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Evaluations of triple test cross progenies of tomato (*Solanum lycopersicum*)

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Abstract
The Experiment was carried out at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur during summer seasons of 2021. Twenty four cross combinations along with eight lines and three testers and one standard check were evaluated in a Randomized Block Design with three replications. The analysis of variance for the traits studied *viz*. days to 50% flowering, days to first harvest, duration of fruit harvest, plant height (cm), fruit length (cm), fruit width (cm), fruit shape index, pericarp thickness (mm) and locules per fruit showed the presence of sufficient variability in the germplasm as revealed by significant differences among genotypes and cross combinations. Mean values along with range, standard error of mean, coefficient of variation and critical difference were calculated for all the traits studied.

Keywords: Tomato, variability studies, triple test cross progenies

Introduction
After potatoes and sweet potatoes, tomatoes (*Solanum lycopersicum* L.) are the most widely planted vegetables, although they rank first among vegetables in terms of processing crops. In India, tomatoes are grown on 789 thousand hectares and produced in 19759 thousand tonnes (Anonymous, 2018) [2]. While it is grown in Himachal Pradesh on an estimated 13794.98 hectares of land and produces 577004.5 MT (Anonymous, 2021) [3]. Because of its unique nutritional and therapeutic qualities, tomatoes are among the most significant foods for preventing disease. The pulp and juice have a mild aperient effect, are easily digested, encourage gastric secretion, and purify the blood (Chattopadhyay and Paul, 2012) [5]. The tomato gives food a variety of colours and flavours. Tomato is grown for its edible fruits, which are consumed either raw or cooked or used in the form of various processed products like ketchup, juices, drinks, soup, preserves, puree, paste, powder and whole peeled tomatoes. Tomato is a valuable source of antioxidants, or chemo-protective compounds, and may be called as a functional food (Akhtar and Hazra, 2013) [1] which provides health benefits beyond basic nutrition. The tomato is a day-neutral, strongly self-pollinating, diploid species with 12 pairs of chromosomes (2n = 2x = 24). It is a warm-season vegetable crop grown in tropical and mild-temperate locations all over the world. It has tap root and growth habit of tomato plants is determinate, semi-determinate and indeterminate. There are number of biometrical techniques for the evaluation of varieties in terms of genetic components but triple test cross analysis (TTC) is one of the most efficient design for investigating genetic architecture.

Material and Methods
The Experiment was carried out at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur during summer season of 2021. The experimental material comprised of eight lines *viz*. DPT 1 (L_1), DPT 3 (L_2), DPT 4 (L_3), DPT 5 (L_4), DPT 6 (L_5), DPT 7 (L_6), DPT 8 (L_7), 2015/TOINVAR-4 (L_8) and three testers namely 12-1 (T_1), Palam Pride (T_2) and F1 ($T_1 \times T_2$) of tomato. Twenty four cross combinations along with eight lines and three testers and one standard check Avatar were evaluated in a Randomized Block Design with three replications. The seeds of 24 cross combinations, eight lines and three testers were sown in the nursery beds on February 02, 2021 inside polytunnel. The transplanting of seedlings was carried out in a Completely Randomized Block Design (RCBD) with three replications on March 26, 2021. Row to row and plant to plant distances was maintained at 75 × 45 cm, with plot size 2.7 × 1.5 m, accommodating 12 plants in each entry per replication.

Results and Discussion

The analysis of variance for the traits studied *viz*. days to 50% flowering, days to first harvest, duration of fruit harvest, plant height (cm), fruit length (cm), fruit width (cm), fruit shape index, pericarp thickness (mm) and locules per fruit are given in Table1. The analysis of variance showed the presence of sufficient variability in the germplasm as revealed by significant differences among genotypes and cross combinations for all the traits studied.

