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Studies on genetic divergence in tomato (*Solanum lycopersicum* L.) under mid hill conditions of Solan District of Himachal Pradesh

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Abstract
Nature has endowed India with many precious gifts, wherein lies its immense potential for vegetable sector. Tomato is cultivated in different parts of the country, including states like Uttar Pradesh, Karnataka, Himachal Pradesh, Maharashtra, Haryana, Punjab and Bihar. Nature and magnitude of variability for yield and other characters owing is an important basic pre-requisite for starting any systematic breeding programme to identify superior lines or varieties. Thus, this investigation was undertaken with thirty four diverse genotypes of tomato including check variety Solan Lalima. All the genotypes were grouped into 4 (I-IV) clusters. Maximum numbers of genotypes were accommodated in cluster III (16) followed by cluster IV (8), while cluster I and II were having 6 & 4 genotypes respectively. The maximum inter cluster distance was recorded between cluster II and IV (30.38) which indicated wide diversity between these two clusters, while lowest (17.09) was observed between cluster III and IV, indicating their close relationship. Therefore, the hybridization between the genotypes of cluster II and IV can be carried out for getting superior hybrids or recombinants in segregating populations.

Keywords: Tomato, *Solanum lycopersicum*, Himachal Pradesh

Introduction
Tomato once considered to be poisonous and inedible, is now one of the most important vegetable crops grown throughout the world after potato and sweet potato, occupying an area of 5.02 million hectare with an annual global production of 170.75 million tonnes (NHB, 2017) [5]. Nature has endowed India with many precious gifts, wherein lies its immense potential for vegetable sector. Tomato is cultivated in different parts of the country, including states like Uttar Pradesh, Karnataka, Himachal Pradesh, Maharashtra, Haryana, Punjab and Bihar. It occupies an area of 808.5 thousand hectares with annual production of 19696.9 thousand metric tonnes and productivity of 24.4 metric tonnes per hectare (NHB, 2017) [5]. Mid hills of Himachal Pradesh has emerged as the leading supplier of high quality fresh vegetables to the plains during summer and rainy season, thus, bringing lucrative returns to the growers. In Himachal Pradesh, it is cultivated over an area of 11.08 thousand hectare with a production of 489.96 metric tonnes and productivity of 44.21 metric tonnes per hectare (NHB, 2017) [5]. In the last three decades, Himachal Pradesh has witnessed a sea change in the scenario of production of tomato with the increasing popularity of hybrids in the commercial cultivation. However, the production and productivity of the crop is still far below as compared to global scenario. There is a strong need to develop hybrids with high yield and desirable horticultural traits from public sector. Hybrids must have yield stability along with excellent quality to compete in the market both in terms of productivity as well as quality. The magnitude of divergence between two groups under consideration is provided by D^2 statistic developed by Mahalanobis (1936) [2]. It considers the variation produced by any character and their consequent effect that it bears on other characters. The technique in the form of generalized distance was first used by Mahalanobis (1936) in an anthropometric survey of the united province in India. For the first time D2 statistic was applied for biological population by Nair and Mukharji (1960) [6] to classify the natural and plantation teak tree types. The choice of parents for hybridization depends on genetic diversity of parents. Precise information on the nature and degree of genetic divergence would help the plant breeder in choosing the selective parents for hybridization. The expression of heterosis is influenced by genetic diversity of parents. Several reports are available to show that hybrids between genetically diverse parents manifest greater heterosis than those between more closely related parents (Ram and Panwar, 1970 [9]; Moll and Stuber, 1974 [4]).

The importance of variability, character association, path analysis and divergence has been well recognized by plant breeders. In tomato, most of the studies made so far in this aspect are based on single environment only. Since, the inter-relationships are known to vary from season to season from different characters, it is essential to study under different environmental conditions. Keeping in view the above facts present investigation was undertaken with an objective to study of genetic diversity in two hundred genotypes of tomato based on thirteen important traits, to help in selecting promising and genetically diverse parents for desired improvement.

Materials and Methods

The present investigation was carried out at the Experimental Farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) during Kharif season of 2018. The experimental site of the Department of Vegetable Science is located at Nauni, about 13 km from Solan, at an altitude of 1276 m above mean sea level lying between latitude 30°52′ 30″ North and longitude 77° 11′ 30″ East. It falls in sub-humid, sub temperate and mid- hill zone of Himachal Pradesh. The experiment was laid out in a Randomized Complete Block Design (RCBD) with thirty four genotypes in three replications. The genotypes were planted at a spacing of 90 x30 cm in a plot size of 1.8x 1.5 m in each replication. Solan Lalima was used as a check for the study. Data were recorded on five randomly taken plants from each plot/treatment and the average was worked out to record the mean value in each replication for all the characters under study. The observations were recorded for various horticultural and yield traits viz., Days to 50 percent flowering, Days to marketable maturity, Number of fruits per cluster, Number of fruits per plant, Average fruit weight (g), Fruit yield per plant (kg),Fruit colour, Fruit shape index Fruit firmness (g/0.503cm^2), Shelf life (Days),Number of locules per fruit, Pericarp thickness, Plant height (cm), Harvest duration (days), Total soluble solids (°B) and Ascorbic acid (mg/100 g).

