Int.J.Curr.Microbiol.App.Sci (2019) *8*(1): 52-61

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 01 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.801.007

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

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Keywords

Heterosis, Hybrids, Line × Tester, Quantitative, Qualitative and Tomato

Article Info

Accepted:
12 December 2018
Available Online:
10 January 2019

A B S T R A C T

Line x Tester analysis was performed by employing fourteen tomato genotypes (10 lines and 4 testers) to develop 40 hybrids. These hybrids along with parental lines and commercial check Naveen 2000+ were evaluated to know the extent of heterosis exhibited to different yield and yield attributing traits. Results revealed that nine hybrid combinations produced significantly increased heterotic effect over the better parent. The top best 5 such combinations were; EC-5863 x Solan Lalima, EC-5863 x Solan Vajr, CLN 2123 A-1 x Solan Lalima, EC-526146 x Solan Lalima and CLN 2123 A-1 x Solan Vajr which registered superiority in term of yield/plant and yield/hectare to the tune of 68.18, 68.00, 67.15, 64.87 and 48.28 per cent, respectively over the better parent. Whereas, 6 cross combinations, reported significant positive heterosis over the standard check viz. EC-5863 x Solan Lalima (26.24 %) followed by EC-5863 x Solan Vajr (25.73 %), CLN 2123 A-1 x Solan Lalima (25.46 %), EC-526146 x Solan Lalima (23.75 %), CLN 2123 A-1 x Solan Vajr (48.23 %) and EC-521041 x Solan Lalima (1.93 %) these hybrids also reported heterosis for yield attributing traits.

Introduction

Tomato (*Solanum lycopersicum* L.) being the crop of importance for both culinary and processing purpose, it has been cultivated over large area around the world. This crop exhibits rich genetic diversity for various horticultural traits and has a scope for its improvement. In tomato, the comparative ease of emasculation, high percentage of fruit setting and good number of seeds per fruit also facilitate the exploitation of heterosis. Yield being a complex quantitative character in tomato can be improved through improving its contributing traits, i.e. mean fruit weight, number of fruits per plant, fruit length, and breadth and plant vigour. The genetic improvement of crop plants and exploitation of heterosis requires the selection of suitable parents and cross combinations. The selection of parents on the basis of *per se* performance does not necessarily lead to desirable results (Allard, 1960). Heterosis for various fruit quantitative and quality characters has been reported by Sahu *et al.*, (2016) and Panchal *et al.*, (2017) in tomato Hence, present investigation was carried out at YS Parmar University of Horticulture and Forestry, Nauni, Solan during 2016 and 2017 to assess the heterosis levels expressed by hybrids over their parents for Yields and yield attributing traits taken under consideration and also to identify best heterotic combinations for the same.

Materials and Methods

Source materials for current study comprised of fourteen diverse genotypes. Six lines (CLN 2070 B-1, CLN 2116 B-1, CLN 2123 A-1, BWR-1, BWR-5, EC- 528372, EC- 521041, EC- 526146, EC- 5863, EC- 521079) and four testers (FT-5, Solan Lalima, Solan Vajr and Arka Meghali) were crossed in Line X Tester fashion at Experimental Farm Department of Vegetable YS Parmar UHF, Nauni, Solan during Rabi of 2016. Evaluation of hybrids for various Yield and yield attributing characters in comparison to their parents along with a standard check (Naveen 2000+) was taken up during summer 2017 in randomized block design with three replications. About 5 fruits from each replication of an entry were considered to record observation for the traits plant height, days to first flowering, days to first harvest, fruit shape index, fruit firmness, pericarp thickness, number of locules, number of fruits per cluster, number of fruits per plant, average fruit weight, marketable fruit yield per plant, yield per hectare, alternaria blight severity, buckeye rot incidence, total soluble solids, ascorbic acid content and lycopene content Heterosis values in negative direction were considered as desirable for the character days to first harvest, days to first flowering number of locules per fruit, alternaria blight severity and buckeye rot incidence.

Results and Discussion

Analysis of variance for seventeen considered yield and yield attributing traits (Table 1) revealed that mean sum of squares for parents and hybrids were significant for all the traits except days to first flowering and number of fruits per cluster indicating presence of heterosis for these characters. Significant positive heterosis for plant height was observed in 11 hybrids over the better parent (BP) as seen through Table 2. Maximum increased heterosis over better parent was found in cross combination EC-521079 x Solan Lalima (64.35 %). Over the standard check (SC), 3 of the combinations viz. EC-521041 x Solan Lalima followed by CLN 2123 A-1 x Solan Lalima and EC-526146 x Solan Lalima gave significant increased heterosis to the tune of 7.89, 5.84 and 5.66 percent, respectively. The results obtained are in line with Fageria *et al.,* (2001). For days to first flowering significant negative heterosis over better parent was observed in as many as 13 cross combinations, maximum being in EC-521079 x Solan Lalima (-20.87 %) as enumerated through Table 2. Negative heterosis for this trait over the better parent has also been reported by Baishya *et al.,* (2001) Over the standard check, only one cross combination i.e. EC-521079 x Solan Lalima (-8.87 %) recorded desirable significant heterosis. Maximum significant negative heterosis over better parent (%) was found in EC-521079 x Solan Lalima (-20.43) for days to first harvest. However, over the standard check, CLN 2123 A-1 x Solan Lalima (-14.68) showed significantly highest negative heterosis similar reports were obtained by Singh *et al.,* (2008). For fruit shape index positive heterotic effect (%) over better parent was reported in 6 cross combinations, highest being in EC-5863 x Solan Vajr (8.03). Over the standard check, as many as 24 crosses showed significant positive heterosis, with maximum in EC-5863 x Solan Lalima (15.38). The results are in line with Premalakshme *et al.,* (2006). Significant positive heterosis (%) over better parent was observed in only 3 cross combinations i.e. EC-