Table 1: Analysis of variance for different traits in genotypes of tomato

	Mean squares due to		
Source of variation	**Replication**	**Treatment**	**Error**
Traits df	**2**	**35**	**70**
Days to 50% flowering	6.36	156952.80*	7.87
Days to first harvest	12.84	639492.60*	25.11
Duration of fruit harvest	7.34	233607.10*	17.28
Plant height (cm)	65.81	1119480.00*	73.53
Fruit length (cm)	0.16	2272.00*	0.18
Fruit width (cm)	0.18	2711.57*	0.20
Fruit shape index	0.00	93.24*	0.00
Pericarp thickness (mm)	0.15	3752.13*	0.18
Locules per fruit	0.07	946.58*	0.08

*Significant at 5% level

Mean performance of genotypes and cross combinations

The mean performance depicted the exact quantified data about the potential of all the genotypes and cross combinations studied. Mean values along with range, standard error of mean [SE (m)±], coefficient of variation (CV%) and critical difference (CD at 5%), are given in Table 2.

Table 2: Mean performance of genotypes and their triple test cross progenies

Genotypes	Days to 50% flowering	Days to first harvest	Duration of fruit harvest	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Fruit shape index	Pericarp thickness (mm)	Locules per fruit
$L_1 \times T_1$	38.00	79.67	46.67	132.67	4.13	4.89	0.85	6.07	2.51
$L_1 \times T_2$	37.00	72.33	51.00	120.27	4.70	4.76	0.99	5.50	2.10
$L_1 \times T_3$	38.00	77.00	47.67	116.27	4.06	4.40	0.92	5.13	3.67
$L_2 \times T_1$	37.00	75.00	47.33	115.47	4.13	4.99	0.83	4.10	3.30
$L_2 \times T_2$	39.00	75.67	49.33	119.37	4.07	4.69	0.87	4.10	3.20
$L_2 \times T_3$	35.33	72.33	45.67	122.87	4.33	4.97	0.87	5.70	3.60
$L_3 \times T_1$	36.67	72.33	52.67	116.40	3.78	4.90	0.77	4.43	3.41
$L_3 \times T_2$	33.33	71.67	45.33	114.43	4.68	5.69	0.82	5.93	3.80
$L_3 \times T_3$	35.67	75.00	47.67	106.67	4.20	4.76	0.88	6.53	3.44
$L_4 \times T_1$	31.00	75.00	41.67	113.17	4.17	5.00	0.83	6.53	2.50
$L_4 \times T_2$	44.67	78.33	41.67	118.07	5.53	5.97	0.93	8.63	3.77
$L_4 \times T_3$	39.00	72.33	48.33	131.60	5.87	6.00	0.98	4.80	2.00
$L_5 \times T_1$	30.33	74.00	51.00	121.47	4.53	5.00	0.91	6.80	3.10
$L_5 \times T_2$	37.33	72.33	50.33	92.73	5.10	5.09	1.01	6.33	3.00
$L_5 \times T_3$	33.67	72.33	50.33	89.87	4.20	4.75	0.88	4.67	2.50
$L_6 \times T_1$	36.00	75.00	47.67	104.87	4.25	5.23	0.81	5.40	2.72
$L_6 \times T_2$	38.00	75.00	47.67	116.57	5.20	6.01	0.86	5.90	3.52
$L_6 \times T_3$	35.67	75.00	48.00	103.37	5.00	5.40	0.92	5.60	3.82
$L_7 \times T_1$	26.00	73.00	50.33	114.83	4.13	5.28	0.78	6.50	2.30
$L_7 \times T_2$	35.33	73.00	47.33	114.87	5.40	5.39	1.00	7.30	3.31
$L_7 \times T_3$	43.00	73.00	52.00	94.80	4.50	5.01	0.90	6.43	2.72
$L_8 \times T_1$	36.00	74.67	48.00	91.80	4.61	4.91	0.94	6.73	2.72
$L_8 \times T_2$	41.00	73.00	42.33	97.97	5.53	5.11	1.08	6.00	3.50
$L_8 \times T_3$	36.00	73.00	45.00	95.97	4.13	4.69	0.88	6.07	2.72
L_1	43.00	73.00	45.00	78.80	5.13	4.65	1.11	7.33	2.50
L_2	41.67	87.00	43.67	82.40	3.90	4.27	0.91	5.00	2.72
L_3	39.00	78.67	42.00	69.67	3.90	4.27	0.91	5.53	3.10
L_4	42.00	73.00	50.33	95.47	3.90	3.96	0.98	6.77	2.48
L_5	41.00	75.67	50.33	78.87	4.80	4.77	1.01	6.93	2.70
L_6	35.67	79.67	38.00	75.07	4.34	5.00	0.87	5.93	3.90
L_7	38.33	78.33	41.67	71.17	4.05	4.03	1.01	5.13	2.70
L_8	40.00	88.33	34.33	60.40	5.80	5.98	0.97	5.93	2.69
T_1	38.00	78.67	38.00	82.67	3.19	4.08	0.78	4.13	2.69
T_2	41.00	82.33	39.33	93.67	4.51	4.31	1.04	6.10	2.90
T_3	42.00	81.00	39.33	72.67	4.10	4.63	0.88	3.80	2.80
Avtar (Resistant check)	38.33	75.67	43.67	85.00	4.91	4.98	0.99	5.33	2.69

