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Heterosis and combining ability studies for shelf life and related traits in tomato (*Lycopersicon esculentum* Mill.)

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Abstract

Shelf life is a major quality attribute, mainly dependent on fruit firmness. The analysis of variance showed significant differences for the trait among parents as well as in hybrids. Among the parents, AI-9 had the highest shelf life, whereas, among the crosses, the maximum shelf life was noted in AI-9 x Solan Vajr. The highest heterobeltiotic effect was observed in the cross UHF-656 x UHF-659. The parents AI-9, EC-15998, UHF-659 and FT-5 were identified as good general combiners for fruit firmness. The Vg/Vs ratio revealed that non-additive gene action held a prominent position for fruit firmness, pericarp thickness, polygalacturonase activity and shelf life while number of locules per fruit had shown additive type of gene action.

Key words: Tomato (*Lycopersicon esculentum* Mill.), heterobeltiosis, combining ability, shelf life.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the major vegetable crops grown both for fresh market and processing. Shelf life is an important trait in a country like India because more than 30 per cent of the produce goes waste during post-harvest handling. Longer storability also helps to avoid over-supply and enables grower to wait for remunerative market price and bear transportation shock better. This character is controlled by genetic factors as well as climatic factors such as temperature. Traits like thick pericarp, fewer locules, high fruit firmness and lesser polygalacturonase (PG) activity are known to be positively correlated with shelf life (Prabhushanker, 1990). However, pericarp thickness alone accounts for 64 per cent of fruit firmness (Ahrens *et al.*, 1987). It implies that the basic need for higher shelf life is the development of firm fruited tomato. So, the present experiment was conducted to identify such parental lines that may be the source material to produce superior hybrid combinations having longer shelf life in tomato.

Material and Methods

In summer 2002, thirty diverse lines of tomato were evaluated for their mean performance and ten lines viz., EC-15998, AI-9, EC-174023, FT-5, Solan Vajr, UHF-656, UHF-553, UHF-659, UHF-612 and UHF-663 were selected and crossed in a diallel fashion excluding reciprocals, to obtain forty five hybrid combinations. The F_1's were evaluated along with parents for shelf life and its related traits. The experiment was laid out according to Randomized Block Design (RBD) with three replications. Eighteen plants of each entry were transplanted at a recommended spacing of 90 cm x 30 cm. Observations were recorded on number of locules per fruit, pericarp thickness, whole fruit firmness, shelf life and polygalacturonase activity of tomato. The whole fruit firmness was determined by the use of a penetrometer. For estimation of shelf life, vine ripe tomato fruits were kept at room temperature (27±2°C) and their firmness was recorded at the time of harvest and subsequently after three days interval till it was more than 500 g/0.503 cm^2. Fruits having firmness below 500 g/0.503 cm^2 were considered unmarketable.

The polygalacturonase (PG) activity of freshly harvested vine ripe tomato fruits was determined as per the method given by Jansen and MacDonnel (1945) and the activity was expressed in PGU. Where, 1 PGU represents 1000 µg of reducing groups liberated per minute per ml of juice. Combining ability variance and effects were worked out by Kempthorne (1957). Heterobeltiotic effect was also estimated.

Results and Discussion

Analysis of variance revealed significant variation among genotypes for all the traits implying a considerable variability.

The combining ability analysis revealed the importance of both additive and non-additive gene action for all these traits. However the ratio of Vg/Vs was less than unity revealed that non-additive gene action held a prominent position for fruit firmness, pericarp thickness, shelf life and polygalacturonase activity whereas number of locules per fruit showed additive type of gene action (Table 1).

Table 1. Analysis of variance for combining ability and genetic components of variation for shelf life and its related traits

Source of variation	d.f.	Mean sum of squares				
		Pericarp thickness (mm)	Fruit firmness (g/0.503 cm^2)	Number of locules per fruit	Polygala-cturonase activity (PGU)	Shelf life (days)
Gca	9	2.592*	105893.88*	0.298*	1982.97*	24.11*
Sca	45	0.569*	14999.21*	0.028*	580.29*	9.01*
Error	108	0.006	2034.11	0.002	1.41	1.33
Genetic components of variation						
V_g		0.22	8654.98	0.027	165.13	1.89
V_s		0.56	12965.10	0.026	578.88	7.68
V_g/V_s		0.39	0.67	1.030	0.29	0.25
V_A		0.44	17309.96	0.052	330.26	3.78
V_D		0.56	12965.10	0.026	578.88	7.68
V_A/V_D		0.78	1.34	2.000	0.57	0.49

