Int.J.Curr.Microbiol.App.Sci (2018) *7*(2): 1949-1957

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 02 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.702.234

Heterosis Studies for Yield and its Components in Tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India

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Keywords

Diallel, *Solanum lycopersicum* L., Heterosis, Yield and yield components

Article Info

Accepted:
17 January 2018
Available Online:
10 February 2018

A B S T R A C T

A 6x6 diallel cross excluding reciprocal of tomato was evaluated with parents for heterotic manifestation of yield and yield attributing characters. The heterosis over better parent (BP) to the extent of -14.64, -7.70, 15.84, 21.29, 15.30 and 38.91 per cent was recorded for days to first flowering, days to marketable maturity, average fruit weight, number of fruit per plant, harvest duration, yield per hectare, and plant height , respectively. The crosses showing heterosis for yield per plant were not heterotic for all the characters under study. The heterosis for yield was generally accompanied by heterosis for yield components. Three promising crosses *viz*., UHFT-9 x Solan Lalima, UHFT-10 x Solan Lalima, and UHFT-22 x Solan Lalima were identified for developing high yielding F_1 hybrids/ varieties of tomato with many desirable horticultural traits.

Introduction

Plant breeders have extensively explored and utilized heterosis to boost yield levels in several cross-pollinated crops in the recent past. However, tomato being a highly self-pollinated species, the scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis, and ease with which hybrid seeds can be produced. Commercial exploitation of hybrid vigour in tomato has received greater importance on account of several advantages of hybrids over pure line varieties with resistance/tolerance to biotic and abiotic stresses. Hence, identification of high yielding and stable varieties and the development of F_1 hybrids will help the farmers to adopt variety/hybrid for successful commercial cultivation of tomato. The reproductive biology and production of appreciable quantity of seeds per fruit provide plentiful opportunity for manifestation of heterosis in tomato (Singh and Singh, 1993). Heterosis in tomato was first observed by Hedrick and Booth (1968) for higher yield and more number of fruits. Since then,

heterosis for yield, its components and quality traits were extensively studied (Ahmad *et al.* 2011; Kurian *et al.* 2011). Choudhary *et al.* (1965) emphasized the extensive utilization of heterosis to step-up the tomato production but the tomato hybrid performed differently under the different agro climatic conditions. Present investigation was undertaken to ascertain the nature and extent of heterosis for yield and its component characters in tomato.

Materials and Methods

Six tomato lines *viz.,* UHFT-22, UHFT-55, UHFT-9, UHFT-10, EC-2798 and Solan Lalima were crossed in diallel fashion (excluding reciprocals) following Griffing (1956). The 21 genotypes (15 direct F_1 crosses + 6 parents) were grown in Experimental Research Farm, Department of Vegetable Science, Dr Y. S. Parmar, UHF, Nauni, Solan (HP), India following randomized complete block design with 3 replications during 2012-13.

Twenty eight days old nursery seedlings were transplanted at a distance of 90 cm × 30 cm. Twelve plants of each genotype per replication were grown by adopting standard agronomic practices to maintain healthy crop stand. The data were recorded on days to first flowering, days to marketable maturity, number of fruits per plant, fruit weight (g), fruit yield per hactare (q) and plant height (cm). Analysis of variance was performed according to Gomez and Gomez (1983). Heterosis over better parent and check for different characters under study were calculated as per standard procedures.

Results and Discussion

Analysis of variance indicated significant differences among genotypes for the various characters analyzed (Table 1). The magnitude of heterosis for different characters under study among the hybrid combinations are presented in Table 1 to 5.