Mean	37.58	75.87	45.85	100.34	4.52	4.94	0.92	5.81	2.92
Range	26-44.67	71.67-88.33	34.33-52.67	60.4-132.67	3.19-5.87	3.96-6.01	0.77-1.11	3.8-8.63	2-3.90
SE (m) ±	1.62	2.89	2.40	4.95	0.24	0.26	0.03	0.24	0.16
CV (%)	7.46	6.60	9.06	8.55	9.34	9.01	6.45	7.30	9.69
CD (5%)	4.57	8.16	6.77	13.96	0.69	0.73	0.10	0.69	0.46

The character-wise performances of different genotypes and cross combinations are given below:

Days to 50% flowering

Days to 50% flowering is very important parameter recorded to determine the earliness of a particular genotype. Earliness is the utmost desirable character, as early crop produce can get a higher price in the market. Different genotypes varies significantly with respect to number of days to 50% flowering. $L_7 \times T_1$ took the minimum days (26.00 days) for 50% plants to get into flowering and it was statistically at par with $L_5 \times T_1$ (30.33 days). The grand mean value for this trait was 37.58 days. Tasisa *et al.* (2011) [17], Chernet *et al.* (2013) [6], Chadha and Walia, (2016) [4], Shweta *et al.* (2016) [15], Singh *et al.* (2018) [16] and Paras, (2019) [11] have also observed wide variation for days to 50% flowering in different tomato cultivars.

Days to first harvest

Early maturing strains hold extensive importance in procuring early markets. The range for this trait varied from 71.67 to 88.33 days with a grand mean of 75.87 days. The minimum number of days to first harvest (71.67 days) were taken by $L_3 \times T_2$ however, all other genotypes were also found statistically at par with this genotype in exhibiting minimum number of days to first harvest except four genotypes *viz.* T_3 (81), T_2 (82.33), L_2 (87.00) and L_8 (88.33). Results are very close with the findings of Sharma *et al.* (2013) [14], Chadha and Walia, (2016) [4], Hasan *et al.* (2016) [7], Kumar and Singh, (2016) [10] and Sehgal, (2017) [13].

Duration of fruit harvest (days)

It is desirable as it will not only avoid glut in the market but off-season nature is also maintained. Therefore, one should concern with the longest harvest duration while doing selections. Statistical analysis showed that genotypes revealed significant variations for duration of harvest. The duration of harvest in genotypes ranged from 34.33 to 52.67 days with the grand mean of 45.85 days. The maximum harvest duration was recorded in $L_3 \times T_1$ (52.67 days), which was statistically at par with other 20 genotypes. Kumar *et al.* (2013) [9], Patil *et al.* (2013) [12], Chadha and Walia, (2016) [4], Sehgal, (2017) [13] and Paras, (2019) [11] had also observed significant variation for duration of fruit harvest in tomato.