528372 x Arka Meghali (32.44) followed by EC-521041 x FT-5 (22.41) and CLN 2070 B-1 x FT-5 (15.11) for fruit firmness (Table 2). Over the standard check, 19 cross combinations were positively heterotic, out of which the best cross combinations was; EC-5863 x Solan Vajr (60.71). Results are in accordance with Joshi *et al.,* (2004). Significantly positive heterosis over better parent was found in 3 cross combinations namely EC-526146 x FT-5 (52.54 %), EC-528372 x Solan Lalima (20.83 %) and BWR-5 x Solan Lalima (8.45 %) for pericarp thickness (Table 3).

Whereas, 4 cross combinations viz. EC-5863 x Solan Lalima (18.60 %), EC-521041 x Solan Lalima (17.94 %), EC-526146 x FT-5 (15.38 %) and CLN 2123 A-1 x Solan Lalima (14.75 %) showed significantly positive heterosis over the standard check the results are in accordance with Sharma and Thakur (2007). Since less number of locules are desirable in tomato, so heterosis over better parent was found significantly negative in 10 cross combinations, maximum being in BWR-5 x Solan Lalima (-67.64 %) (Table 3). Over the check, as many as 22 combinations revealed negative heterosis, maximum being in EC-521041 x Solan Lalima (-39.72 %). Similar results were obtained by Kurian *et al.,* (2001). For number of fruits per cluster only one i.e., CLN 2116 B-1 x Solan Lalima showed significant positive heterosis over better parent (7.44 %) as well as standard check (17.11 %) heterosis for number of fruits per cluster was also reported by Kumar *et al.,* (2012). Highest significant heterosis for number of fruits per plant (Table 4) over better parent was found in 3 of the hybrid combinations viz. EC-526146 x FT-5 (11.82 %), EC-5863 x Solan Vajr (11.32 %) and EC- 5863 x Solan Lalima (10.66 %) whereas, 5 cross combinations viz. EC-5863 x Solan Lalima (30.20 %), EC-5863 x Solan Vajr (22.50 %), EC-521041 x Solan Lalima (22.14 %), EC-526146 x Solan Lalima (16.17 %) and CLN 2123 A-1 x Solan Lalima (14.68 %) showed significant positive heterosis over the check hybrid (Naveen 2000 +) results are in line with the findings of Yadav *et al.,* (2013). Significant positive heterosis for fruit weight over better parent was found in 18 cross combinations (Table 4) with maximum heterosis in; BWR-5 x Arka Meghali (67.58 %). Whereas, Over the standard check, 2 of the crosses; EC-526146 x FT-5 (8.64 %) and CLN 2123 A-1 x Solan Vajr (7.17 %) showed significant positive heterosis. Results are in accordance with Kurian *et al.,* (2001).

Nine hybrid combinations produced significantly increased heterotic effect over the better parent in term of yield/plant and yield per hectare. The top best 5 such combinations were; EC-5863 x Solan Lalima, EC-5863 x Solan Vajr, CLN 2123 A-1 x Solan Lalima, EC-526146 x Solan Lalima and CLN 2123 A-1 x Solan Vajr which registered superiority to the tune of 68.18, 68.00, 67.15, 64.87 and 48.28 per cent, respectively over the better parent. Over the standard check, 6 cross combinations reported significant positive heterosis viz. EC-5863 x Solan Lalima (26.24 %) followed by EC-5863 x Solan Vajr (25.73 %), CLN 2123 A-1 x Solan Lalima (25.46 %), EC-526146 x Solan Lalima (23.75 %), CLN 2123 A-1 x Solan Vajr (48.23 %) and EC-521041 x Solan Lalima (1.93 %) (Table 4). Similar results were reported by Gaikwad and Cheema (2010). Negative heterosis is desirable for alternaria blight severity as such; 16 of the cross combinations observed significant negative heterosis (%) over better parent, maximum depicted in CLN 2116 B-1 x Solan Lalima (-62.17). Further, as many as 15 cross combinations showed desirable significant negative heterotic effects over the standard check; maximum being in CLN 2116 B-1 x Solan lalima (-47.26) (Table 5). Similar results on alternaria blight were reported by Rao *et al.,* (2007).

