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Research Article

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Studies of Genetic Variability of Tomato (*Solanum lycopersicum* L.) Hybrids under Protected Environment

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Abstract

A study was conducted to estimate genetic variability among horticultural traits and to evaluate_these hybrids for protected environmental cultivation during spring-summer season, 2019 (April-September). Twelve hybrids of tomato were evaluated under modified naturally ventilated poly-house at the Vegetable Research Farm, Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya following Randomized Complete Block Design (RBD) with three replications, Palampur, Himachal Pradesh, India. Based on the mean performance, hybrid CLN2126×CLN1314G was found promising for yield plant^{-1} (4.37 kg) yield m^{-2} area (26.24 kg), TSS (6.53 °B), days to 50% flowering (26.66 days), days to first picking (67.33 days), number of fruits per plant (64.01), inter-nodal length (17.71 cm), number of nodes plant^{-1} (16.70 nodes) and plant height 316.87 cm). So, an ideal plant type producing a higher yield per plant will be the one having traits like a higher number of fruits per plant, and lesser days to first picking. It is concluded that the hybrid combination CLN2126×CLN1314G is promising for these traits. This can be included for multi-locational testing in different agro-climatic zones of Himachal Pradesh under protected environment.

Keywords: Hybrids, protected cultivation, tomato, traits, variability

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a self-pollinated crop that belongs to the family Solanaceae with chromosome number (2n=2x=24) and native to Central and South America (Vavilov, 1951). Popularly tomato is called as 'Love Apple'. It is considered a nutritional crop because it contains vitamin A and C, minerals, sugar, organic acids, and lycopene (Rana et al., 2014). Tomato is being cultivated in most of the countries of the world with global production of 183.9 million mt from an area of 7.6 million ha (Anonymous, 2018) China is the major producer of tomatoes in the world followed by India, the USA, Turkey, and Egypt. In India, tomato is cultivated in all agro-climatic regions under an area of about 8.09 lakh hectares with a production of 19.70 million mt (Anonymous, 2018), and the productivity is 25 mt ha^{-1} (Anonymous, 2018). In the low and mid-hills of Himachal Pradesh, tomato is mainly grown as an off-season vegetable

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crop. In Himachal Pradesh, tomato is grown on an area of 8.01 thousand ha with an annual production of 22.33 thousand mt (Anonymous, 2018).

Protected cultivation has been gaining importance for the last twenty years in Himachal Pradesh on account of favorable growing conditions inside. Throughout the year production is not possible in open field conditions due to the susceptibility of crops to several biotic and abiotic stresses; to overcome these stresses, protected cultivation is the best substitute (Sinha et al., 2020). It offers many benefits to the producers like; earliness, higher quality, and productivity, pesticide residue-free produce with higher returns to growers. As per the crop species, the microclimate surrounding the crop is partially/ fully controlled, so protected cultivation is a specialized and unique form of agriculture. Despite its economic importance, growers are not in a position to produce a good quality tomato with high productivity due to various biotic (pest and disease), abiotic (rainfall, temperature, relative humidity, and light intensity), and crop factors (flower and fruit drop). Identification of suitable hybrids is the most important factor for raising crops in a protected environment. Generally, under-protected environmental conditions indeterminate hybrids of tomatoes having the character of creeping nature are considered best for higher yield and high return due to their longer period growth and utilize vertical space (Singh and Kumar, 2017).

Since yield is an ultimate goal and is a complex character; therefore, it is necessary to judge the genetic variability of characters concerning different characters which helps in planning a successful breeding program to develop hybrids suitable for a protected environment. For the genetic improvement of the tomato crop, the basic requirement is to utilize or create genetic variability. Genetic variability is the occurrence of a high degree of variation among individuals due to differences in their genetic composition and the environment in which they are raised. The cultivation of local varieties under a protected environment is an uneconomical enterprise due to various reasons like susceptibility to various insect/pests and diseases which results in poor yield. To coop-up these challenges, hybrids are more suitable for ensured yield under such extreme agro-ecological situations of hills like Himachal Pradesh. With the view to combating these problems, evaluation of new combinations/hybrids under the protected condition in temperate hills of Himachal Pradesh is the need of the hour for boosting the production of tomatoes in the state. Therefore, present investigations were undertaken to study the performance of new hybrid combinations, public and private sector hybrids of tomato in modified naturally ventilated poly-house during spring-summer with the objectives: to estimate genetic variability among horticultural traits and to evaluate tomato hybrids for marketable yield.