The genetic divergence was estimated by Mahalanobis D^2 statistics as suggested by (Rao, 1952). Treating D^2 as the generalized statistical distance between a pair of populations (genotypes), all populations were grouped into number of clusters according to the method described by Rao, 1952. The criterion used in clustering by this method was that, any two genotypes belonging to the same cluster, at least on an average, show a small D^2 value than those belonging to two different clusters. In other words, if genotypes V1 and V2 are close together and V3 genotype is distant from both as shown by their generalised distance, than V1 and V2 will be grouped, in the same cluster. The average D^2 values of all possible genotypes combinations in one cluster with those in the other were computed and its square root was used to represent the 'statistical distance' between two clusters.

Results and Discussion

The analysis of variance showed highly significant differences among the genotypes for sixteen yield and its component traits. This indicated that large variability existed among the genotypes and that further analysis of genetic divergence is reasonable (Mehta *et al*. 2004). [3] The use of Mahalanobis D^2 statistic (Rao, 1952). [8] for estimating genetic divergence have also been emphasized by many workers in tomato because it permits precise comparison among all possible pairs of population in any given group affecting actual crosses. List of genotypes along with their sources have been presented in Table-1.

Table 1: List of genotypes along with their sources

S. No	Genotype	Source
1.	BT-1-1	OUAT, Bhubneshwar
2.	BT-1-3	OUAT, Bhubneshwar
3.	BT- Best	OUAT, Bhubneshwar
4.	BT-12	OUAT, Bhubneshwar
5.	BT-10-12	OUAT, Bhubneshwar
6.	S-208	UHF, Nauni Solan
7.	97/754	UHF, Nauni Solan
8.	EC-620424	IIVR, Varanasi
9.	EC-620374	IIVR, Varanasi
10.	EC-535580	IIVR, Varanasi
11.	EC-521060	IIVR, Varanasi
12.	EC-526146	IIVR, Varanasi
13.	EC-620378	IIVR, Varanasi
14.	EC-14078	IIVR, Varanasi
15.	EC-191531	IIVR, Varanasi
16.	EC-141847	IIVR, Varanasi
17.	EC-267727	IIVR, Varanasi
18.	EC-9046	IIVR, Varanasi
19.	EC-27995	IIVR, Varanasi
20.	EC-620435	IIVR, Varanasi
21.	EC-1915353	IIVR, Varanasi
22.	EC-174913	IIVR, Varanasi
23.	EC-620410	IIVR, Varanasi
24.	EC-620398	IIVR, Varanasi
25.	EC-16465	IIVR, Varanasi
26.	EC-620396	IIVR, Varanasi
27.	EC-531803	IIVR, Varanasi
28.	EC-37239	IIVR, Varanasi
39.	EC-620402	IIVR, Varanasi
30.	EC-529083	IIVR, Varanasi
31.	EC-620397	IIVR, Varanasi
32.	EC-620370	IIVR, Varanasi
33.	EC-357838	IIVR, Varanasi
34.	Solan Lalima (check)	UHF, Nauni Solan

I) Composition of clusters

On the basis of performance of various traits, the clustering pattern of thirty four genotypes of tomato has been presented in the Table 1. All the genotypes were grouped into 4 (I-IV) clusters. Maximum numbers of genotypes were accommodated in cluster III (16) followed by cluster IV (8), while cluster I and II were having 6 & 4 genotypes respectively. The genotypes appearing in the same cluster were due to their genetic homogeneity with each other. Group constellation of tomato genotypes through genetic divergence has also been reported by Sharma *et al*. (2006), Reddy *et al*. (2013) and Lekshmi and Celine (2016) in tomato.

Table 2: Clustering pattern of thirty four genotypes of tomato on the basis of genetic divergence

Cluster	Number of genotypes	Name of genotypes
I	6	BT-10-12, EC-620410, EC-14078, EC-37239, EC-620397 and EC-620370.
II	4	EC-174913, BT-Best, EC-620396 and Solan Lalima.
III	16	97/754, EC-191531, EC-915353, EC-620424, EC-620398, EC-267727, BT-1-1, EC-620378, EC-9046, EC-620374, EC-521060, EC-16465, EC-620435, BT-12, EC-620402, EC-531803.
IV	8	EC-141847, BT-1-3, EC-535580, S-208, EC-27995, EC-526146, EC-529083, EC-357838.

