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Estimation of heterosis for earliness, yield and yield contributing traits in tomato (*Solanum lycopersicum* L.)

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ABSTRACT

With an objective to estimate the heterosis for earliness, yield and yield contributing traits in tomato, 20 hybrids were produced from ten lines and two testers and were evaluated. BT-1-1 × FT-5 and EC-191531 × FT-5 had maximum negative heterobeltiosis, whereas, EC-620410 × Solan Lalima showed maximum negative standard heterosis for days to 50% flowering. EC-8910155 × FT-5 recorded maximum negative value for both heterobeltiosis and standard heterosis for days to marketable maturity. BT-1-1 × FT-5 showed maximum heterobeltiosis for number of fruits per cluster, yield per plant and harvest duration. Moreover, it had maximum standard heterosis for the former two traits. Furthermore, it recorded maximum heterobeltiosis for number of marketable fruits per plant, whereas, LE-79-5 × FT-5 recorded maximum standard heterosis for this trait. BT-1-1 × Solan Lalima had maximum heterobeltiosis and standard heterosis for average fruit weight. LE-79-5 × FT-5 showed maximum negative heterobeltiosis and standard heterosis for severity to Alternaria.

***Keywords*:** Earliness, heterosis, standard heterosis, tomato, yield.

Tomato is one of the most important commercial vegetable crops grown extensively in the tropical and subtropical regions of the world (Rao *et al*., 2007). Although, India produced 18.73 million tonnes of tomato from an area of 0.88 million hectares and ranked second just after China (Raj *et al*., 2018), the national productivity (21.2 tonnes ha^{-1}) is much lesser than that of world average (33.99 tonnes ha^{-1}) (FAOSTAT, 2014). This yield gap could be overcome by developing high yielding hybrids with minimum severity of economically important diseases. Keeping in view the above fact, the present study was undertaken to develop an early, high yielding F_1 cultivar of tomato by adopting line × tester mating design (Kempthorne, 1957).

MATERIALS AND METHODS

The present investigation was conducted at the Experimental Research Farm, RHR and TS, Jachh, Kangra. During *Rabi*, 2015, twenty crosses were made in a line × tester involving ten lines *viz.*, EC-8910155, EC-191531, EC-191535, EC-620410, EC-174913, EC-267727, EC-37239, LE-79-5, Yalabingo, BT-1-1 and two testers *viz*., Solan Lalima and FT-5, which are procured from different sources and are being maintained at Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The resulting 20 F_1s and the parents were evaluated in a Randomized Complete Block Design (RCBD) with three replications during *Kharif*, 2016. The row to row and plant to plant spacing was 90 cm and 30 cm, respectively, keeping 20 plants per plot (2.7 × 2.0 m) in each entry. Standard cultural practices for raising healthy crop of tomato were followed (Raj *et al.*, 2017).

For plant characters, observations were recorded from five randomly selected plants at the end of the flowering season and for observing the fruit characters, ten random fruits were selected from each entry in each replication from the third harvest and the mean value was taken. Data were recorded for days to 50% flowering, number of fruits per cluster, number of marketable fruits $plant^{-1}$, average fruit weight (g), plant height (cm), days to marketable maturity, harvest duration (days) and early blight severity (%) and fruit yield $plant^{-1}$ (g). For recording *Alternaria* blight severity, ten random leaves were selected in each of the five randomly selected plants in each entry at 50 days after transplanting. We adopted 0-4 scale of Dey and Chakraborty (2012) for recording the *Alternaria* blight severity, where, grade 0 denotes plants completely free from disease infection (resistant) and 4 implied more than 10% plants infected (highly susceptible). The Percent Disease Index (PDI) was calculated by adopting the formula of McKinney (1923), which is as follows

$$\text{PDI of } \textit{Alternaria}\,(\%) = \frac{\text{Sum of all disease ratings}}{\text{Total number of ratings} \times \text{Highest disease grade}}$$