2. Materials and Methods

The experiment was conducted at the experimental farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India during spring-summer, 2019 (April–September) under a protected environment. It is located at an elevation of 1290.80 m above mean sea level with 32°6'N latitude and 76°3' E longitude with East-West orientation of poly-house. Twelve diverse genotypes of tomato, including Palam Tomato Hybrid-1 as a check, were evaluated under a naturally ventilated poly-house having a 250 m^2 area. The details of the hybrids along with their sources are presented in (Table 1).

Table 1: List of tomato (*Solanum lycopersicum* L.) hybrids and their sources

Sl. No.	Hybrids	Source
1.	15-2×12-1	CSKHPKV, Palampur
2.	7-2×Palam Pride	CSKHPKV, Palampur
3.	CLN2126×Palam Pride	CSKHPKV, Palampur
4.	CLN1314G×Palam Pride	CSKHPKV, Palampur
5.	7-2×16-B	CSKHPKV, Palampur
6.	CLN2126×CLN1314G	CSKHPKV, Palampur
7.	15-2×CLN1314G	CSKHPKV, Palampur
8.	16-B×Palam Pride	CSKHPKV, Palampur
9.	12-1×16-B	CSKHPKV, Palampur
10.	12-1×CLN1314 G	CSKHPKV, Palampur
11.	12-1×BWR-5	CSKHPKV, Palampur
12.	Palam Tomato Hybrid-1	CSKHPKV, Palampur

The experiment was conducted in a randomized block design (RBD) with three replications inside the modified naturally ventilated poly-house (25×10 m^2). Ten plants of each hybrid were planted at a spacing of 70×30 cm^2 and trained on two stems in each replication.

Besides the application of vermicompost @ t ha^{-1} chemical fertilizers were applied as per adhoc recommendation of CSKHPKV for protected cultivation (50 kg each of N, P, and kg ha^{-1}) through straight fertilizers. The fertigation was given twice a week by applying liquid fertilizer (19:19:19) @ 2.2 g m^{-2} of the effective area of poly-house after the third week of transplanting and was stopped 15 days before final harvest. The seeds of each entry were sown in plug-trays on 4th April 2019 in soil-less media having a mixture of cocopeat: perlite: vermiculite in the ratio of 3:1:1 respectively, in a growth chamber. The seedlings were transplanted at 3–4 leaf stage in the modified naturally ventilated poly-house on 6th May 2019.

The intercultural operations *viz*., hoeing, earthing up, irrigation, fertigation, weeding, cutting, training, pruning, and staking were carried out following recommended package of practices to ensure a healthy crop development. Irrigation was done through a drip irrigation system three to four times a week as per the crop requirement. The plants were trained on two stems through jute and nylon twines.

For the data recording, five plants of each hybrid were randomly tagged in each replication and the characters studied during the evaluation were days to 50% flowering, days to first picking, number of fruits plant^{-1}, fruit shape index, pericarp thickness (mm), inter-nodal length (cm), number of nodes per plant, plant height (cm), yield per plant (kg), yield m^{-2} area (kg m^{-2}) and total soluble solids (^{o}B). The data for different characters were analyzed statistically to work out an analysis of variance and mean performance as per the method (Panse and Sukhatme, 1984).

3. Results and Discussion

3.1. Analysis of variance for the experimental design

The values of the mean sum of squares of Analysis of variance (ANOVA) revealed highly significant differences among the tested hybrids for all the traits studies viz., days to 50% flowering, days to first picking, number of fruits plant^{-1}, fruit shape index, pericarp thickness (mm), inter-nodal length (cm), number of nodes plant^{-1}, plant height (cm), yield plant^{-1} (kg), yield m^{-2} area (kg m^{-2}), total soluble solids (^{o}B) and bacterial wilt incidence (Plant survival %). The significant variations among the hybrids presented in Table 2, showed the presence of adequate variability which can be exploited through selection (Hidayatullah et al., 2008; Kaushik et al., 2011; Dar and Sharma, 2011; Meena and Bahadur, 2015; Sanchez et al., 2019; Sinha et al., 2020). Earlier researchers had also observed a similar trend.

