar et al (2006) for fruit width and Kulakarni (1999) for average fruit weight. The less number of locules per fruit indicates the fruit firmness in tomato (Dundi and Madalageri 1991). Hence negative standard heterosis is considered as desirable. Pericarp thickness is a desirable attribute as it imparts fruit firmness and such fruits are suitable for long distance transport,

Table 1a: ANOVA for yield, yield contributing and quality characters in tomato

Source	Mean Sum of Squares								
	df	Plant height (cm)	# of primary branches/ plant	Days to 50% flowering	# of flowers / cluster	# of fruits/ cluster	Fruit length (cm)	Fruit width (cm)	Average fruit weight (g)
Replications	2	294.672	2.482**	0.102	0.107	0.132	0.285*	0.011	12.632*
Treatments	34	1776.575**	5.001**	12.525**	0.691**	0.801**	1.227**	1.580**	874.390**
Parents	10	1703.639**	7.705***	7.255**	0.945**	1.052**	1.975**	3.073**	810.407**
Parents (Line)	7	2388.785**	7.903**	4.929**	1.084**	0.575**	2.452**	1.430**	825.604**
Parents (Testers)	2	15.098	5.604**	19.000**	0.641**	0.754**	1.258**	1.924**	161.898**
Parents (L vs T)	1	284.700	10.525**	0.045	0.584*	4.980**	0.069	16.873**	2001.047**
Parents vs Crosses	1	3468.586**	14.887**	118.316**	0.515*	2.822**	0.012	2.488**	2119.157**
Error	68	108.324	0.259	0.629	0.128	0.078	0.086	0.030	2.616
Total	104	657.297	1.852	4.508	0.312	0.315	0.463	0.537	287.811

*Significant at 5 per cent level

**Significant at 1 per cent level

Table 1b: ANOVA for yield, yield contributing and quality characters in tomato

Source	Mean Sum of Squares								
	df	Yield per plant (kg)	# of locules per fruit	Pericarp thickness (mm)	TSS (^{0}Brix)	Titrable acidity (%)	Vit C (mg/ 100g)	Lycopene (mg/100 g)	Shelf life (days)
Replications	2	0.834**	0.384	0.002	0.001	0.026**	395.814**	0.051	0.849
Treatments	34	1.858**	1.981**	1.813**	0.506**	0.054**	141.109**	17.311**	7.463**
Parents	10	0.573**	4.539**	1.539**	0.402**	0.072**	150.142**	29.885**	5.073**
Parents (Line)	7	0.668**	4.102**	1.708**	0.529**	0.092**	187.613**	37.042**	5.143**
Parents (Testers)	2	0.374**	4.361**	0.081	0.068	0.013	56.444**	6.268**	7.000**
Parents (L vs T)	1	0.299**	7.960**	3.271**	0.179	0.050**	75.233**	27.025**	0.727
Parents vs Crosses	1	26.353**	0.485	10.703**	0.165	0.010	0.405**	4.639**	45.991**
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 per cent level
**Significant at 1 per cent level

Table 2. Range of per se performance, relative heterosis (h_1), heterobeltiosis (h_2) and standard heterosis of F_1s for yield and yield contributing and quality characters