II) Intra and Inter cluster genetic divergence (D^2)

Average intra and inter cluster divergence (D^2) values are presented in the Table II. The diagonal figures in the table represent the intra cluster distances. The intra cluster distance was maximum in cluster II (24.21) and minimum in cluster III (15.78). High intra cluster distance indicated that the genotypes included in II cluster were genetically heterogeneous to a great extent. The maximum inter cluster distance was recorded between cluster II and IV (30.38) which indicated wide diversity between these two clusters, while lowest (17.09) was observed between cluster III and IV, indicating their close relationship.

Table 3: Intra (diagonal) and inter cluster ($\sqrt{D^2}$) values among 34 genotypes of tomato

	I	II	III	IV
I	15.82			
II	18.48	24.24		
III	17.56	25.37	15.78	
IV	24.43	30.38	17.09	22.09

III) Mean performance of cluster

Further, for getting the reliable conformity on the basis of cluster means, it was calculated for various horticultural traits and has been presented in Table III. The days to 50 per cent flowering was earliest in cluster IV (29.88), cluster III (30.88) and cluster I (32.00) while gradual delay was observed in cluster II (32.67). Days to marketable maturity was depicted minimum in cluster II (70.67) followed by cluster IV (70.75), cluster I (71.39) while this ratio was maximum in cluster III (71.56). The number of fruits per cluster orderly increased through cluster III (4.28), clusters IV (4.70), cluster I (5.10) and cluster II (5.34). The maximum number of fruits per plant was observed in cluster IV (43.84) followed by cluster II (25.58), cluster I (18.29) and cluster III (17.58). Similarly, cluster-wise increment in average fruit weight (g) was observed as; cluster IV (19.62), cluster III (51.76), cluster I (62.01) and cluster II (67.45). The highest yield per plant (kg) was depicted in cluster II (1.71) followed by I (1.14), III (0.89) and lowest in the cluster IV (0.83). The highest yield per hectare (q) was depicted in cluster II (507.19) followed by I (337.50), III (264.65) and lowest in the cluster IV (245.91). Fruit firmness (g/0.0503cm^2) was having highest value in cluster II (1527.08) followed by cluster I (1232.22), cluster III (933.50), while lowest value was recorded in cluster IV (645.46). Highest shelf life (days) was observed in cluster II (17.06) followed by cluster I (12.60), cluster III (10.15), while lowest was observed in cluster IV (8.51). Lowest to highest values of number of locules per fruit were scaled through cluster II (2.54), cluster I (2.71), cluster III (3.27) and IV (5.25). Pericarp thickness (mm) was found highest in cluster II (6.17) followed by cluster I (5.48), cluster III (4.54), while lowest value was recorded in cluster IV (2.73). The tallest plants (cm) were observed in cluster II (165.29) followed by cluster I (39.12), cluster III (116.52) and cluster IV (103.35). The highest value of harvest duration (days) was observed in cluster II (41.83) followed by cluster I (37.54), cluster III (34.37), while lowest value was recorded in cluster IV (32.32).

Table 4: Intra cluster group means for various components of fruit yield in tomato

S. No.	Characters	Cluster Means			
		I	II	III	IV
1.	Days to 50% flowering	32.00	32.67	30.88	29.88
2.	Days to marketable maturity	71.39	70.67	71.56	70.75
3.	Number of fruits per cluster	5.10	5.34	4.28	4.70
4.	Number of fruits per plant	18.29	25.58	17.58	43.84
5.	Average fruit weight (g)	62.01	67.45	51.76	19.62
6.	Yield per plant (kg)	1.14	1.71	0.89	0.83
7.	Yield per hectare (q)	337.50	507.19	264.65	245.91
8.	Fruit shape index	0.96	0.94	0.93	0.93
9.	Fruit firmness (g/0.503cm^2)	1232.22	1527.08	933.50	645.46
10.	Shelf life (Days)	12.60	17.06	10.15	8.51
11.	Number of locules per fruit	2.71	2.54	3.27	5.25
12.	Pericarp thickness (mm)	5.48	6.17	4.54	2.73
13.	Plant height (cm)	139.12	165.29	116.52	103.35
14.	Harvest duration (Days)	37.54	41.83	34.37	32.32
15.	Total soluble solids (°Brix)	4.48	3.83	4.20	4.27
16.	Ascorbic acid content (mg/100g)	23.12	21.31	25.88	25.84

Highest total soluble solids (°Brix) were estimated in the order *viz*; cluster I (4.48), cluster IV (4.27), cluster III (4.20) and cluster II (3.83). Similarly, maximum ascorbic acid content (mg/100 g) was observed in cluster III (25.88) followed by cluster IV (25.84), cluster I (23.12) and cluster II (21.31). Variable cluster mean for different plant growth and yield characters have also been reported by Sharma *et al.* (2006) [10], Prashanth *et al.* (2008) [7], Singh *et al.* (2008) [11], Ullah *et al.* (2015) [12] and Lekshmi and Celine (2016) [2] in tomato.

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