*Significant at 5% level

The parents AI-9, EC-15998, UHF-659 and FT-5 were identified as good general combiners for fruit firmness. For low polygalacturonase activity, the parents AI-9, UHF-663 and EC-15998 were identified as good general combiners. The parents FT-5, UHF-663, Solan Vajr and AI-9 were observed to be good general combiners for pericarp thickness. The parents FT-5, AI-9 and UHF-659 were good general combiners for longer shelf life. So these parents can be used to improve the shelf life of tomato (Table 2).

The highest significant positive sca estimates was observed in cross combination EC-15998 x AI-9 for the traits pericarp thickness, fruit firmness and shelf life except number of locules per fruit and PG activity (Table 3). Pericarp thickness is a primary character contributing towards the whole fruit firmness and shelf life (Ahrens *et al.*, 1987). Thickest pericarp among the parents was observed in Solan Vajr, followed by FT-5 and UHF-656, while among the crosses EC-15998 x AI-9, FT-5 x UHF-656 and FT-5 x Solan Vajr exhibited thickest pericarp (Table 4).

Table 2. Estimates of general combining ability effects of parents for shelf life and its related traits

Parents	Pericarp thickness (mm)	Fruit firmness (g/0.503 cm^2)	No. of locules/ fruit	Polygala-cturonase activity (PGU)	Shelf life (days)
EC-15998	0.03	70.03*	-0.09*	-3.61*	-0.84*
AI-9	0.19*	157.33*	-0.19*	-18.79*	2.18*
EC-174023	-0.72*	-111.02*	0.20*	4.41*	-1.82*
FT-5	0.69*	34.13*	-0.14*	-3.30*	2.41*
Solan Vajr	0.34*	20.36	-0.17*	10.97*	-0.51
UHF-656	-0.26*	10.25	-0.02	3.94*	-0.43
UHF-553	-0.47*	-111.34*	0.03	25.03*	-1.32*
UHF-659	-0.11*	82.78*	0.17*	-1.15*	0.88*
UHF-612	-0.32*	-125.62*	0.14*	0.58	-0.73*
UHF-663	0.63*	-26.89*	0.05*	-18.09*	0.18
SE(gi)±	0.02	12.35	0.02	0.33	0.32
SE(gi-gj)±	0.03	18.41	0.03	0.48	0.47

* Significant at 5% level

Table 3. Estimates of specific combining ability effects of cross combinations for shelf life and its related traits