Days to first flowering

Earliness is important to fetch premium prices in a market and hybrids being early are preferred over pure line varieties in tomato. Therefore, days to first flowering are primary indicator to predict earliness in a crop like tomato. Heterosis studies revealed that three cross combinations *viz.*, UHFT-55 x EC-2798 (-14.64), UHFT-55 x UHFT-10 (-7.26) and UHFT-55 x Solan Lalima (-6.38) showed significant negative heterosis over better parent. Further, the cross UHFT-22 x Solan Lalima showed highest significant negative heterosis over check Naveen and can be a better alternative for earliness. Early flowering in hybrids has also been reported by Mirshamssi *et al*. (2006), Hannan *et al.* (2007), Kumari *et al.* (2010) and Kumari and Sharma (2011).

Days to marketable maturity

Commonly varieties/hybrids may flower early but availability of produce is not maturing hence, days to marketable maturity provides more realistic estimates for deciding the maturity period of a variety. The three cross combinations *viz.,* UHFT-55 x EC-2798 (-7.70), UHFT-55 x UHFT-10(-5.23) and UHFT-55 x Solan Lalima (-3.29) resulted in significant negative heterosis over better parent. Cross combination UHFT-22 x Solan Lalima (-7.68) revealed highest negative heterosis over check cultivar. Negative heterobeltiosis for earliness has also been reported by Kumar *et al.* (2009), Kumari *et al.* (2010) and Singh and Sastry (2011).

Average fruit weight (g)

Average fruit weight has direct contribution to yield. The seven cross combinations

resulted in significant positive heterosis over better parent and UHF-10 x EC-2798(15.84), UHFT-22 x EC-2798 (15.68), UHFT-9 x UHFT-10 (8.10), and UHFT-55 x EC-2798 (7.74) were the top four crosses. Significant positive heterosis over the check was revealed by the two cross combinations viz., UHFT-9 x Solan Lalima (9.53) and UHFT-9 x UHFT-10 (4.65). The studies corroborate with the findings of Kumar *et al.* (2009), Kumari *et al.* (2010), Gul *et al.* (2010), Ahmed *et al.* (2011), Singh and Sastry (2011) and Kumari and Sharma (2011).

Number of fruits per plant

Number of fruits per plant is the most important component trait which is directly related to increased fruit yield per plant. Among all the crosses, ten cross combinations resulted in significant positive heterosis over better parent. whereas, significant positive heterosis over the check (Naveen) was revealed by four cross combinations *viz.*, UHFT-10 x Solan Lalima (12.30), UHFT-55 x Solan Lalima (11.00), UHFT-9 x Solan Lalima(11.00) and UHFT-10 x EC-2798 (6.15). Positive heterosis over better parent for this trait has also been reported by Rani and Veeraragavathatham (2008), Kumar *et al*. (2009), Kumari *et al*. (2010), Kumari and Sharma (2011), Ahmed *et al.* (2011), Singh and Sastry (2011) and Singh *et al.* (2012).

Harvest duration (days)

Longer harvest duration ensures the continuous supply of produce and good price of tomato for over a longer period. It also keeps a balance between the demand and supply, thereby avoiding glut in the market and fall in prices. Most of the crosses (eleven) showed significant positive heterosis over better parent for this trait, being highest in UHFT-55 x EC-2798 (15.30). Significant positive heterosis over the check was revealed by only four cross combinations *viz.*, UHFT-10 x Solan Lalima (9.22), UHFT-55 x Solan Lalima (8.25), UHFT-9 x Solan Lalima (8.25) and UHFT-10 x EC-2798 (4.61). Positive heterosis for this trait has also been reported by Thakur *et al.* (2004), Sharma and Thakur (2008) and Kumari and Sharma (2011).