Table 2: Analysis of variance for different characters in tomato hybrids

Traits	Mean Sum of Squares			
	Source	Replication	Treatment	Error
	df	2	11	22
Days to 50% flowering		0.333	29.061*	9.485
Days to first picking		1.333	36.492*	10.03
Total no. of fruits plant^{-1}		8.428	628.106*	19.597
Fruit shape index		0.008	0.016*	0.006
Pericarp thickness (mm)		0.362	1.317*	0.181
Inter-nodal length (cm)		0.778	14.447*	5.504
No. of nodes plant^{-1}		0.111	35.526*	1.008
Plant height (cm)		0.604	4973.556*	60.034
Yield plant^{-1} (kg)		0.001	2.722*	0.099
Yield m^{-2} area (kg m^{-2})		0.037	97.981*	3.567
Total soluble solids (°B)		0.324	2.349*	0.094

*: Significant at (p=0.05)

3.2. Mean performance of genotypes

3.2.1. Days to 50% flowering

Earliness is the utmost desirable parameter, as the early crop produce can obtain a higher price in the market due to its high demand and less produce at that time. Days to 50% flowering is one of the crucial parameters observed to determine the earliness of a particular genotype. The mean values of genotypes for a number of days to 50% flowering varied from 26.66 to 36.00 days with an overall mean of 33.16 days (Table 3). Among all genotypes, the hybrids CLN2126×CLN1314G (26.66 days) took a minimum number of days to 50% flowering and was earlier, however it was found to be statistically at par with the check Palam Tomato Hybrid-1 (27.66 days). Whereas, hybrid CLN1314G×palam pride took maximum days to 50% flowering (36.00) and was late among all the tested hybrids. On the basis of days to 50% flowering none of the hybrids was significantly earlier than the check palam tomato Hybrid-1. (Sharanappa and Mogali, 2014), observed wide variations for days to 50 percent flowering in different tomato genotypes.

3.2.2. Days to first picking

Early crop fetches high market value, so we should select only those genotypes of tomato which are early in fruiting to avoid a market glut. So, early fruit maturity and picking is a very important trait of superior genotype. Significant variations for days to first picking were observed among the genotypes under study (Table 3). The observation ranged from 67.33 to77.66 days with an overall mean of 73.41 days. Mean values for different hybrids revealed that hybrid CLN2126×CLN1314G took a minimum number of days to first picking and was the earliest in maturity (67.33 days) but statistically at par with the check Palam Tomato Hybrid-1 (67.66 days). Hybrid combinations *viz.,* 15-2×12-1 (77.66), CLN1314G×palam pride (77.00), 7-2×palam pride (75.66), 7-2×16-Band15-2×CLN1314G (75.33), CLN2126×palam pride (75.00), 12-1×BWR-5 (74.66) and 16-B×palam pride (74.00) took more days to first picking. Based on days to first picking none of the genotypes was found significantly earlier than the Check Palam Tomato Hybrid-1. Considerable variation for this character was also reported earlier (Chapagain et al., 2011; Patel et al., 2013; Mitul et al., 2016).

3.2.3. No. of fruits plant^{-1}

The number of fruits plant^{-1} is one of the most desirable parameters which plays an important role as yield contributing trait. Range mean value of data recorded for this trait lies between 21.72 to 64.01 fruits plant^{-1} (Table 3). Among all

Table 3: Mean performance of tomato hybrids for yield and its attributing traits

Genotypes	Days to 50% flowering	Days to first picking	No. of fruits plant^{-1}	Fruit shape index	Pericarp thickness (mm)	Inter-nodal length (cm)	No.of nodes plant^{-1}	Plant height (cm)	Yield plant^{-1} (kg)	Yield m^{-2} area (kg m^{-2})	Total Soluble Solids (°B)
15-2×12-1	35.66	77.66	21.72	0.88	4.60	24.35	6.20	160.83	1.40	8.44	3.76
7-2×Palam Pride	35.00	75.66	29.90	1.03	5.63	23.97	7.93	231.92	1.94	11.64	3.76
CLN2126×Palam Pride	35.33	75.00	45.46	1.06	4.60	24.28	10.33	294.03	3.04	18.26	5.10
CLN131 4G×Palam Pride	36.00	77.00	23.14	1.10	4.46	22.03	7.53	254.43	1.50	9.00	5.16
7-2×16-B	32.66	75.33	35.30	1.04	6.66	21.94	8.06	271.36	2.36	14.16	5.90
CLN2126× CLN1314G	26.66	67.33	64.01	1.01	6.13	17.71	16.70	316.87	4.37	26.24	6.53
15-2×CLN1314G	36.00	75.33	27.80	1.09	4.93	21.34	6.90	245.33	1.80	10.80	4.73
16-B×Palam Pride	34.00	74.00	61.66	0.94	4.80	19.87	14.50	295.93	3.68	22.08	5.50
12-1×16-B	32.33	71.33	42.53	0.93	5.53	21.81	9.66	263.33	2.84	17.06	5.66
12-1×CLN1314G	32.33	70.00	37.62	1.01	5.40	21.92	8.46	262.90	2.53	15.18	4.33
12-1×BWR-5	34.33	74.66	48.69	1.12	5.46	23.20	11.06	286.60	3.24	19.48	4.56
Palam Tomato Hybrid-1 (Check)	27.66	67.66	56.29	1.03	5.23	18.19	14.86	293.10	3.76	22.60	6.03
Range	26.66-36.00	67.33-77.66	21.72-64.01	0.88-1.12	4.46-6.66	17.71-24.35	6.20-16.7	160.83-316.87	1.40-4.37	8.44-26.24	3.76-6.53
Overall Mean	33.16	73.41	41.17	1.02	5.28	21.71	10.18	264.71	2.70	16.25	5.08
SEm±	1.77	1.82	2.55	0.04	0.24	1.35	0.58	4.47	0.18	1.09	0.17
CD (*p*=0.05)	5.24	5.39	7.54	0.12	0.72	3.99	1.71	13.20	0.53	3.21	0.52