Table.1 Analysis of variance for combining ability for various traits in tomato

Sr. No.	Source of variation→	Replications	Crosses	Lines	Tester	Line x Tester	Error
	Trait ↓ df→	**2**	**39**	**9**	**3**	**27**	**78**
1	Plant height (cm)	9.96	1263.39*	3670.59*	299.44*	568.10*	18.30
2	Days to first flowering	2.72	13.03*	19.66*	0.74	12.18*	4.50
3	Days to first harvest	21.15	50.50*	82.85*	58.75*	38.80*	10.79
4	Fruit shape index	0.00	0.09*	0.09*	0.16*	0.08*	0.00
5	Fruit firmness (kg/cm^2)	346901.69*	316407.63*	268889.39*	666823.93*	293311.89*	41121.44
6	Pericarp thickness (mm)	0.07	2.10*	2.50*	2.84*	1.88*	0.20
7	Number of locules per fruit	0.004	0.916*	1.63*	1.13*	0.66*	0.20
8	Number of fruits per cluster	0.48	1.002*	2.32*	0.23	0.65*	0.24
9	Number of fruits per plant	4.52	59.07*	119.009*	45.67*	40.59*	6.23
10	Average fruit weight (g)	24.85	689.09*	304.82*	1695.04*	705.40*	11.09
11	Marketable fruit yield per plant (g)	51.30	484,725.43*	698,923.77*	571,756.87*	403,655.82*	49.644
12	Marketable yield (q/ha)	3.59	48,096.64*	69,350.44*	56,731.91*	40,052.56*	4.95
13	Alternaria blight severity (%)	21.59	358.40*	610.38*	119.91*	293.68*	15.01
14	Buckeye rot incidence (%)	98.32*	263.59*	695.77*	117.24*	135.79*	15.17
15	Total soluble solids (°Brix)	8.08*	0.55*	0.52*	0.39*	0.58*	0.12
16	Ascorbic acid content (mg/100g)	3.55	19.13*	17.03*	38.41*	17.69*	5.44
17	Lycopene content (mg/100g)	0.04	2.49*	3.48*	3.54*	2.05*	0.05

*Significant at 5 % level of significance

Table.2 Estimation of heterosis for plant height, days to first flowering, days to first harvest and fruit shape index