Table.1 Analysis of variance for various horticultural traits in tomato

Source / Character	Mean Sum of Squares			
	Replications	**Genotypes**	**Errors**	**Total**
Df	2	21	42	65
Days to first flowering	0.73	23.76*	0.85	25.33
Days to marketable maturity	1.29	34.82*	1.26	37.37
Average fruit weight (g)	0.43	386.49*	2.11	389.03
Number of fruits per plant	0.51	20.22*	1.06	21.78
Harvest duration (days)	0.32	20.85*	1.02	22.19
Yield per plant (kg)	0.00	0.62*	0.01	0.63
Yield per plot (kg)	0.15	89.07*	1.27	90.48
Plant height (cm)	3.15	4446.59*	11.93	4461.67

*Significant at 5% level of significance

Table.2 Mean performance and heterotic response over Better parents (BP) and Check variety for days to first flowering in tomato and marketable maturity

Sr.No	Parents/crosses	Mean	Heterotic response for days to first flowering		Mean	Heterotic response for Marketable maturity	
			BP	Check		BP	Check
	Parents						
1	UHFT-55	31.20			71.43		
2	UHFT-22	26.93			66.30		
3	UHFT-9	33.37			74.03		
4	UHFT-10	32.97			73.57		
5	EC-2798	35.07			76.10		
6	Solan Lalima	30.83			70.97		
	Crosses						
	1×2	28.00	3.96	-8.79*	67.60	1.96	-3.19*
	1×3	31.97	2.46	4.13	72.37	1.31	3.63*
	1×4	28.93	-7.26*	-5.75*	67.70	-5.23*	-3.05*
	1×5	26.63	-14.64*	-13.25*	65.93	-7.70*	-5.58*
	1×6	28.87	-6.38*	-5.97*	68.63	-3.29*	-1.71
	2×3	28.47	5.69	-7.27*	68.13	2.77	-2.43
	2×4	26.93	0.00	-12.27*	66.30	0.00	-5.06*
	2×5	25.67	-4.70	-16.40*	64.80	-2.26	-7.20*
	2×6	25.40	-5.69	-17.26*	64.47	-2.77	-7.68*
	3×4	32.97	0.00	7.38*	73.53	-0.05	5.30*
	3×5	33.57	0.60	9.34*	74.27	0.32	6.35*
	3×6	30.43	-1.30	-0.87	70.20	-1.08	0.53
	4×5	31.77	-3.64	3.47	72.10	-1.99	3.25*
	4×6	31.90	3.46	3.91	72.27	1.83	3.49*
	5×6	32.83	6.49*	6.95*	73.37	3.38*	5.06*
	Naveen (check)	**30.70**			**69.83**		
	Population mean	**30.25**			**70.18**		
	SE(m)±	**0.75**			**0.92**		
	$CD_{(0.05)}$	**1.50**			**1.84**		

*Significant at 5% level of significance

Table.3 Mean performance and heterotic response over Better parents (BP) and Check variety for Average fruit weight (g) and No. of fruit per plant

Sr.No	Parents/crosses	Mean	Heterotic response for Average fruit weight (g)		Mean	Heterotic response for No. of fruit per plant	
			BP	Check		BP	Check
	Parents						
1	UHFT-55	57.73			26.30		
2	UHFT-22	41.63			24.80		
3	UHFT-9	72.80			28.20		
4	UHFT-10	60.60			30.80		
5	EC-2798	45.27			23.20		
6	Solan Lalima	76.60			28.70		
	Crosses						
	1×2	55.73	-3.46	-25.89*	29.80	13.31*	-3.56
	1×3	61.63	-15.34*	-18.04*	30.20	7.09*	-2.27
	1×4	65.13	7.48*	-13.39*	32.10	4.22	3.88
	1×5	62.20	7.74*	-17.29*	31.90	21.29*	3.24
	1×6	72.63	-5.18*	-3.41*	34.30	19.51*	11.00*
	2×3	63.40	-12.91*	-15.69*	30.00	6.38*	-2.91
	2×4	60.77	0.28	-19.19*	28.40	-7.79*	-8.09*
	2×5	52.37	15.68*	-30.36*	29.30	18.15*	-5.18
	2×6	46.20	-39.69*	-38.56*	27.40	-4.53	-11.33*
	3×4	78.70	8.10*	4.65*	30.80	0.00	-0.32
	3×5	75.67	3.94*	0.62	29.70	5.32	-3.88
	3×6	82.37	7.53*	9.53*	34.30	19.51*	11.00*
	4×5	70.20	15.84*	-6.65*	32.80	6.49*	6.15*
	4×6	73.87	-3.57*	-1.77	34.70	12.66*	12.30*
	5×6	65.97	-13.88*	-12.28*	32.00	11.50*	3.56
	Naveen (check)	**75.20**			**30.90**		
	Population mean	**64.39**			**30.07**		
	SE(m)±	**1.19**			**0.84**		
	$CD_{(0.05)}$	**2.37**			**1.68**		