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Table 1: Analysis of variance for earliness, yield and its contributing traits in tomato

Sources of Variation	Mean Sum of Squares								
	Replications	Treatments	Parents (P)	Crosses (C)	P *vs* C	Lines	Testers	Lines × Testers	Error
Degrees of Freedom	2.00	31.00	11.00	19.00	1.00	9.00	1.00	9.00	62.00
Days to 50% flowering	1.53	19.71*	8.48*	21.38*	111.67*	28.15*	4.82*	16.45*	0.55
Days to marketablematurity	2.95	60.41*	11.85*	26.37*	1241.37*	24.04*	19.27*	29.49*	0.29
Number of fruits per cluster	0.03	1.14*	0.68*	1.19*	5.21*	0.81*	0.12*	1.68*	0.02
Number of marketable fruits per plant	0.46	36.55*	19.28*	44.35*	78.44*	76.67*	41.00*	12.40*	0.25
Average fruit weight	1.66	211.30*	67.11*	221.98*	1594.54*	372..40*	174.75*	76.81*	0.55
Yield per plant	482.29	135121.74*	58466.67*	113288.68*	1393155.63*	174385.37*	60801.67*	58023.89*	458.64
Harvest duration	0.28	6.90*	9.42*	2.02*	72.00*	3.42*	0.02*	0.83	0.42
Plant height	0.51	1153.11*	1685.72*	450.24*	8649.02*	684.00*	16.66*	264.66*	1.75
***Alternaria* blight severity**	80.94	129.85*	121.53*	130.84*	202.48*	162.62*	500.78*	57.95*	22.24

*Note : *Significant at 5% level of significance*

The recorded data was subjected to analysis by MS-EXCEL and OPSTAT (Sheoran *et al.*, 1998). Heterobeltiosis and standard heterosis were calculated by using the following formula,

$$\text{Heterobeltiosis (\%)} = \frac{F_1 - BP}{BP}$$

$$\text{Standard Heterosis (\%)} = \frac{F_1 - SV}{SV}$$

Where, F_1 = mean performance of the cross, BP= Mean performance of the Better Parent and SV= Standard check Variety (NAVEEN 2000$^+$, which is a leading commercial variety of the North Indian states).

RESULTS AND DISCUSSIONS

The analysis of variance, as presented in table 1, showed significant differences among the lines, testers and the line × testers for all the traits under study. Range, number of significant crosses, best three crosses and mean performance with respect to heterobeltiosis and standard heterosis for different important traits in tomato has been presented in table 2 and table 3, respectively.

Out of the 20 derived crosses, BT-1-1 × FT-5 and EC-191531 × FT-5 had maximum negative heterobeltiosis (-23.08%), whereas the cross EC- 620410 × Solan Lalima showed maximum negative standard heterosis (-21.00%) for days to 50% flowering. The cross EC-8910155 × FT-5 recorded maximum negative value for both heterobeltiosis (-19.73%) as well as standard heterosis (-12.67%) for days taken to marketable maturity. These two traits are the most important earliness trait, which ensures a higher market price of tomato. Similar heterotic pattern was also recorded by Singh *et al.* (2012) and Patwary *et al.* (2013). The resultant of the cross between BT-1-1 and FT-5 showed maximum heterobeltiosis (46.48%) as well as standard heterosis (67.88%) for number of fruits per cluster. Moreover, it recorded maximum heterobeltiosis (41.32%) for number of marketable fruits per plant, whereas, the cross, LE-79-5 × FT-5 had maximum standard heterosis (43.43%) for this trait. Number of fruits per cluster and number of marketable fruits per plant directly contribute towards higher yield. Similar trends of heterosis for these traits were reported by Ahmad *et al.* (2015) and Kumar and Singh (2016). Fruit weight is also one of the important components of fruit yield and among all the twenty crosses, the combination, BT-1-1 × Solan Lalima showed maximum extent of both heterobeltiosis (37.01%) as well as standard heterosis (24.79%) for this trait. Similar results of heterobeltiosis and standard heterosis for this trait was reported by Kumari and

Table 2: Best three crosses, range, number of significant crosses and mean performance with respect to heterobeltiosis for different traits.