		Percent increase or decrease over							
Sr. No	**Crosses**	**Plant height (cm)**		**Days to first flowering**		**Days to first harvest**		**Fruit shape index**	
		BP	**SC**	**BP**	**SC**	**BP**	**SC**	**BP**	**SC**
1	CLN 2070 B-1 x FT-5	9.28*	-7.13*	-1.23	4.55	-3.52	3.16	-0.30	7.39*
2	CLN 2116 B-1 x FT-5	-14.13	-13.37*	4.29	10.39*	-3.89	1.94	-34.97*	-27.88*
3	CLN 2123 A-1 x FT-5	5.51*	-6.10*	-1.34	11.47*	0.92	7.04	-4.45*	3.19
4	BWR-1 x FT-5	54.25	-14.35*	-11.25*	-6.06	-14.70*	-7.77*	-6.83	0.64
5	BWR-5 x FT-5	2.99	-12.48*	-11.31*	-1.52	-14.64*	-8.74*	-7.42*	0.00
6	EC-528372 x FT-5	-7.95*	-7.13*	-9.36	0.65	-11.39*	-10.31*	-2.02*	8.65*
7	EC-521041 x FT-5	6.16*	-5.53*	-9.96	1.73	3.00	4.25	-1.48*	6.16*
8	EC-526146 x FT-5	43.07	-5.70*	1.37	12.56*	-4.94	2.79	3.56*	11.86*
9	EC-5863 x FT-5	-21.13	-16.18*	8.84*	11.91*	-14.08*	-8.13*	-8.17*	4.62*
10	EC-521079 x FT-5	-20.80	-15.82*	9.80	6.71	11.17	0.24	-8.73	3.85*
11	CLN 2070 B-1 x Solan Lalima	-31.61*	-27.32*	-2.68	9.96*	-0.27	-10.07*	-4.23	8.97*
12	CLN 2116 B-1 x Solan Lalima	-12.91*	-7.44*	-6.29*	-6.49	-16.95*	-10.19*	-7.61*	5.14*
13	CLN 2123 A-1 x Solan Lalima	24.54*	5.84*	-5.07	1.30	-21.80	-14.68*	7.10	11.22*
14	BWR-1 x Solan Lalima	-6.14*	-5.308	3.65	10.61*	-17.24*	-9.71*	-2.89	7.47*
15	BWR-5 x Solan Lalima	-17.68*	-26.74*	-13.79*	-2.60	-20.02	-12.74*	2.09	9.62*
16	EC-528372 x Solan Lalima	38.90	1.52	1.22*	8.01*	-5.45	3.16	-3.13*	-30.45*
17	EC-521041 x Solan Lalima	26.95*	7.89*	-16.35*	-3.68	-16.01	-10.19*	6.48*	10.58*
18	EC-526146 x Solan Lalima	4.73*	5.66*	-18.42*	-6.06	0.97	-11.16*	2.02	13.14*
19	EC-5863 x Solan Lalima	18.58*	-5.53*	-12.41	0.87	1.53	-11.53*	7.46	15.38*
20	EC-521079 x Solan Lalima	64.35*	-6.10*	-20.87*	-8.87*	-20.43*	-13.96*	-0.93*	-31.73*
21	CLN 2070 B-1 x Solan Vajr	-16.15*	-28.74*	-8.00*	-5.41	-9.31*	-3.03	5.86	9.94*
22	CLN 2116 B-1 x Solan Vajr	-16.12*	-15.37*	0.00	-1.95	-3.07	-4.25	0.87*	11.86*
23	CLN 2123 A-1 x Solan Vajr	4.81*	-6.738*	-13.99*	-2.81	-9.09	-10.19*	2.69	10.26*
24	BWR-1 x Solan Vajr	31.86*	-29.55*	1.52*	1.30	-15.60*	-8.74*	31.27	8.97*
25	BWR-5 x Solan Vajr	-14.31	-14.08*	-7.00*	0.65	-16.23	-10.44*	-38.23*	-28.53*
26	EC-528372 x Solan Vajr	-24.12*	-23.44*	-11.40*	-4.11	14.06*	6.31	-1.94*	13.46*
27	EC-521041 x Solan Vajr	-6.58*	-6.33*	-0.38	12.56*	-5.73	-12.13*	-6.93*	7.52*
28	EC-526146 x Solan Vajr	-12.80*	-12.57*	-11.80*	-4.55	-15.49	-8.62*	-29.92*	-18.91*
29	EC-5863 x Solan Vajr	4.84*	-0.49	1.69	17.31*	-10.44*	-4.25	8.03*	12.18*
30	EC-521079 x Solan Vajr	-26.90*	-26.25*	-8.63	5.41	20.13	8.62*	-4.05	6.54*
31	CLN 2070 B-1 x Arka Meghali	-36.20*	-39.44*	-14.63	-1.52	17.85	6.55	-36.72*	-32.05*
32	CLN 2116 B-1 x Arka Meghali	-23.52*	-27.41*	-6.19	8.22*	-18.07*	-11.41*	-19.94*	-18.91*
33	CLN 2123 A-1 x Arka Meghali	-21.73*	-32.26*	5.05*	8.01*	-3.52	3.16	-24.73*	-11.22*
34	BWR-1 x Arka Meghali	-41.21*	-40.69*	15.21	11.47*	16.55	2.55	-23.10*	-9.29*
35	BWR-5 x Arka Meghali	-26.09*	-34.22*	-6.51*	5.63	22.04	6.19	-8.42*	7.73*
36	EC-528372 x Arka Meghali	-20.08*	-30.84*	11.28*	11.04*	-14.37*	-7.40*	-37.50*	-26.28*
37	EC-521041 x Arka Meghali	-20.77*	-32.67*	-1.47	1.30	0.23	7.16	5.25*	9.59*
38	EC-526146 x Arka Meghali	-31.71*	-31.10*	0.00	0.65	0.59	3.52	-28.04*	-20.19*
39	EC-5863 x Arka Meghali	-20.73*	-29.46*	-14.18	-3.03	3.54	6.55	-34.93*	-30.13*
40	EC-521079 x Arka Meghali	-3.17	-33.20*	7.53	8.22*	-15.60*	-8.74*	7.48*	-26.28*

Table.3 Estimation of heterosis for fruits firmness, pericarp thickness, number of locules per fruit and number of fruits per cluster