Plant height (cm)

Indeterminate types of genotypes or long plant height are preferred over semi-determinate and determinate types in high rainfall areas. In mid hills of Himachal Pradesh, the fruiting period of tomato coincides with heavy rainfall, causing huge losses to fruits due to fruit rot disease. Determinate type of cultivars experiences more infection of the diseases than semi-determinate and indeterminate cultivars. The range of plant height varied from 60.4 (L_8) to 132.67 cm ($L_1 \times T_1$) with grand mean value of 100.34 cm. $L_1 \times T_1$ was found significantly taller than all other genotypes and standard check. Other genotypes which had long height of the plants were $L_4 \times T_3$ (131.60 cm), $L_2 \times T_3$ (122.87 cm), $L_5 \times T_1$ (121.47 cm), $L_1 \times T_2$ (120.27 cm) and $L_2 \times T_2$ (119.37cm). In general, these findings are in line with Paras, (2019) [11] and Chadha and Walia, (2016) [4].

Fruit length (cm)

The range for this trait varied from 3.19 (T_1) to 5.87 ($L_4 \times T_3$) with a grand mean of 4.52. Cross combination $L_4 \times T_3$ was found with maximum fruit length and was statistically at par with L_8 (5.80), $L_8 \times T_2$ (5.53), $L_4 \times T_2$ (5.53), $L_7 \times T_2$ (5.4) and $L_6 \times T_2$ (5.20). Khapte and Jansirani, (2014) [8] and Singh *et al.* (2018) [16] had also observed variation in fruit shape index among different tomato cultivars.

Fruit width (cm)

The range for this trait varied from 3.96 (L_4) to 6.01 ($L_6 \times T_2$) with a grand mean of 4.94. Cross combination $L_6 \times T_2$ was found with maximum fruit width and was statistically at par with $L_4 \times T_3$ (6.00), L_8 (5.98), $L_4 \times T_2$ (5.97), $L_6 \times T_3$ (5.40) and $L_7 \times T_2$ (5.39).

Fruit shape index

One of the most important features to analyze fruit shape in tomato is the fruit shape index and it is defined as the ratio of fruit length and fruit width. Usually, consumer's preference is towards spherical fruit shape. Flat-round shape is not desirable as it is oftenly observed that during rainy season, water-droplets stagnate on pedicel area of tomato fruit which generally exaggerate fruit rot disease. The range for this trait varied from 0.77 ($L_3 \times T_1$) to 1.11 (L_1) with a grand mean of 0.92. Chernet *et al.* (2013) [6], Khapte and Jansirani, (2014) [8], Chadha and Walia, (2016) [4], Sehgal, (2017) [13] and Singh *et al.* (2018) [16] had also observed variation in fruit shape index among different tomato cultivars.

Pericarp thickness (mm)

Fruits with thick pericarp are desirable for long transportation of the produce as fruits can tolerate transportation losses/jerks much better and remain firm for more number of days as compared to fruits which are having thin layer of pericarp. The grand mean value for this trait was 5.81 mm and the range varied from 3.8 (T_3) to 8.63 mm ($L_4 \times T_2$). $L_4 \times T_2$ which gave the maximum pericarp thickness was found to be significantly superior to all other genotypes. $L_1 \times T_3$ (5.13), L_7 (5.13), L_2 (5.00) and $L_5 \times T_3$ (4.67) were found statistically at par with standard check Avatar (5.33). Shweta *et al.* (2016) [15] and Thapa *et al.* (2016) [18] had also observed significant variation in pericarp thickness among different tomato cultivars.

Locules per fruit

Generally, fruits with lesser locules per fruit are preferred as they advocate higher fruit firmness. The minimum locules per fruit were observed in the genotype $L_4 \times T_3$ (2.00) and it was found statistically at par with $L_1 \times T_2$ (2.10) and $L_7 \times T_1$ (2.30). The grand mean value for this trait was 2.92. Similar findings were also observed by Chernet *et al.* (2013) [6], Patil

et al. (2013) [12], Khapte and Jansirani, (2014) [8], Chadha and Walia, (2016) [4] and Sehgal, (2017) [13].

Conclusion

The analysis of variance revealed significant differences among genotypes and cross combinations for all the traits studied *viz.* days to 50% flowering, days to first harvest, duration of fruit harvest, plant height (cm), fruit length (cm), fruit width (cm), fruit shape index, pericarp thickness (mm) and locules per fruit. It highlighted the presence of sufficient genetic variability in the existing genetic material. Therefore, genotypes hold good promise for further exploitation in hybrid development programme.

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