Crosses	Pericarp thickness (mm)	Fruit firmness (g/0.503 cm^2)	Number of locules per fruit	Polygalacturonase activity (PGU)	Shelf life (days)
EC-15998 x AI-9	1.37*	218.19*	-0.49*	-34.63*	6.04*
EC-15998 x EC-174023	0.02	174.53*	0.12*	-48.22*	3.04*
EC-15998 x FT-5	-0.70*	-33.64	-0.10	-15.57*	-4.18*
EC-15998 x Solan Vajr	-0.27*	-183.77*	0.54*	24.95*	-3.26*
EC-15998 x UHF-656	0.03	-36.74	0.26	2.17	-2.68*
EC-15998 x UHF-553	-0.42*	-19.21	-0.45*	29.07*	-1.46
EC-15998 x UHF-659	-0.31*	108.71*	-0.03	11.52*	-2.65*
EC-15998 x UHF-612	-0.69*	-111.99*	0.51*	-22.58*	2.96*
EC-15998 x UHF-663	0.50*	-154.60*	-0.21*	21.67*	-1.96
AI-9 x EC-174023	-0.41*	109.38*	-0.16*	-21.93*	-0.98
AI-9 x FT-5	0.63*	110.06*	-0.38*	-16.16*	3.79*
AI-9 x Solan Vajr	-0.14*	167.83*	-0.42*	-20.46*	-1.29
AI-9 x UHF-656	-0.53*	-36.24	0.67*	38.89*	-4.37*
AI-9 x UHF-553	-0.92*	-175.70*	0.05	38.68*	-2.48*
AI-9 x UHF-659	0.24*	-196.56*	-0.40*	-7.84*	-3.68*
AI-9 x UHF-612	0.17*	-53.19	-0.54*	18.16*	-4.07*
AI-9 x UHF-663	-0.34*	-71.09	0.03	15.30*	0.02
EC-174023 x FT-5	-1.14*	-133.52*	0.37*	10.66*	-2.21*
EC-174023 x Solan Vajr	-0.84*	45.30	0.21*	0.69	-0.29
EC-174023 x UHF-656	-0.58*	-64.64	0.21*	6.04*	-0.37
EC-174023 x UHF-553	0.64	-106.21*	0.09	23.26*	-0.48
EC-174023 x UHF-659	-0.61*	31.15	0.15*	-14.73*	1.32
EC-174023 x UHF-612	0.67*	-71.84	0.16*	-9.47*	-0.07
EC-174023 x UHF-663	0.09	-7.57	0.12*	14.95*	0.02
FT-5 x Solan Vajr	0.98	217.68*	-0.02	-14.19*	3.49*
FT-5 x UHF-656	1.17*	57.02	0.03	-25.31*	2.40*
FT-5 x UHF-553	-0.15*	-43.00	-0.09	-8.37*	-0.71
FT-5 x UHF-659	0.82*	-140.16*	0.33*	35.06*	-3.23*
FT-5 x UHF-612	0.51*	-149.91*	0.16*	40.26*	-4.29*
FT-5 x UHF-663	-0.90*	128.77*	-1.01*	19.75*	0.79
Solan Vajr x UHF-656	-0.95*	-104.93*	-0.13*	1.47	0.32
Solan Vajr x UHF-553	0.87*	-144.55	0.25*	15.53*	-1.79
Solan Vajr x UHF-659	0.60*	50.43	-0.37*	-22.09*	0.68
Solan Vajr x UHF-612	-0.14*	-8.05	-0.02	-12.97*	-0.37
Solan Vajr x UHF-663	-0.86*	56.38	-0.16*	-28.71*	1.71
UHF-656 x UHF-553	-0.10	-32.69	-0.30*	3.23*	0.13
UHF-656 x UHF-659	-0.12	155.52*	0.06	22.98*	5.93*
UHF-656 x UHF-612	0.78*	135.67*	-0.27*	-19.05*	2.54*
UHF-656 x UHF-663	0.69	19.31	0.00	4.30*	-2.37*
UHF-553 x UHF-659	0.98*	193.22*	0.42	25.11*	4.82*
UHF-553 x UHF-612	0.35*	178.40*	1.18*	-27.40*	1.43
UHF-553 x UHF-663	0.41*	-15.37	1.17*	-17.59*	-1.48
UHF-659 x UHF-612	-1.03*	-63.85	1.31*	28.16*	-1.76
UHF-659 x UHF-663	-1.05*	-10.52	-0.54*	8.37*	-0.68
UHF-612 x UHF-663	0.46*	-27.99	-0.15*	-1.95	-0.07
SE(sij)±	0.06	41.54	0.05	1.09	1.06
SE(sij-sik)±	0.10	61.07	0.07	1.61	1.57
SE(sij-skl)±	0.09	58.22	0.06	1.53	1.49

* Significant at 5% level

Table 4. Mean performance and heterobeltiosis for shelf life and its related traits