Character	Per se performance	h_1 (%)	h_2 (%)	h_3 (%)
Plant height (cm)	58.3 to 153.63	-22.49 to 36.75	-41.40 to 33.21	- 34.07 to83.26
# of primary branches/plant	6.73 to 10.37	-25 to 30.53	-31.46 to 27.16	-10.22 to 38.22
Days to 50% flowering	28 to 35	-13.89 to 1.49	-16.22 to 1.96	-10.64 to 11.70
# of flowers/ cluster	4.57 to 6. 37	-6.23 to 24.49	- 18.13 to 20.39	-9.87 to 25.66
# of fruits/ clusters	1.97 to 3.60	5.63 to 71.76	-24.72 to 46.00	5.36 to 92.86
Fruit length (cm)	3.83 to 4.60	-15.97 to 25.28	-32.43 to 22.06	-31.51 to 13.70
Fruit width (cm)	4.43 to 6.43	-11.11 to 13.79	-28.23 to 2.96	- 28.49 to 3.76
Average fruit weight (g)	41.43 to 105. 53	-17.62 to 34.47	-36.48 to 23.38	-49.27 to 29.22
Yield/plant (kg)	1.6 to 3.90	-4.27 to 126.37	4. 35 to 101.72	-36.00 to 56.00
# of locules/ fruit	3.17 to 5.8	-35.73 to 42.31	-40.51 to 24.43	-29.63 to 28.89
Pericarp thickness (mm)	4.3 to 6.7	-6.52 to 42.05	-17.31 to 28.85	-28.33 to 11.67
TSS (^{0}Brix)	3.17 to 5	-10.53 to 20.16	-22.22 to 19.67	-25.20 to 18.11
Titrable acidity (%)	0.27 to 0.7	-55.56 to 72.73	-55.56 to 35.71	-33.33 to 75.00
Ascorbic acid (mg/100g)	14.67 to 40.0	-32.25 to 66.04	-40 to 62.96	-29.41 to 79.41
Lycopene (mg/100g)	2.53 to 8.73	-74.40 to 68.84	-78.41 to 15.38	-54.55 to 58.79
Shelf life (days)	7.87 to 12.00	-29.41 to 71.43	-33.33 to 50	-34.44 to 0.00

canning and also have better quality (Kalloo 1988). Hence positive standard heterosis was desirable. The cross LE-62 × Arka Vikas (-29.63%) for number of locules per fruit and EC-157568 × Arka Vikas (11.67%) for pericarp thickness registered significantly high standard heterosis. Above results are in conformity with the findings of Sharma et al (2006).

Majority of the crosses registered positive and significant heterosis for fruit yield per plant. Out of 24 crosses 21, 21 and 15 crosses exhibited positively significant relative heterosis, heterobeltiosis and standard heterosis respectively. In general the crosses viz LE-64 × Arka Vikas (56.00%), LE-53 × Arka Alok (53.33%), LE-53 × Arka Meghali and LE-64 × Arka Meghali (41.33%), LE-62 × Arka Alok (38.67%), EC-157568 × Arka vikas (37.33%), LE-53 × Arka Vikas and LE-56 × Arka Meghali (30.67%) were the outstanding crosses based on standard

Table 3. Overall performance of superior crosses based on per se performance and standard heterosis for six teen characters in tomato

Cross	Per se performance	Heterosis (%) h_1	h_2	h_3
Plant height (cm)				
EC-157568 × Arka Vikas	153.63	34.04**	16.92**	83.26**
EC-164838 × Arka Vikas	137.43	36.75**	33.21**	63.94**
EC-163611 × Arka Vikas	133.60	23.91**	13.41	59.36**
EC-163611 × Arka Meghali	132.57	22.54**	12.54	58.13**
LE-53 × Arka Meghali	124.57	26.96**	26.38**	48.59**
# of primary branches/plant				
LE-62 × Arka Vikas	10.37	19.16**	2.98	38.22**
LE-62 × Arka Meghali	7.23	30.53**	27.16** 3	1.11**
EC-164838 × Arka Alok	9.67	5.84	-8.81*	28.89**
EC-164838 × Arka Meghali	9.63	5.09	-9.12*	28.44**
EC-164838 × Arka Vikas	9.37	-9.35*	-11.64**	24.89**
Days to 50% flowering				
LE-62 × Arka Vikas	28.00	-13.85**	-15.15**	-10.64**
LE-62 × Arka Meghali	29.00	-13.43**	-14.71**	-7.45**
LE-56 × Arka Alok	30.67	-8.92**	-12.61**	3.19
EC-164838 × Arka Vikas	30.00	-7.69**	-9.09**	-4.26*
# of flowers/cluster				
LE-53 × Arka Alok	6.37	10.09*	7.30	25.66**
LE-64 × Arka Meghali	6.10	24.49*	20.39**	20.39**
EC-157568 × Arka Alok	6.03	2.84	-1.09	19.08**
EC-157568 × Arka Meghali	5.90	8.92	-3.28	16.45**
LE-56 × Arka Alok	5.87	0.28	-3.30	15.79**
# of fruits/cluster				
EC-164838 × Arka Alok	3.60	54.29**	38.46**	92.86**
LE-56 × Arka Vikas	3.57	71.20**	18.89*	91.07**