*Significant at 5% level of significance

Table.4 Mean performance and heterotic response over Better parents (BP) and Check variety for harvest duration and yield per plant

Sr.No	Parents/crosses	Mean	Heterotic response for days to first flowering		Mean	Heterotic response for Marketable maturity	
			BP	Check		BP	Check
	Parents						
1	UHFT-55	36.60			1.59		
2	UHFT-22	33.50			1.08		
3	UHFT-9	38.50			2.07		
4	UHFT-10	39.00			1.84		
5	EC-2798	35.10			1.10		
6	Solan Lalima	41.10			2.17		
	Crosses						
	1×2	40.10	9.56*	-2.67	1.68	5.71	-25.44*
	1×3	40.50	5.19*	-1.70	1.90	-8.07*	-15.89*
	1×4	42.40	8.72*	2.91	2.12	15.52*	-6.03
	1×5	42.20	15.30*	2.43	1.94	21.54*	-14.28*
	1×6	44.60	8.52*	8.25*	2.50	15.16*	10.61*
	2×3	40.30	4.68*	-2.18	1.89	-8.65*	-16.42*
	2×4	38.70	-0.77	-6.07*	1.81	-1.69	-20.03*
	2×5	38.60	9.97*	-6.31*	1.53	38.91*	-32.33*
	2×6	37.70	-8.27*	-8.50*	1.21	-44.36*	-46.56*
	3×4	41.10	5.38*	-0.24	2.47	19.55*	9.38*
	3×5	40.00	3.90	-2.91	2.26	9.31*	0.01
	3×6	44.60	8.52*	8.25*	2.74	26.17*	21.19*
	4×5	43.10	10.51*	4.61*	2.21	20.21*	-2.22
	4×6	45.00	9.49*	9.22*	2.48	14.31*	9.79*
	5×6	42.30	2.92	2.67	2.18	0.35	-3.61
	Naveen (check)	**41.20**			**2.26**		
	Population mean	**40.27**			**1.96**		
	SE(m)±	**0.82**			**0.08**		
	$CD_{(0.05)}$	**1.65**			**0.15**		

*Significant at 5% level of significance

Table.5 Mean performance and heterotic response over Better parents (BP) and Check variety for Yield per plot and plant height

