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Performance of tomato hybrids for quality traits under Mid-hill conditions of Himachal Pradesh

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Abstract
An experiment was conducted during *Kharif* 2016 at the Experimental Farm of RHR&TS, Jachh, Kangra, Himachal Pradesh with an objective to evaluate the quality traits of 20 hybrids resulting from ten lines and two testers mated in a line × tester mating design. The hybrid, EC-620410 × Solan Lalima had maximum fruit shape index while the hybrid EC-37239 × Solan Lalima recorded least number of locules per fruit. Both these traits are desired for long distance transportation as well as processing. Maximum pericarp thickness was recorded the hybrid EC-37239 × FT-5, whereas, the hybrid between LE-79-5 and FT-5 excelled among all with respect to TSS. Ascorbic acid content in the fresh fruits was maximum in BT-1-1 × FT-5. All the studied traits are among the key traits desired for processing and for long distance transportation. Keeping the consumers' preferences and specific end use in view, for commercial exploitation of heterosis, these hybrids may further be evaluated in multiple locations for yield and other yield contributing traits before releasing them as a variety.

Keywords: Tomato, quality traits, performance, mid-hills, Himachal Pradesh

Introduction
Tomato, *Solanum lycopersicum* L, a member of family Solanaceae and native of Central and South America (Vavilov, 1951) [1], is regarded as one of the most important, popular and widely grown vegetables around the globe. Mature and ripe fruits are consumed raw as salad or cooked with other vegetables. Moreover, it holds a top position in the list of processed vegetables (Chaudhary, 1996) [2]. It is processed into different forms *viz.*, puree, paste, sauce etc. Based on the nutritive value and the antioxidant properties owing to presence of lycopene, vitamin c (ascorbic acid) and flavonoides, it is globally considered as 'protective food' (Raj *et al.*, 2017) [3]. Consumption of fresh tomato and/or tomato based products can act against major lifestyle diseases *viz.*, cancer and cardiovascular diseases (Canene-Adams *et al*., 2005) [4].
In Himachal Pradesh, tomato is cultivated throughout the year and thus, this state has become a leading supplier of fresh tomato in the North Indian states during off-season. In most of the states of India, a huge proportion of the fresh produce is lost due to market glut in the peak production season and a lean availability period is observed in the off-season. The loss is mainly attributed to lack of processing and storage facilities and unsuitability of most of the leading fresh-market commercial varieties for processing, which requires high total soluble solids and ascorbic acid content, high acidity (low pH) and dry matter content, lesser number of locules, thick pericarp, oblong shapped fruits resulting into long storage life. Keeping these facts in mind, the experiment was formulated to generate twenty hybrids from ten lines and 2 testers, mated in a line × tester mating design (Kempthorne, 1957) [5] and to evaluate their performance in terms of quality traits in the Mid-hill conditions of Himachal Pradesh.

Materials and Methods
The experiment was conducted at the Experimental Research Farm, RHR&TS, Jachh, Kangra, Himachal Pradesh. 20 hybrids were produced by following a line × tester mating design with 10 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 during Rabi, 2015. Both the lines and the testers, except Solan Lalima were procured from NBPGR, New Delhi and Solan Lalima is an indeterminate pure line released from the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The resultant hybrids and their parents were evaluated in a Randomized Complete Block Design (RCBD) with three replications during *Kharif*, 2016.

For each entry, 20 plants were kept per plot (2.7 m × 2.0 m), maintaining 90 cm row to row and 30 cm plant to plant spacing. Standard cultural practices for raising healthy crop of tomato were followed in both the seasons (Anonymous, 2013)[6]. For comparison of the hybrids, a leading commercial variety of Himachal Pradesh, Naveen 2000+ was taken as standard check. We recorded observations from ten random, fresh and marketable fruits taken from third harvest for quality traits *viz.*, fruit shape index, fruit colour, number of locules per fruit, pericarp thickness (mm), Total Soluble Solids (TSS) and ascorbic acid content (mg/100g of edible portion). The fruit shape index was estimated by dividing polar diameter by equatorial diameter and the mean value was calculated. The fruits with index value ≥1.00 were considered as oval, value between 0.99 to 0.86 was considered as spherical, value between 0.85 to 0.71 was noted as flat round and value ≤ 0.70 was noted as flat (Roy and Choudhary, 1972) [7]. Fruit colour was observed visually with the help of the colour chart of the Royal Horticultural Society, London. Number of locules was counted after cutting the transverse section of the fruits. Pericarp thickness was measured with a digital vernier caliper, whereas, TSS was estimated with the help of hand refractometer (ERMA, Japan). Ascorbic acid content was estimated by following titration method of Ranganna (1986) [8] and was calculated by adopting the following formula-

$$\text{mg of ascorbic acid per 100g of fresh fruit} = \frac{\text{Titrate} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Volume of sample taken for estimation}}$$

The collected data was subjected to analysis by using MS-EXCEL and OPSTAT software packages (Sheron *et al*., 1998) [9].