Percent increase or decrease over									
Sr. No	**Crosses**	**Fruit firmness (kg/cm^2)**		**Pericarp thickness (mm)**		**Number of locules per fruit**		**Number of fruits per cluster**	
		BP	**SC**	**BP**	**SC**	**BP**	**SC**	**BP**	**SC**
1	CLN 2070 B-1 x FT-5	15.11*	39.94*	-23.23*	-23.71*	-8.77	-18.17*	-9.80	-17.11*
2	CLN 2116 B-1 x FT-5	9.48	38.85*	-23.89*	-12.17*	18.45*	-0.96	-5.46	-6.30
3	CLN 2123 A-1 x FT-5	-22.61*	18.29*	-4.23*	-12.83*	-24.91*	-13.88*	-14.75	-6.30
4	BWR-1 x FT-5	-18.30*	-5.32	-28.68*	-37.83*	29.06*	8.53	-29.41*	-35.14*
5	BWR-5 x FT-5	3.45	11.51	-21.29*	-21.79*	-29.00*	-17.31*	4.00	-6.30
6	EC-528372 x FT-5	0.20	8.02	-34.44*	-24.37*	22.11*	5.94	-9.09	-9.92
7	EC-521041 x FT-5	22.41*	55.24*	9.86	0.00	12.50	-12.14	-14.75	-6.30
8	EC-526146 x FT-5	-14.59*	15.23	52.54*	15.38*	-17.77*	-36.25*	11.00	0.00
9	EC-5863 x FT-5	-18.22*	24.63*	-5.66*	-3.85	-50.10*	-36.25*	-40.50*	-35.14*
10	EC-521079 x FT-5	-17.92*	-4.89	-38.89*	-29.48*	45.42*	6.80	-10.74	-2.70
11	CLN 2070 B-1 x Solan Lalima	-15.46*	32.72*	-13.21*	-11.54*	-44.21*	-37.98*	0.00	9.92
12	CLN 2116 B-1 x Solan Lalima	-10.86*	39.94*	-5.03*	-3.21	-15.54*	-31.09*	7.44*	17.11*
13	CLN 2123 A-1 x Solan Lalima	-2.51	53.06*	15.48	14.75*	-51.97*	-36.25*	4.51	4.51
14	BWR-1 x Solan Lalima	-41.51*	-8.17	-44.44*	-35.90*	15.25*	-22.48*	0.90	0.89
15	BWR-5 x Solan Lalima	-4.32	50.22*	8.45*	-1.29	-67.64*	-36.25*	-21.31*	-13.51
16	EC-528372 x Solan Lalima	-27.58*	13.70	20.83*	-7.06	3.27	-13.88*	-1.80	-1.81
17	EC-521041 x Solan Lalima	-2.65	52.84*	18.71	17.94*	-3.03	-39.72*	1.70	8.11
18	EC-526146 x Solan Lalima	-6.69	46.50*	-26.67*	-15.38*	-8.23	-32.82*	3.39	9.92
19	EC-5863 x Solan Lalima	-0.42	56.34*	30.28	18.60*	-41.79*	-27.65*	-2.46	7.22
20	EC-521079 x Solan Lalima	-43.45*	-11.22	-7.63*	-30.13*	23.50*	-13.88*	-0.85	5.41
21	CLN 2070 B-1 x Solan Vajr	-30.63*	10.42	-10.97	-11.54*	-6.79	-15.58*	27.27	0.89
22	CLN 2116 B-1 x Solan Vajr	-34.20*	4.74	-39.44*	-30.13*	-8.75	-25.06*	-3.64	-4.51
23	CLN 2123 A-1 x Solan Vajr	-7.97	46.50*	14.09	3.85	-30.09*	-18.17*	0.00	9.92
24	BWR-1 x Solan Vajr	-31.04*	9.76	13.04	0.00	39.54*	4.21	21.43	7.22
25	BWR-5 x Solan Vajr	-41.62*	-7.07	-28.03*	-27.56*	-2.92	3.36	-31.09*	-26.14*
26	EC-528372 x Solan Vajr	-45.05*	-12.54	-39.44*	-30.13*	20.47*	4.21	-38.66*	-34.24*
27	EC-521041 x Solan Vajr	-27.75*	15.01	-10.83*	-10.25*	33.44*	-9.56	-11.48	-2.70
28	EC-526146 x Solan Vajr	-24.59*	20.04*	-19.11*	-18.60*	8.23	-22.48*	-7.56	-0.89
29	EC-5863 x Solan Vajr	0.96	60.71*	-3.87*	-4.48	-10.82	-5.25	-9.57*	-6.30
30	EC-521079 x Solan Vajr	-20.74*	26.17*	-19.44	-7.06	-2.59	-13.00*	-20.00*	-17.11*
31	CLN 2070 B-1 x Arka Meghali	-33.27*	-18.88*	-22.00*	-25.00*	-2.97	-13.00*	-14.75	-6.30
32	CLN 2116 B-1 x Arka Meghali	-16.72*	5.61	-31.33	-33.98*	6.63	-4.39	-37.39*	-35.14*
33	CLN 2123 A-1 x Arka Meghali	-12.88*	33.16*	-21.86*	-8.33	-9.51	-1.81	-24.62*	-11.70
34	BWR-1 x Arka Meghali	-20.75*	-8.16	-26.23	-13.46*	5.57	-4.39	-32.31*	-20.73*
35	BWR-5 x Arka Meghali	10.68	6.49	-47.54*	-38.46*	-6.83	-0.96	-47.69*	-38.73*
36	EC-528372 x Arka Meghali	32.44*	18.73*	-38.80*	-28.21*	2.38	-7.83	-33.85	-22.51*
37	EC-521041 x Arka Meghali	-36.03*	-18.88*	-36.77*	-37.17*	-4.90	-14.73*	-33.93*	-33.32*
38	EC-526146 x Arka Meghali	-35.17*	-12.54	-35.56*	-25.63*	11.44	-0.08	-28.57*	-27.92*
39	EC-5863 x Arka Meghali	-14.63*	30.10*	-16.20*	-23.71*	-16.43*	-12.14	-27.87*	-20.73*
40	EC-521079 x Arka Meghali	-14.34*	-0.73	-13.56*	-34.62*	99.92*	2.51	-34.82*	-34.24*

Table.4 Estimation of heterosis for number of fruits per plant, average fruit weight, marketable fruit yield per plant and yield