Traits	Three superior crosses based on heterobeltiosis (%)	Range of heterosis over BP	Number of significant crosses	Mean performance of crosses
Days to 50% flowering	BT-1-1 × FT-5 (-23.08)	-23.08 (BT-1-1 × FT-5 and EC-191531 × FT-5) to	11	26.67
	EC-191531 × FT-5 (-23.08)	-0.96 (EC-191535 × FT-5)		26.67
	EC- 620410 × Solan Lalima (-21.00)			26.33
Days to marketable maturity	EC-8910155 × FT-5 (-19.73)	-19.73 (EC-8910155 × FT-5) to -6.91 (EC-8910155 ×	20	59.67
	LE-79-5 × FT-5 (-18.83)	Solan Lalima and EC-267727 × Solan Lalima)		60.33
	EC- 174913 × FT-5 (-18.39)			60.67
Number of fruits per cluster	BT-1-1 × FT-5 (46.48)	-15.03 (BT-1-1 × Solan Lalima) to 46.48 (BT-1-1 × FT-5)	5	6.93
	EC-267727 × FT-5 (23.94)			5.87
	Yalabingo × Solan Lalima (10.46)			5.63
Number of marketable fruits per plant	BT-1-1 × FT-5 (41.32)	-33.81 (EC-37239 × Solan Lalima) to 41.32 (BT-1-1 × FT-5)	6	22.80
	LE-79-5 × FT-5 (36.80)			28.50
	EC-8910155 × FT-5 (34.62)			21.00
Average fruit weight	BT-1-1 × Solan Lalima (37.01)	-9.46 (LE-79-5 × Solan Lalima) to 37.01 (BT-1-1 × Solan Lalima)	17	85.58
	EC-37239 × Solan Lalima (32.74)			80.75
	EC-191531 × FT-5 (25.31)			77.00
Yield per plant	BT-1-1 × FT-5 (66.01)	14.90 (EC- 174913 × Solan Lalima) to 66.01 (BT-1-1 × FT-5)	16	1676.67
	EC-8910155 × FT-5 (38.41)			1273.33
	Yalabingo × Solan Lalima (35.05)			1400.00
Harvest duration	BT-1-1 × FT-5 (9.57)	-4.08 (EC-267727 × Solan Lalima) to 9.57 (BT-1-1 × FT-5)	4	34.33
	EC-191531 × FT-5 (7.45)			33.67
	EC-37239 × FT-5 and EC-191535 × FT-5 (6.38)			33.33
Plant height	EC- 174913 × FT-5 (10.28)	-36.98 (EC- 620410 × Solan Lalima) to 10.28 (EC- 174913 × FT-5)	5	134.66
	EC-37239 × FT-5 (9.40)			120.39
	EC-191535 × FT-5 (3.34)			126.18
Alternaria blight severity	LE-79-5 × FT-5 (-54.55)	-54.55 (LE-79-5 × FT-5) to 23.07 (EC- 620410 × Solan Lalima)	4	11.11 [19.26]#
	EC-267727 × FT-5 (-50.01)			13.33 [20.97]#
	BT-1-1 × FT-5 (-45.46)			13.33 [20.97]#

Note : Values in the parenthesis all are sine transformed values.