Results and Discussions

We observed significant differences among the parents as well as the resultant hybrids for all the quality traits under this study. The analysis of variance is presented in Table 1. The perusal of data as presented in table 2 clearly indicates wide variation in fruit colour among all the entries. Fruit colour of tomato depends upon the proportion of lycopene, pro-lycopene and β-carotene. Wide range of variation in lycopene content of tomato fruit was also reported by Kumar and Paliwal (2016) [10] and Salve *et al.* (2017) [11]. Fruit shape of tomato is one of the most important traits which determine the consumer acceptance for a particular end-use. For instance, round shaped fruits are preferred for salad purpose, whereas, oval or oblong shaped fruits are preferred for long distance transportation and processing. Among the parents, minimum (0.78) and maximum (1.06) index of fruit shape was observed in EC-37239 and LE-79-5 respectively, while among the hybrids, EC-191535 × Solan Lalima had minimum (0.74) and EC-620410 × Solan Lalima had maximum value (1.11) of fruit shape index. The standard check, Naveen 2000+ had flat-round shaped fruits (0.77). Out of all the entries, 9 entries had oval shaped, 11 had spherical shaped and 13 had flat-round shaped fruits (Table 3). A wide range of variation with respect to this trait was earlier reported by Gunasekera and Parera (1999) [12], Premalakshme *et al.* (2002) [13] and Kumar *et al.* (2013) [14]. Number of locules per fruit has a great role in determining the ability to withstand long distance transportation. Generally it is observed that with lesser number of locules, fruits tend to get pear shape and attain the ability to stand long distant transportation. This trait ranged from 2.07 (EC-37239) to 3.70 (EC-191531) among the parents, while it ranged from 2.10 (EC- 37239 × Solan Lalima) to 4.53 (LE-79-5 × FT-5) and the standard check, Naveen 2000+ had 4.00 number of locules on an average. In total, 19 hybrids had lesser number of locules than that of the standard check. The resulting crosses with greater or lesser number of locules (table 3) per fruit may further be evaluated for yield traits and can be taken up for commercial production for fresh market or for processing, respectively. Similar range of variation for this trait was also reported by Sethi and Anand (1986) [15], Ghosh *et al.* (1997) [16], Anita *et al.* (2005) [17] and Ahmed *et al.* (2011) [18]. Fruits with thick pericarp remain firm during long distance transportation as compared to the fruits with thin pericarp. Out of all the entries, as presented in table 3, EC-620410 × Solan Lalima had minimum (2.51), while EC- 174913 had maximum (6.83) pericarp thickness. Among the hybrids, maximum pericarp thickness (5.46) was recorded in EC-37239 × FT-5. The standard check Naveen 2000+ had a pericarp thickness of 5.14 mm. Similar variation for this trait was also reported by Gaikwad and Cheema (2010) [19], Kumari and Sharma (2011) [20] and Rajan (2014) [21]. Total soluble solids (TSS) is one of the key trait that influences the suitability of a variety for processing. The perusal of data in table 3 revealed that total soluble solids among the parents ranged from 3.30 (LE-79-5) to 4.39˚B (EC- 191535), whereas, among the hybrids, maximum (4.71˚B) was recorded in LE-79-5 × FT-5 and minimum TSS (3.12˚B) was recorded in EC- 8910155 × Solan Lalima. The former was found statistically at par with that of EC-267727 × FT-5 (4.63˚B), EC-37239 × FT-5 (4.65˚B) and BT-1-1 × FT-5 (4.60˚B). Standard check, Naveen 2000+ recorded TSS of 4.50ºB. The hybrids with high TSS may further be evaluated for other yield contributing traits before releasing as a variety for processing. Similar variation for this trait was also reported by Sharma *et al.* (2001) [22], Duhan *et al.* (2005) [23] and Kumar *et al.* (2009) [24]. Ascorbic acid is a nutritionally important constituent and a free radical scavenger, which protects our body from cancer. Among the parents, the content ranged from 21.00 mg in EC-267727 to 29.38 mg/100g of fresh fruits in Solan Lalima. Among the hybrids, the highest ascorbic acid content (31.77 mg/100g) was found in BT-1-1 × FT-5, which was statistically at par with that of LE-79-5 × Solan Lalima (31.23 mg/100g) and lowest content was recorded in EC-174913 × FT-5 (22.40 mg/100g). 30.87 mg ascorbic acid /100 g of fresh fruit was recorded in Naveen 2000+. The results corroborate with the findings of Tiwai and Lal (2004) [25], Anita *et al.* (2005) [17] and Kumar *et al.* (2013) [14].

Conclusion

From the results, it is evident that the hybrid EC-620410 × Solan Lalima excelled in terms of desirable fruit shape for processing; the hybrid EC-37239 × Solan Lalima recorded least number of locules per fruit; the hybrid EC-37239 × FT-5 had maximum pericarp thickness; LE-79-5 × FT-5 recorded maximum TSS and BT-1-1 × FT-5 contained maximum ascorbic acid. Hence, depending upon the consumers' preferences and specific end use, these hybrids may further be evaluated in multiple locations for yield and other yield contributing traits before releasing them as a variety.