Percent increase or decrease over									
Sr. No.	**Crosses**	**Number of fruits per plant**		**Average fruit weight (g)**		**Marketable fruit yield per plant (g)**		**Marketable fruit yield (q/ha)**	
		BP	**SC**	**BP**	**SC**	**BP**	**SC**	**BP**	**SC8**
1	CLN 2070 B-1 x FT-5	-25.70*	-26.62*	40.42*	-15.32*	22.33*	-24.46*	22.33*	-24.46*
2	CLN 2116 B-1 x FT-5	7.79	6.47	20.84*	-28.20*	-4.21*	-43.52*	-4.21*	-43.52*
3	CLN 2123 A-1 x FT-5	-26.63*	-16.42*	26.92*	-2.36	-19.61*	-39.74*	-19.61*	-39.74*
4	BWR-1 x FT-5	-2.78	-3.98	-16.46*	-50.37*	-8.97*	-46.32*	-8.97*	-46.32*
5	BWR-5 x FT-5	-20.92*	-21.89*	24.84*	-25.83*	-23.02*	-54.61*	-23.02*	-54.61*
6	EC-528372 x FT-5	4.02	2.74	-13.85*	-48.82*	-31.77*	-59.77	-31.77*	-59.77
7	EC-521041 x FT-5	-29.20*	-20.40*	37.21*	-0.24	-30.68*	-48.28*	-30.68*	-48.28*
8	EC-526146 x FT-5	11.82*	10.45	30.31*	8.64*	16.13*	-23.73*	16.13*	-23.73*
9	EC-5863 x FT-5	-8.16	0.75	-11.63*	-34.39*	-24.37*	-43.40*	-24.37*	-43.40*
10	EC-521079 x FT-5	-17.90*	-18.91*	20.43*	-28.44*	-11.68*	-47.92*	-11.68*	-47.92*
11	CLN 2070 B-1 x Solan Lalima	-8.45	7.71	-4.13	-29.91*	-2.28	-26.66*	-2.28	-26.66*
12	CLN 2116 B-1 x Solan Lalima	-33.61*	-21.89*	29.98*	-4.97*	-1.01	-25.70*	-1.01	-25.70*
13	CLN 2123 A-1 x Solan Lalima	-2.53	14.68*	7.31*	-17.44*	67.15*	25.46*	67.15*	25.46*
14	BWR-1 x Solan Lalima	-32.55*	-20.65*	-20.62*	-41.97*	-42.96*	-57.18*	-42.96*	-57.18*
15	BWR-5 x Solan Lalima	-8.45	7.71	29.21*	-5.54*	-10.268	-32.64*	-10.26	-32.64*
16	EC-528372 x Solan Lalima	-7.60	8.71	-1.00	-27.63*	-9.19*	-31.84*	-9.19*	-31.84*
17	EC-521041 x Solan Lalima	3.82	22.14*	41.25*	3.26	35.80*	1.93*	35.80*	1.93*
18	EC-526146 x Solan Lalima	-1.26	16.17*	-23.46*	-36.19*	64.87*	23.75*	64.87*	23.75*
19	EC-5863 x Solan Lalima	10.66*	30.20*	37.84*	2.33	68.18*	26.24*	68.18*	26.24*
20	EC-521079 x Solan Lalima	-23.88*	-10.45	-29.43*	-48.41*	-51.32*	-63.46*	-51.32*	-63.46*
21	CLN 2070 B-1 x Solan Vajr	-5.63	4.23	-40.94*	-51.67*	-39.76*	-55.05*	-39.76*	-55.05*
22	CLN 2116 B-1 x Solan Vajr	-9.91*	-0.50	-37.25*	-48.66*	-49.10*	-62.03*	-49.10*	-62.03*
23	CLN 2123 A-1 x Solan Vajr	-41.48*	-33.33*	30.99*	7.17*	48.23*	11.11*	48.23*	11.11*
24	BWR-1 x Solan Vajr	-13.51*	-4.48	2.90	-15.81*	-16.01*	-37.34*	-16.01*	-37.34*
25	BWR-5 x Solan Vajr	-18.92*	-10.45	-36.46*	-48.00*	-58.52*	-69.06*	-58.52*	-69.06*
26	EC-528372 x Solan Vajr	-24.77*	-16.91*	14.94*	-5.95*	-1.34	-26.39*	-1.34	-26.39*
27	EC-521041 x Solan Vajr	-21.65*	-11.94*	7.68*	-11.90*	-0.17	-25.51*	-0.17	-25.51*
28	EC-526146 x Solan Vajr	-32.66*	-25.62*	-28.05*	-40.02*	-44.64*	-58.70*	-44.64*	-58.70*
29	EC-5863 x Solan Vajr	11.32*	22.50*	20.02*	-1.79	68.00*	25.73*	68.00*	25.73*
30	EC-521079 x Solan Vajr	-23.65*	-15.67*	-7.77*	-24.53*	-21.33*	-41.31*	-21.33*	-41.31*
31	CLN 2070 B-1 x Arka Meghali	-22.22*	-32.09*	-4.32	-42.30*	-53.82*	-71.48*	-53.82*	-71.48*
32	CLN 2116 B-1 x Arka Meghali	-5.66	-25.62*	-5.72	-44.83*	-47.34*	-72.71*	-47.34*	-72.71*
33	CLN 2123 A-1 x Arka Meghali	-27.72*	-17.66*	-20.75*	-39.04*	-55.36*	-66.54*	-55.36*	-66.54*
34	BWR-1 x Arka Meghali	-15.75*	-28.11*	-7.74	-52.49*	-39.95*	-74.30*	-39.95*	-74.30*
35	BWR-5 x Arka Meghali	3.98	-28.61*	67.58*	-13.69*	46.65*	-40.41*	46.65*	-40.41*
36	EC-528372 x Arka Meghali	-20.42*	-36.07*	35.46*	-30.24*	-28.41*	-70.91*	-28.41*	-70.91*
37	EC-521041 x Arka Meghali	-27.21*	-18.16*	-9.65*	-34.31*	-18.79	-39.41*	-18.79	-39.41*
38	EC-526146 x Arka Meghali	-29.26*	-30.85*	-35.09*	-45.88*	-55.88*	-71.02*	-55.88*	-71.02*
39	EC-5863 x Arka Meghali	-33.11*	-26.62*	-0.87	-26.41*	-63.52*	-72.70*	-63.52*	-72.70*
40	EC-521079 x Arka Meghali	-7.13	-31.84*	-3.63	-50.37*	-40.89*	-75.98*	-40.89*	-75.98*