EC-163611 × Arka Alok	3.37	47.45**	34.67**	80.36**
LE-53 × Arka Alok	3.27	29.80**	10.11	75.00**
EC-164838 × Arka Vikas	3.10	64.60**	19.23*	66.07**
LE-62 × Arka Alok	3.10	22.37**	3.33	66.07**
Fruit length (cm)				
LE-64 × Arka Alok	5.53	25.28**	22.06**	13.70**
LE-53 × Arka Alok	5.53	- 9.29*	27.69**	13.70**
Fruit width (cm)				
LE-64 × Arka Meghali	6.43	4.61*	-7.66**	3.76
EC-157568 × Arka Meghali	6.27	5.92**	-10.05**	1.08
LE-64 × Arka Alok	6.23	7.78**	0.00	0.54
LE-53 × Arka Meghali	6.07	5.51*	-12.92**	-2.15
Average fruit weight (g)				
LE-64 × Arka Alok	105.53	34.47**	223.38**	29.22**
EC-165749 × Arka Alok	100.67	19.72**	17.69**	23.27**
LE-53 × Arka Alok	100.10	18.84**	17.03**	22.57**
LE-62 × Arka Alok	97.80	31.66*	14.34**	19.76**
LE-64 × Arka Meghali	90.40	19.29**	12.81**	10.69**
Yield per plant (kg)				
LE-64 × Arka Vikas	3.90	125.00**	101.72**	56.00**
LE-53 × Arka Alok	3.83	60.84**	51.32**	53.33**
LE-53 × Arka Meghali	3.53	63.08**	39.47**	41.33**
LE-64 × Arka Meghali	3.53	89.29**	82.76**	41.33**
LE-62 × Arka Alok	3.47	70.49**	55.22**	38.67**
EC-157568 × Arka Vikas	3.43	126.37**	123.91**	37.33**
LE-53 × Arka Vikas	3.27	60.66**	28.95**	30.67**
# of locules/fruit				
LE-62 × Arka Vikas	3.17	-7.32	-29.63**	-29.63**
EC-165749 × Arka Meghali	4.47	-35.75**	-40.51**	-14.07
EC-157568 × Arka Vikas	3.90	-15.52*	-17.61*	-13.33
Pericarp thickness (mm)				
EC-157568 × Arka Vikas	6.70	42.05**	28.85**	11.67**

LE-62 × Arka Meghali	6.47	30.64**	23.57**	7.78*
EC-165749 × Arka Alok	6.40	31.96**	16.36**	6.67
LE-62 × Arka Vikas	6.20	25.68**	19.23**	3.33
LE-64 × Arka Meghali	6.17	18.97**	17.83**	2.78
TSS (^{0}Brix)				
EC-163611 × Arka Vikas	5.00	11.94**	2.74	18.11**
EC-157568 × Arka Vikas	4.87	20.16**	19.67**	14.96**
LE-53 × Arka Alok	5.00	17.89**	12.40**	14.17**
Titrable acidity (%)				
EC-165749 × Arka Meghali	0.70	2.44	-8.70	75.00**
EC-165749 × Arka Alok	0.63	2.70	-17.39*	58.33**
EC-163611 × Arka Alok	0.63	72.75**	35.71**	58.33**
EC-163611 × Arka Vikas	0.63	58.33**	18.75	58.33**
Ascorbic acid (mg/100g)				
LE-56 × Arka Meghali	40.67	40.23**	1.67**	79.41**
LE-56 × Arka Alok	38.67	24.73**	-3.33**	70.59**
LE-56 × Arka Vikas	37.33	12.00**	-6.67**	64.71**
LE-62 × Arka Meghali	30.00	57.89**	50.00**	32.35**
LE-64 × Arka Meghali	29.33	66.04**	62.96**	29.41**
Lycopene (mg/100g)				
LE-62 × Arka Meghali	8.73	20.46**	13.42**	58.79**
LE-53 × Arka Vikas	8.53	48.41**	-6.23	55.15**
LE-62 × Arka Alok	8.20	16.04**	-6.23	49.09**
LE-56 × Arka Meghali	8.00	-13.67**	-31.82**	45.45**
EC-164838 × Arka Meghali	8.00	16.50**	15.38**	45.45**
LE-53 × Arka Meghali	7.77	68.84**	14.22**	41.21**
Shelf life (days)				
EC-163611 × Arka Alok	12.00	71.45**	50.00**	0.00
EC-157568 × Arka Alok	10.00	53.85**	42.86**	-16.67**
EC-165749 × Arka Alok	9.00	50.00**	50.00**	-25.00**
EC-164838 × Arka Alok	9.50	46.15**	35.71**	-20.83**