Table 3: Best three crosses, range, number of significant crosses and mean performance with respect to standard heterosis for different traits

Traits	Three superior crosses based on standard heterosis (%)	Range of heterosis over standard check	Number of significant crosses	Mean performance of crosses
Days to 50% flowering	EC- 620410 × Solan Lalima (-21.00) BT-1-1 × FT-5 (-19.18) EC-191531 × FT-5 (-19.18)	-21.00 (EC- 620410 × Solan Lalima) to 2.03 (Yalabingo × FT-5)	13	26.33 26.67 26.67
Days to marketable maturity	EC-8910155 × FT-5 (-12.67) EC-267727 × FT-5 and EC-267727 LE-79-5 × FT-5 (-11.71) EC- 174913 × FT-5 and EC- 620410 × Solan Lalima (-11.21)	-12.67 (EC-8910155 × FT-5) to -1.46 (EC-191535 × FT-5; EC-8910155 × Solan Lalima; EC-191531 × FT-5; × Solan Lalima)	20	59.67 60.33 60.67
Number of fruits per cluster	BT-1-1 × FT-5 (67.88) EC-267727 × FT-5(42.05) EC- 174913 × Solan Lalima (38.82)	-1.53 (EC- 620410 × FT-5) to 67.88 (BT-1-1 × FT-5)	18	6.93 5.87 5.73
Number of marketable fruits per plant	LE-79-5 × FT-5 (43.43) LE-79-5 × Solan Lalima (27.83) BT-1-1 × FT-5 (14.75)	-37.93 (EC-37239 × Solan Lalima) to 43.43 (LE-79-5 × FT-5)	4	28.50 25.40 22.80
Average fruit weight	BT-1-1 × Solan Lalima (24.79) EC-37239 × Solan Lalima (17.75) EC-191535 × Solan Lalima (15.31)	-23.69 (LE-79-5 × Solan Lalima) to 24.79 (BT-1-1 × Solan Lalima)	10	85.58 80.75 79.08
Yield per plant	BT-1-1 × FT-5 (24.20)	-32.35 (EC- 620410 × Solan Lalima) to 24.20 (BT-1-1 × FT-5)	4	1676.67

Sharma (2011) and Agarwal *et al*. (2014). For fruit yield plant^{-1}, the cross between BT-1-1 and FT-5 had highest positive value for both heterobeltiosis (66.01%) and standard heterosis (24.20%). These results are in accordance with the findings of Kumar *et al*. (2009); Singh and Sastry (2011) and Kumar and Singh (2016). As the ultimate goal of any breeding programme is to achieve the maximum marketable yield plant^{-1}, from our study, this cross combination may be further evaluated in multiple locations for the commercial utilization of heterosis for earliness and yield. Furthermore, harvest duration is one of the major contributing factors towards the ultimate yield. In our study, the cross, BT-1-1 × FT-5 had maximum harvest duration over better parent (9.57%), whereas, all the crosses failed to exceed the harvest duration of the standard check and as a result, none of them were found significant for standard heterosis. Similar heterobeltiosis pattern for harvest duration was also noted by Sharma and Thakur (2008) and Kumari and Sharma (2011). In determination of the harvest duration of the crop, plant height plays a major role in tomato as indeterminate varieties have a longer plants height resulting into longer harvest duration. Out of all the crosses, EC-174913 × FT-5 recorded maximum heterobeltiosis (10.28%) but all crosses had significantly lesser plant height than that of the standard check. Similar findings of positive heterosis over the better parent for this trait were reported earlier by Kumar *et al*. (2009) and Kumari *et al*. (2010). As *Alternaria* blight (early blight) is one of the most devastating diseases of tomato all over the country, it is better to have a variety with minimum early blight severity, which can be achieved by exploring negative heterosis. In our study, the cross, LE-79-5 × FT-5 had maximum value of negative heterosis both over better parent (-54.55%) and standard check (-50.00%) for this trait. Earlier, Rao *et al*. (2007) also identified two cross combinations with higher yield and lesser intensity of early blight in tomato. As the cross, BT-1-1 × FT-5 performed best for most of the traits under study, it may be further tested in multiple locations in order to exploit heterosis for earliness and yield in tomato.

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