Table.5 Estimation of heterosis for alternaria blight severity, buckeye rot incidence, total soluble solids, ascorbic acid content and lycopene content

Sr. No	Crosses	Alternaria blight severity (%)		Buckeye rot incidence (%)		Total soluble solids (°Brix)		Ascorbic acid content (mg/100g)		Lycopene content (mg/100g)	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	CLN 2070 B-1 x FT-5	-9.61	-3.83	22.07*	26.05*	11.50*	5.00	-8.09*	3.56	0.77	-14.06*
2	CLN 2116 B-1 x FT-5	-10.98	-5.29	-4.47	-0.72	-19.38	-13.33*	-22.67*	-12.44*	-34.79*	-33.46*
3	CLN 2123 A-1 x FT-5	-24.70*	-19.89*	-16.30	-13.18	-16.81*	-21.68*	-0.40	11.11*	5.29*	14.65*
4	BWR-1 x FT-5	-35.21*	-9.67	-18.58*	9.89	5.31	-0.82	-6.34*	-3.22	23.64	-17.29*
5	BWR-5 x FT-5	13.17	8.21	12.12	9.06	-7.34	-15.83*	8.60	7.33	-40.34*	-49.11*
6	EC-528372 x FT-5	0.58*	-5.29	23.30*	13.70	-45.74*	-41.68*	-13.91*	-10.22*	-29.79*	-28.34*
7	EC-521041 x FT-5	10.76	8.94	8.92	1.03	0.00	-9.18	11.42	14.33*	0.74*	9.71
8	EC-526146 x FT-5	-39.14	-15.15*	-22.54	4.63	8.26*	-1.68	10.65*	4.44	38.78*	-7.13
9	EC-5863 x FT-5	2.48	-2.01	35.71*	31.00*	-7.08	-12.50*	3.34	10.00*	12.24*	6.93
10	EC-521079 x FT-5	32.28	14.42*	75.04*	10.09	-15.50	-9.18	-14.90*	-4.78	-26.29	-24.78*
11	CLN 2070 B-1 x Solan Lalima	-32.28*	-33.39*	-17.63*	-38.00*	4.43	-1.68	-13.11*	-4.22	-18.68*	-11.44*
12	CLN 2116 B-1 x Solan Lalima	-62.17*	-47.26*	-52.40*	-35.84*	22.12	15.00*	-1.42*	0.56	-8.49*	-12.81*
13	CLN 2123 A-1 x Solan Lalima	-27.01	-13.69*	-50.99	-37.59*	-0.82	0.83	7.83	7.11	39.92*	19.33*
14	BWR-1 x Solan Lalima	-54.48*	-46.17*	-48.28*	-35.22*	-16.28*	-10.00*	-9.86*	-5.56	-13.64*	-11.87*
15	BWR-5 x Solan Lalima	-23.30	-9.31	-46.72*	-32.55*	-8.20*	-6.68	-9.91*	-7.11	-23.56*	-16.75*
16	EC-528372 x Solan Lalima	-28.40	-0.18	-39.45*	-17.51*	-19.67*	-18.33*	-12.18*	-16.67*	6.52*	-28.71*
17	EC-521041 x Solan Lalima	-43.32*	-45.80*	-47.08*	-48.51*	17.65	0.00	0.32	6.22	52.05*	29.67*
18	EC-526146 x Solan Lalima	-43.05*	-46.90*	-24.40	-29.56*	-13.18*	-6.68	3.19	14.89*	-12.07*	-10.28
19	EC-5863 x Solan Lalima	-33.40	-34.49*	-44.73*	-47.79*	2.83*	-9.18	-2.23	7.22	11.85*	21.80*
20	EC-521079 x Solan Lalima	9.03*	52.01*	-24.60*	3.40	4.90*	-10.83*	-4.82*	-3.44	4.88*	-18.59*
21	CLN 2070 B-1 x Solan Vajr	-51.94*	-45.80*	-57.42*	-42.64*	-6.93*	-21.68*	3.66	2.22	-17.61*	-29.74*
22	CLN 2116 B-1 x Solan Vajr	1.29*	14.23*	-17.81*	10.92	-12.40	-5.83	-7.74*	-4.00	4.64	6.78
23	CLN 2123 A-1 x Solan Vajr	-51.78*	-45.62*	-45.34	-26.78*	2.83	-9.18	2.12	4.56	-7.36	0.87
24	BWR-1 x Solan Vajr	-43.72*	-21.53*	-23.99*	2.47	16.83	-1.68	1.48*	-4.44	28.65*	-13.91*
25	BWR-5 x Solan Vajr	5.34	0.73	7.62*	10.61	11.22*	-0.82	-10.73	-1.11	-30.76*	-34.55*
26	EC-528372 x Solan Vajr	-38.95*	-42.52*	-27.35*	-25.54*	-26.36	-20.83*	-21.22*	-8.44	-38.93*	-37.68*
27	EC-521041 x Solan Vajr	-31.54*	-32.66*	-22.24*	-20.19*	9.35	-2.50	-0.10	14.44*	-16.20*	-8.75
28	EC-526146 x Solan Vajr	-30.12	-2.55	-26.05*	0.20	17.76	5.00	-0.73*	5.56	-5.32*	-10.50
29	EC-5863 x Solan Vajr	-44.28*	-46.71*	-30.71	-32.96*	-23.88	-15.00*	8.11*	15.56*	8.37*	19.83*
30	EC-521079 x Solan Vajr	49.76	14.78*	57.80*	-0.41	-14.93*	-5.00	-14.94	-4.44	-41.00*	-34.77*
31	CLN 2070 B-1 x Arka Meghali	41.37	39.05*	92.84	44.59*	-8.96	1.68	-21.19*	-12.78*	-42.98	-36.96*
32	CLN 2116 B-1 x Arka Meghali	-29.06*	-1.09	-11.35*	19.57*	-29.10*	-20.83*	-1.74	0.67	-41.20	-34.99*
33	CLN 2123 A-1 x Arka Meghali	37.02	31.02*	38.90	35.01*	0.00	-5.83	-14.66	-5.56	-25.44*	-31.40*
34	BWR-1 x Arka Meghali	45.71*	11.68	92.15	30.79*	-5.43	1.68	-15.69*	-2.11	-38.21	-36.96*
35	BWR-5 x Arka Meghali	37.66	35.40*	84.85	38.62*	15.04*	8.33	-26.60*	-16.00*	-43.44*	-38.40*
36	EC-528372 x Arka Meghali	-14.92*	18.61*	2.36	38.21*	6.20*	0.00	-9.52*	-3.89	-33.68	-38.99*
37	EC-521041 x Arka Meghali	21.71	35.04*	-12.24	30.48*	-32.84*	-25.00*	4.01*	0.89	-10.94*	-24.05*
38	EC-526146 x Arka Meghali	27.30	41.24*	-6.89	38.41*	-11.94*	-1.68	0.87*	3.33	-31.07*	-29.65*
39	EC-5863 x Arka Meghali	-10.36*	-0.55	-14.88	25.85*	-13.43	-3.33	-1.54	-0.78	-32.40*	-26.37*
40	EC-521079 x Arka Meghali	11.13*	54.93*	1.95	51.49*	-29.85*	-21.68*	-2.04*	-9.33	2.51	-31.40*