hybrids, maximum numbers of fruits plant^{-1} were recorded in hybrid CLN2126×CLN1314G (64.01), which were significantly higher than the check but statistically at par with the hybrid combination 16-B×palam pride (61.66). The significant increase in fruit number might be due to the reason this hybrid combination was early in fruiting and its plant height was also maximum than others. Earlier researchers (Prajapati et al., 2015; Meena et al., 2015; Kumar and Singh 2016; Thapa et al., 2016; Lekshmi and Celine, 2017), also mentioned maximum number of fruits plant^{-1} due to these reasons.

3.2.4. Fruit shape index

Fruit shape and size are important not only for the consumer but also for the market. Fruit shape is one of the most promising traits which can be visualized by the naked eye and can be utilized for clear-cut identification of tomato cultivars during a field inspection. Significant variations (Table 3) were recorded for the fruit shape index. Its mean values ranged from 0.88 (15-2×12-1) to 1.12 (12-1×BWR-5). All hybrid combinations except 15-2×12-1 were statistically at par with the check Palam Tomato Hybrid-1 (1.03). The present studies revealed that out of 12 genotypes 9 hybrids were oval and 3 were of spherical shape. This character is stable and not influenced by biotic and abiotic stresses. Likewise, tomato genotypes were also classified into oval, spherical and flat round categories in earlier studies (Mahesha et al., 2006; Bilashini, 2010; Singh, 2013; Chernet et al., 2014; Shiksha, 2018), in various tomato genotypes.

3.2.5. Pericarp thickness (mm)

Pericarp thickness is a very important parameter in tomato fruit, as thicker pericarp is desirable for longer shelf life and transportation. There were significant differences among the hybrids for the trait and its mean value ranged from 4.46 to 6.66 mm with an overall mean of 5.28 mm (Table 3). Statistically, comparison for pericarp thickness revealed that the hybrid 7-2×16-B (6.66 mm) and CLN2126×CLN1314G (6.13 mm) had significantly thicker pericarp than the check Palam Tomato Hybrid-1 and hybrid 7-2×palam pride (5.63 mm), 12-1×16-B (5.53 mm), 12-1×BWR-5 (5.46 mm) and 12-1×CLN1314G (5.40 mm) were statistically at par with check Palam Tomato Hybrid-1. Based on this trait hybrids 7-2×16-B

and CLN2126×CLN1314G were found significantly superior to the check Palam Tomato Hybrid-1. This variation might be due to the genetic difference in the genotypes. These results are in agreement with (Singh et al., 2014; Thapa et al., 2016).

3.2.6. Inter-nodal length (cm)

Variation was observed among the hybrids for inter-nodal length. Its mean values (Table 3) ranged from 17.71 to 24.35 cm with an overall mean of 21.71 cm. Hybrid CLN2126×CLN1314G had a shorter and minimum inter-nodal length (17.71 cm) statistically at par with check palam tomato Hybrid-1 (18.19 cm). Longer but statistically at par inter-nodal length with the check was found in hybrid CLN1314G×palam pride (22.03), 7-2×16-B (21.94 cm), 121×CLN1314G (21.92 cm), 121×16B (21.81 cm), 152×CLN1314G (21.34 cm) and 16B×palam pride (19.87 cm). Based on this traitmeant performance none of the hybrids was found significantly superior to check Palam Tomato Hybrid-1, as short inter-nodal length contributes more yield. Considerable variability for this trait is in line with the findings (Singh, 2013; Shiksha, 2018).