Traits	Pericarp thickness (mm)		Fruit firmness (g/0.503 cm^3)		Number of locules per fruit		Polygalacturonase activity (PGU)		Shelf life (days)	
Parents/ Crosses	Mean	Per cent heterobeltiosis	Mean	Per cent heterobeltiosis	Mean	Per cent heterobeltiosis	Mean	Per cent heterobeltiosis	Mean	Per cent heterobeltiosis
Parents										
EC-15998	5.92		1278.67		2.54		72.61		13.00	
AI-9	6.38		1397.71		2.72		20.73		21.00	
EC-174023	5.24		908.39		3.42		97.21		9.00	
FT-5	7.23		1180.51		2.98		49.34		20.00	
Solan Vajr	7.46		1111.46		2.78		116.71		12.00	
UHF-656	4.67		1043.40		3.17		87.52		11.00	
UHF-553	3.84		964.37		3.40		123.42		9.00	
UHF-659	5.63		1220.31		3.84		86.53		12.00	
UHF-612	4.43		889.53		2.87		73.59		13.00	
UHF-663	6.72		1106.45		3.38		23.38		15.00	
Crosses										
EC-15998 x AI-9	7.64	19.75*	1563.45	11.86*	2.93	15.35*	22.70	9.54	20.00	-4.76
EC-15998 x EC-174023	4.94	16.60*	1252.43	-2.05	3.09	21.65*	21.60	-70.26*	13.00	0.00
EC-15998 x FT-5	5.64	-22.04*	1189.42	-6.98	3.80	49.61*	46.54	-5.68	10.00	-50.00*
EC-15998 x Solan Vajr	5.71	-24.04*	1025.52	-19.08	3.53	39.11*	101.33	39.55*	8.00	-38.46*
EC-15998 x UHF-656	5.41	-8.61*	1162.44	-9.09	3.41	34.38*	71.53	-1.49	8.67	-33.33*
EC-15998 x UHF-553	4.76	-19.64*	1058.47	-17.22*	2.76	8.53*	119.51	64.59*	9.00	-30.77*
EC-15998 x UHF-659	5.70	-3.71	1380.41	7.96	3.30	30.05*	75.77	4.35	10.00	-23.08
EC-15998 x UHF-612	4.64	-21.72*	951.31	-25.60*	3.82	50.39*	43.41	-40.22*	14.00	7.69
EC-15998 x UHF-663	6.64	-1.19	1007.44	-21.21*	3.01	18.37*	68.28	192.00*	10.00	-33.33*
AI-9 x EC-174023	4.65	-27.10*	1274.59	-8.81	3.10	13.97*	33.42	61.24*	12.00	-42.86*
AI-9 x FT-5	7.11	-1.71	1420.40	1.62	2.70	-0.73	31.47	51.85*	21.00	0.00
AI-9 x Solan Vajr	7.00	-6.17*	1464.42	4.77	2.65	-2.57	30.50	47.12*	21.33	1.57
AI-9 x UHF-656	5.00	-21.72*	1250.29	-10.55	4.00	47.05*	93.77	352.41*	10.00	-52.38*
AI-9 x UHF-553	4.40	-31.02*	989.20	-29.23*	3.56	30.88*	114.65	453.15*	11.00	-47.62*
AI-9 x UHF-659	6.18	-3.13	1162.45	-16.83*	3.23	18.75*	41.95	102.38*	12.00	-42.86*
AI-9 x UHF-612	5.64	-11.59*	1097.42	-21.48*	3.02	11.02*	69.67	236.90*	10.00	-52.38*
AI-9 x UHF-663	6.57	-2.23	1178.26	-15.70	3.54	30.14*	47.44	128.90*	15.00	-28.57*
EC-174023 x FT-5	4.42	-38.82*	908.49b	-23.04*	3.30	10.73	80.78	63.73*	11.00	-45.00*
EC-174023 x Solan Vajr	4.37	-41.82*	1073.54	-3.41	2.98	7.19*	85.08	-12.48*	10.00	-16.67
EC-174023 x UHF-656	4.04	-22.95*	953.49	-8.62	3.42	7.88*	83.41	-4.69*	10.00	-9.09
EC-174023 x UHF-553	5.06	-3.56	790.34	-18.05*	3.50	2.33	121.71	25.20*	9.00	0.00
EC-174023 x UHF-659	4.17	-25.95*	1122.17	-8.04	3.91	14.32*	57.54	-35.50*	13.00	8.33
EC-174023 x UHF-612	5.23	-0.19	810.42	-10.79	3.69	28.57*	64.53	-12.31*	10.00	-23.08
EC-174023 x UHF-663	5.60	-16.63*	973.42	-12.02*	3.40	0.59	69.58	197.58*	11.00	-26.67*
FT-5 x Solan Vajr	7.25	-2.81	1391.06	17.84*	2.93	5.39	29.62	-39.96*	20.33	1.65
FT-5 x UHF-656	7.45	3.04*	1220.30	3.37	3.13	5.03	44.35	-10.11*	17.00	-15.00
FT-5 x UHF-553	5.68	-21.44*	998.70	-15.40*	3.08	3.24	82.37	66.95*	13.00	-35.00*
FT-5 x UHF-659	7.02	-2.90	1095.65	-7.19	3.62	21.34*	99.61	101.90*	12.67	-36.67*
FT-5 x UHF-612	6.48	-10.42*	877.49	-25.67*	3.42	19.03*	106.55	115.96*	10.00	-50.00*
FT-5 x UHF-663	6.03	-16.64*	1254.91	6.30	2.45	-17.75*	66.66	185.09*	16.00	-20.00*
Solan Vajr x UHF-656	4.73	-37.07*	1044.58	-6.02	2.93	5.39	85.40	-2.42	12.00	0.00
Solan Vajr x UHF-553	6.35	-15.57*	883.37b	-20.52*	3.39	21.82*	120.54	3.28*	9.00	-25.00
Solan Vajr x UHF-659	6.44	-14.32*	1272.47	4.27	2.88	3.60	56.74	-34.43*	12.67	13.89
Solan Vajr x UHF-612	5.48	-27.05*	1005.59	-9.53	3.21	15.47*	67.59	-8.16*	11.00	-15.38
Solan Vajr x UHF-663	5.71	-23.99*	1168.75	5.15	2.98	7.19*	32.48	38.89*	14.00	-6.67
UHF-656 x UHF-553	4.77	2.21	984.85	-5.61	2.98	-5.99*	101.22	15.65*	11.00	0.00
UHF-656 x UHF-659	5.48	-2.66	1367.46	12.06*	3.47	9.45*	38.33	-55.13*	19.00	58.33*
UHF-656 x UHF-612	5.80	24.20*	1139.20	9.18	3.11	8.35*	54.49	-25.96*	14.00	7.69
UHF-656 x UHF-663	6.91	2.82	1121.58	1.37	3.29	3.68	58.46	150.02*	10.00	-33.33*
UHF-553 x UHF-659	6.02	6.93*	1283.57	2.18	3.29	-3.23	57.77	-33.23*	18.00	50.00*
UHF-553 x UHF-612	5.16	16.55*	1089.34	12.96	3.63	26.33*	67.22	-8.66*	12.00	-7.69
UHF-553 x UHF-663	6.18	-8.03*	965.31	-12.76*	4.52	33.86*	47.66	103.84*	10.00	-33.33*
UHF-659 x UHF-612	4.14	-26.36*	1012.31	-17.05*	4.56	58.88*	96.59	31.25*	11.00	-15.38
UHF-659 x UHF-663	5.08	-24.37*	1164.28	-4.59	3.15	-6.81	57.43	145.60*	13.00	-13.33
UHF-612 x UHF-663	6.37	-5.11*	938.40	-15.19*	3.30	14.97*	48.85	108.91*	12.00	-20.00
Naveen (Check)	6.97		1450.61		3.30		31.50		18.33	
Population Mean	5.92		1118.90		3.26		69.01		12.67	
SE(m)±	0.08		45.10		0.06		1.19		1.16	
CD (P=0.05)	0.23		126.29		0.16		3.32		3.23	