Desirably significant negative heterosis over better parent ranged from maximum -57.42 per cent (CLN 2070 B-1 x Solan Vajr) to undesirably high incidence of 75.04 % in EC-521079 x FT-5 for buckeye rot incidence, respectively over the better parents. Over the standard check, while 14 cross combinations showed significantly lesser disease menace, with EC-521041 x Solan Lalima (-48.51) showing the maximum negative heterosis. For TSS 7 combinations produced significant positive heterosis over the better parent, maximum being in BWR-5 x Arka Meghali (15.04 %) (Table 5), on the contrary, only one combination (CLN 2116 x Solan Lalima (15.00 %) developed and evaluated significantly surpassed in positive heterotic effect over the standard check. Gul *et al.,* (2013) reported similar results over better parent. An insight into the (Table 5) revealed that heterosis over better parent was found significant positive in EC-526146 x FT-5 (10.65 %) followed by 4 more crosses for ascorbic acid content whereas, 6 cross combinations showed significant positive heterosis over the standard check, maximum being in EC-5863 x Solan Vajr (15.56 %) the results are in line with Anita *et al.,* (2005). Eleven of the cross combinations surpassed the better parent in heterotic values in case of lycopene content maximum being in EC-521041 x Solan Lalima (52.05 %). Five cross combinations exceeded the standard check in heterotic values as presented in Table 5 maximum was reported in EC-521041 x Solan Lalima (29.67) Mondal *et al.,* (2009) reported similar results over the better parent.

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How to cite this article:

Shilpi Khar and Divya Arti. 2019. Heterosis Studies for Yield and Yield Attributing Traits in Tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India. *Int.J.Curr.Microbiol.App.Sci.* 8(01): 52-61. doi: https://doi.org/10.20546/ijcmas.2019.801.007