*Significant at 5 per cent level
**Significant at 1 per cent level

heterosis for fruit yield per plant. Hence these can be commercially exploited after assessing their stability. Similar results were also reported by Makesh et al (2002).

For fruit quality the crosses viz EC-163611 × Arka Vikas (18.11%), EC-165749 × Arka Meghali (75%), LE-56 × Arka Meghali (79.41%) and LE-62 × Arka Meghali (58.79%) exhibited highest standard heterosis for TSS, titrable acidity, ascorbic acid and lycopenerespectively. Hence these are suitable for quality improvement through heterosis breeding. Similar results were also reported by Makesh et al (2002) for TSS, ascorbic acid

Table 4. Promising hybrids showing higher per se performance and standard heterosis for yield/plant and significant standard heterosis for other characters

Cross combination	Yield per plant (kg)	Standard heterosis (%)	Heterosis for other characters
LE-64 × Arka Vikas	3.90	56.00**	# of flowers/cluster, # of fruits/ cluster and average fruit weight
LE-53 × Arka Alok	3.83	53.33**	# of flowers/cluster, # of fruits/ cluster, average fruit weight, fruit length, TSS and titrable acidity
LE-53 × Arka Meghali	3.53	41.33**	Plant height, # fruits/cluster, average fruit weight, titrable acidity and lycopene
LE- 64 × Arka Meghali	3.53	41.33**	Plant height, # of flowers/ cluster, # of fruits/cluster, average fruit weight, titrable acidity and ascorbic acid
LE-62 × Arka Alok	3.47	38.67**	# of primary branches/plant, # of fruits/cluster, # of flowers/cluster, average fruit weight and lycopene
EC-157568 × Arka Vikas	3.43	37.33**	Plant height, pericarp thickness and TSS

** significant at 1 per cent level

and titrable acidity and Kumar et al (2006) and Bhatt et al (2004) for lycopene. The cross EC-163611 × Arka Alok exhibited highest significant positive heterobeltiosis (50%) for shelf life of the fruit. Heterobeltiosis in positive and negative direction was observed in certain crosses and it is in accordance with work of Joshi and Thakur (2004).

None of the cross combinations was heterotic for all characters simultaneously. In this study (Table 4) promising hybrids for yield per plant with positive and significant standard heterosis also revealed heterosis for other traits viz number of flowers per cluster, number of fruits per cluster, average fruit weight and plant height. Hence high heterosis for yield appears to be the consequence of heterosis of these yield attributing traits.

Among promising hybrids for yield per plant the crosses LE-53 × Arka Alok for TSS and titrable acidity, LE-53 × Arka Meghali for titrable acidity and lycopene content and LE-64 × Arka Meghali for titrable acidity and ascorbic acid showed significant standard heterosis. These are appreciable for processing purpose (Table 4).

In the present study hybrids exhibiting high per se performance also showed high heterotic performance over the commercial checks (Table 3) implying the role of heterosis for selection of best cross combination coupled with significant sca effects for the corresponding character.

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