*Significant at 5% level

The best performance with respect to fruit firmness was found in the parent AI-9 and the cross EC-15998 x AI-9 followed by FT-5 x UHF-656. Heterobeltiotic effect for this trait was also observed by Ashok Kumar (2002).

Less number of locules alongwith thicker pericarp leads to higher fruit firmness (Dundi and Madalageri, 1991). In the present studies, lowest number of locules were observed in the parents EC-15998, AI-9 and Solan Vajr and crosses FT-5 x UHF-663, AI-9 x Solan Vajr and AI-9 x FT-5. These findings are in accordance with Dod and Kale (1992).

Heterobeltiotic effect was found to be maximum in the cross FT-5 x UHF-663. However, most of the cross combinations

showed positive heterosis for number of locules per fruit. Polygalacturonase activity is inversely related to shelf life of tomato. Increased pectin solubilization in locular gel and pericarp is a result of polygalacturonase action (Burns and Pressey, 1988). In present studies, the minimum PG activity was observed in AI-9 among the parents, whereas among the crosses EC-15998 x EC-174023 had the lowest value followed by EC-15998 x AI-9 for this trait. The results are in consonance with the findings Ng (1977), Joshi (2002).

The longest shelf life (21 days) among parents was found in AI-9 whereas, among the crosses, the maximum shelf life (21.33 days) was noted in AI-9 x Solan Vajr. The highest heterobeltiotic was observed in the cross UHF-656 x UHF-659. Only two crosses showed statistically significant increase in shelf life over their respective better parents. Increase in shelf life due to heterotic effects was also reported by Dundi and Madalageri (1991) and Joshi (2002).

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