3.2.7. No. of nodes plant^{-1}

The mean value for the number of nodes plant^{-1} ranged from 6.20 to 16.70 (Table 3) with an overall mean of 10.18 nodes. The study revealed that significantly higher numbers of nodes per plant were recorded in hybrid CLN2126×CLN1314G (16.7) than the check palam tomato Hybrid-1 (14.86). The minimum number of nodes plants^{-1} was recorded in hybrid 15-2×12-1 (6.20). For this trait, hybrid CLN2126×CLN1314G was found to be superior to check Palam Tomato Hybrid-1, as more nodes per plant contribute higher yield. The reasons for a higher number of nodes per plant in this hybrid combination could be its maximum plant height and earliness. Significant variation in the number of nodes on the main stem has also been recorded (Tasisa et al., 2011) in tomato.

3.2.8. Plant height (cm)

It is evident from Table 3 that significant differences were recorded in plant height by tomato genotypes. In high rainfall regions, indeterminate types of genotypes are preferred over semi-determinate and determinate types. The observation showed that the mean values ranged from 160.83 cm (15-2×12-1) to 316.87 cm (CLN2126×CLN1314G) with an overall mean of 264.71 cm. The hybrid CLN2126×CLN1314G was found to be significantly taller than the check Palam Tomato Hybrid-1 whereas, hybrids *viz.,* 16-B×palam pride (295.93 cm) and CLN2126×palam pride (294.03 cm) were taller but statistically at par with it. The tallness, shortness, and other morphological differences are the varietal characteristics, which are controlled and expressed by certain genes. These results conform with the findings (Sharma and Singh, 2015; Ahmad et al., 2016), who reported a wide range for plant height in different tomato cultivars.

3.2.9. Yield plant^{-1} (kg)

Yield per plant^{-1} is one of the crucial parameters attaining utmost consideration in crop breeding programs. The recorded data on fruit yield per plant revealed significant variation among various hybrids (Table 3). Its mean values ranged from 1.40 to 4.37 kg having an overall mean of 2.70 kg. Comparison of data recorded on fruit yield per plant indicated that the hybrid CLN2126×CLN1314G (4.37 kg) had a significantly higher yield plant^{-1} than check Palam Tomato Hybrid-1 (3.76 kg), whereas minimum yield per plant was recorded in 15-2×12-1 (1.40 kg). Hybrid CLN2126×CLN1314G was significantly superior because of its genetic makeup and said the combination had a maximum number of fruits per plant, nodes per plant, and plant height; and minimum inter-nodal length and was early in flowering and fruiting. Such kind of genetic differences for marketable fruit yield and other plant characters in different tomato hybrids had also been reported (Arora et al., 2006; Chernet et al., 2014; Meena et al., 2015; Ahmad et al., 2016; Lekshmi and Celine 2017; Prakash et al., 2019).

3.2.10. Yield m^{-2} area (kg m^{-2})

This particular trait depends upon fruit yield plant^{-1} and plant population. Yield per square meter means values ranged from 8.44 to 26.24 kg with an overall mean value of 16.25 kg (Table 3). The significantly higher yield m^{-2} was recorded in hybrid CLN2126×CLN1314G (26.24 kg) as compared to check Palam Tomato Hybrid-1 (22.60 kg). This might be again because of the genetic makeup of the genotype and said combination had a maximum number of fruits plant^{-1}, nodes plant^{-1}, and plant height; and minimum inter-nodal length and was early in flowering and fruiting. Such kind of genetic differences for marketable fruit yield m^{-2} had also been reported (Chaudhry et al., 2006; Cheema et al., 2013).

3.2.11. Total soluble solids (°B)

Higher total soluble solids are a desirable quality attribute for tomato in processing as well as for fresh consumption. Hybrids revealed significant differences for this trait (Table 3). Highest TSS was found in CLN2126×CLN1314G (6.53 °B), however, it was at par with the check Palam Tomato Hybrid-1 (6.03 ^{0}B). The differences in total soluble solids were due to variations in genotypes and environmental conditions that prevailed during the growing seasons. Significant variability among the tomato genotypes for this trait was also observed by many earlier researchers (Meena and Bahadur 2015; Mitul et al., 2016; Rai et al., 2016; Prakash et al., 2019).

4. Conclusion

The mean performance, the hybrid combination CLN2126×CLN1314G was having a significantly higher fruit yield plant^{-1} than the check Palam Tomato Hybrid-1. This top-performing hybrid combination CLN2126×CLN1314G also outperformed other hybrids for days to 50% flowering, days to first picking, number of fruits plant^{-1}, inter-nodal length, number of nodes plant^{-1}, plant height, total soluble solids, and yield m^{-2} area. Therefore, it could be used in further

multi-location testing to verify its potential before release.

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