Table 1: Analysis of variance for different quality traits in tomato.

Sources of Variation	Mean Sum of Squares			
	Replications	Treatments	Error	Total
Degrees of freedom	2	32	64	98
Traits				
Fruit shape index	0.001	0.032*	0.0002	0.0333
Number of locules per fruit	0.001	1.05*	0.02	1.177
Pericarp thickness	0.02	3.60*	0.01	3.55
Total soluble solids	0.004	0.63*	0.01	0.651
Ascorbic acid content	2.40	29.58*	0.32	33.47

*Significant at 1% level of significance

Table 2: Ripe fruit colour of the lines, testers and the hybrids as per the Colour Chart, Royal Horticultural Society, London

Fruit colour	Genotypes
Orange Red Group 30 A	EC-174913 × FT-5
Orange Red Group 33 A	EC-191535, EC-8910155, Yalabingo, Solan Lalima, EC-37239 × FT-5, EC-37239 × Solan Lalima, EC-191535 × FT-5, EC-191535 × Solan Lalima, EC-267727 × FT-5
Orange Red Group 33 B	EC-620410 × Solan Lalima
Orange Red Group 34 A	BT-1-1, EC-191531, EC-174913, EC-620410, FT-5, BT-1-1 × FT-5, EC-8910155 × FT-5, EC-8910155 × Solan Lalima, EC- 174913 × Solan Lalima, EC-191531 × FT-5, EC-191531 × Solan Lalima, Yalabingo × FT-5, EC-620410 × FT-5
Orange Red Group 34 B	EC-267727
Red Group 39 A	LE-79-5
Red Group 40 A	Yalabingo × Solan Lalima
Red Group 44 A	EC-37239, BT-1-1 × Solan Lalima, EC-267727 × Solan Lalima, Naveen 2000+ (Standard Check)
Red Group 45 A	LE-79-5 × FT-5, LE-79-5 × Solan Lalima

Table 3: Mean performance of parents and their hybrids for different quality traits in tomato

Genotypes	Fruit shape index	Number of locules per fruit	Pericarp thickness (mm)	Total Soluble Solids (ºB)	Ascorbic acid (mg/100 g fresh fruits)
BT-1-1	0.84	2.63	3.79	3.81	25.23
EC-37239	0.78	2.07	5.36	4.09	21.49
EC-191535	0.81	3.37	6.20	4.39	23.27
EC-8910155	0.85	2.30	3.37	3.84	26.27
EC-174913	0.81	2.30	6.83	3.73	23.43
EC-191531	0.93	3.70	5.79	3.43	21.67
Yalabingo	0.87	3.20	6.19	3.66	21.83
EC-267727	1.03	3.13	4.79	4.34	21.00
LE-79-5	1.06	3.17	5.85	3.30	26.58
EC-620410	1.01	2.70	5.21	4.11	22.53
FT-5	0.88	2.83	4.11	3.91	24.40
Solan Lalima	0.94	2.30	6.30	4.02	29.38
BT-1-1 × FT-5	0.85	2.60	5.20	4.60	31.77
BT-1-1 × Solan Lalima	0.82	2.27	4.07	4.20	30.43
EC-37239 × FT-5	0.88	2.63	5.46	4.65	26.15
EC-37239 × Solan Lalima	0.86	2.10	5.15	3.22	25.57
EC-191535 × FT-5	0.84	4.03	4.26	4.37	28.67
EC-191535 × Solan Lalima	0.74	2.50	4.55	4.17	30.33
EC-8910155 × FT-5	0.82	2.20	4.88	3.34	28.23
EC-8910155 × Solan Lalima	0.85	2.70	3.61	3.12	25.23
EC- 174913 × FT-5	0.84	2.37	3.75	3.66	22.40
EC- 174913 × Solan Lalima	0.78	2.90	5.05	3.45	24.33
EC-191531 × FT-5	0.87	2.90	4.34	3.55	25.40
EC-191531 × Solan Lalima	0.99	2.27	4.55	3.20	22.47
Yalabingo × FT-5	0.86	2.67	3.81	4.21	30.23
Yalabingo × Solan Lalima	0.93	2.33	4.18	3.69	27.40
EC-267727 × FT-5	1.05	2.87	4.12	4.63	25.00
EC-267727 × Solan Lalima	1.02	2.13	4.54	4.01	23.77
LE-79-5 × FT-5	1.02	4.53	2.72	4.71	29.57
LE-79-5 × Solan Lalima	1.06	2.50	2.58	3.92	31.23
EC- 620410 × FT-5	1.08	3.60	3.57	4.45	25.33
EC- 620410 × Solan Lalima	1.11	2.23	2.51	3.88	23.70
Naveen 2000+ (Standard Check)	0.77	4.00	5.14	4.50	30.87
SE (d)±	0.01	0.11	0.09	0.06	0.47
$CD_{(0.05)}$	0.03	0.21	0.17	0.12	0.92

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