Sr.No	Parents/crosses	Mean	Heterotic response for yield per hactare		Mean	Heterotic response plant height	
			BP	Check		BP	Check
	Parents						
1	UHFT-55	19.13			155.39		
2	UHFT-22	12.92			76.19		
3	UHFT-9	24.81			162.54		
4	UHFT-10	22.06			158.40		
5	EC-2798	13.21			151.76		
6	Solan Lalima	26.05			166.60		
	Crosses						
	1×2	20.22	5.71	-25.44*	158.08	1.73	-6.68*
	1×3	22.81	-8.07*	-15.89*	152.19	-6.37*	-10.16*
	1×4	25.48	15.52*	-6.03	154.44	-2.50	-8.83*
	1×5	23.25	21.54*	-14.28*	149.16	-4.01*	-11.95*
	1×6	30.00	15.16*	10.61*	152.09	-8.71*	-10.22*
	2×3	22.67	-8.65*	-16.42*	72.18	-55.59*	-57.39*
	2×4	21.69	-1.69	-20.03*	70.14	-55.72*	-58.60*
	2×5	18.35	38.91*	-32.33*	73.15	-51.80*	-56.82*
	2×6	14.49	-44.36*	-46.56*	83.72	-49.75*	-50.58*
	3×4	29.66	19.55*	9.38*	175.14	7.75*	3.39
	3×5	27.12	9.31*	0.01	148.62	-8.57*	-12.27*
	3×6	32.87	26.17*	21.19*	174.13	4.52*	2.79
	4×5	26.52	20.21*	-2.22	150.36	-5.07*	-11.24*
	4×6	29.78	14.31*	9.79*	184.38	10.67*	8.84*
	5×6	26.14	0.35	-3.61	181.86	9.16*	7.36*
	Naveen (check)	**27.09**			**169.40**		
	Population mean	**23.47**			**141.81**		
	SE(m)±	**0.92**			**2.82**		
	$CD_{(0.05)}$	**1.84**			**5.65**		

*Significant at 5% level of significance

Yield (kg /plant and kg/ plot)

The ultimate goal of any breeding programme is to achieve more marketable yield per unit of area. The nine cross combinations resulted in significant positive heterosis over better parent, UHFT-22 x EC-2798 (38.91) being highest. Whereas, four cross combinations *viz.*, UHFT-9 x Solan Lalima (21.19), UHFT-55 x Solan Lalima (10.61), UHFT-10 x Solan Lalima (9.79) and UHFT-9 x UHFT-10 (9.38) revealed significant positive heterosis over the check cultivar 'Naveen'. Positive heterosis for fruit yield was reported earlier by Gul *et al.* (2010), Kumari *et al.* (2010), Kumari and Sharma (2011), Singh and Shastry (2011), Ahmed *et al.* (2011) and Singh *et al.* (2012).

Plant height (cm)

Tall/Indeterminate varieties are generally grown in the mid hill zone of Himachal Pradesh. Such Varieties are preferred because the growing period here coincides with monsoon rains, which leads to increased incidence of buckeye rot disease of tomato and other soil borne and foliar diseases in dwarf/determinate varieties. Also more plant height is considered desirable, because it leads to more number of branches and ultimately results in increased productivity. Four cross combinations *viz.*, UHFT-10 x Solan Lalima (10.67), EC-2798 x Solan Lalima (9.16), UHFT-9 x UHFT-10 (7.75) and UHFT-9 x Solan Lalima (4.52) revealed significant positive heterosis over better parent. Significant positive heterosis over the check was revealed by only two cross combinations *viz.*, UHFT-10 x Solan Lalima (8.84) and EC-2798 x Solan Lalima (7.36). Positive heterosis for this trait has also been reported by Singh and Asati (2011), Singh and Sastry (2011), Kumari and Sharma (2011), Ahmed *et al.*, (2011) and Singh *et al.*, (2012).

On the basis of heterosis studies, it is concluded that the hybrids, UHFT-9 x Solan Lalima, UHFT-10 x Solan Lalima and UHFT-55 x Solan Lalima were found promising for most of the yield and yield components. Whereas, for earliness UHFT-22 x Solan Lalima and UHFT-22 x EC-2798 were found best, hence multilocation testing can be adopted for commercial cultivation of tomato in the potential pockets of the state.

Acknowledgements

The authors' wish to express their gratitude to Indian Institute of Vegetable Research (Varanasi, India) and Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.) India for providing germplasm for conducting present experiment and providing facility to conduct the experiment.

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How to cite this article:

Nidhish Gautam, Manish Kumar, Amit Vikram, Sandeep Kumar and Shikha Sharma. 2018. Heterosis Studies for Yield and its Components in Tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India. *Int.J.Curr.Microbiol.App.Sci.* 7(02): 1949-1957.
doi: https://doi.org/10.20546/ijcmas.2018.702.234