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Sunilkumar MK
Division of Vegetable Science, University of Horticultural Sciences, Bagalkot, Karnataka, India

Vijeth S
Department of Vegetable Science, Kerala Agricultura Uiniversity, Vellayani, Kerala, India

Vijayakumar Rathod
Division of Vegetable Science, University of Horticultural Sciences, Bagalkot, Karnataka, India

Prashant Kaushik
Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, Valencia, Spain

Correspondence
Prashant Kaushik
Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, Valencia, Spain

Genetic divergence in exotic tomato (*Solanum lycopersicum* L.) genotypes cultivated in southern India

Sunilkumar MK, Vijeth S, Vijayakumar Rathod and Prashant Kaushik

Abstract
Sixty tomato genotypes of various geographical origin were being assessed to grasp the worth and magnitude of genetic divergence applying Mahalanobis D^2 studies. A broad genetic range was noticed among the genotypes and was grouped into 9 clusters. The clustering pattern indicated that geographical diversity and genetic diversity are not related to each other. The maximum inter-cluster distance was observed between clusters IV and VIII (D^2 = 3363.063) followed by clusters IV and VI (D^2 = 3293.227), clusters I and IV (D^2 = 2300.552), clusters IV and VII (D^2 = 2300.461) and clusters IV and V (D^2 = 2106.041). Cluster I revealed the least inter-cluster distance (D^2= 714.097) with the cluster III. the Hence, the selection based on the divergent parent is dependent on these cluster length, that is usually recommended for having superior hybrids or segregants in tomato.

Keywords: Genetic divergence, D^2 analysis, the clustering pattern

Introduction
Tomato is one of the most popular, widely grown and versatile vegetables grown in the world. Tomato can be consumed either in the form of fresh as salads, after cooking and utilized in the preparation of range of processed products such as puree, paste, ketchup, sauce, soup, pickles, chutney and canned whole fruits. Now a day's cultivation of commercial F_1 hybrids are very common to achieve higher productivity, uniformity and good quality fruits and selection of newer parents for higher heterosis is thus a continuous process (Kaushik et al., 2015) [4]. Generally, diverse parents are expected to give high hybrid vigour (Harrington, 1940) [3]. Mahalanobis D^2 multivariate analysis (Mahalonobis, 1936) is one of the valuable tools for obtaining quantitative estimates of genetic divergence between biological populations. Further grouping of the genotypes based on Touchers method strategy is going to be far more valuable in deciding parental genotypes for heterosis breeding (Kaushik, 2015) [5]. For that reason, this investigation was carried out to identify the level of genetic divergence in tomato genotypes.

Material and Methods
Sixty genotypes collected from different sources were evaluated during 2014-15 in the Department of Vegetable Science, Arabhavi. The plants were grown in a randomized complete block design with two replications with a spacing of 90 x 60 cm. Further, five randomly selected plants in every replication were tagged and used for documenting the findings. The genotypes were grouped based on the Tochers method, as outlined by Rao (1952) [12].

Results and Discussion
Analysis of variance uncovered the significant differences among the genotypes for most of the traits except stem girth, days to first fruit maturity and fruit density. Based on D^2 values for all the possible pairs, sixty genotypes were grouped into nine clusters (Table 1). Cluster I was the largest having 20 genotypes followed by cluster V (18), cluster II (9), cluster IV (3) and cluster III, VI, VII, VIII, IX had two genotypes each. Dharmatti *et al.* (2001) [2] and Parthasarathy and Aswath (2002) [11] reported similar results. Intra-cluster distance (Table 2) revealed that, cluster IX with 2 number of genotypes showed maximum intra-cluster diversity (D^2 = 1385.104) followed by cluster II (D^2 = 1264.743), cluster V (D^2 = 1155.040) and cluster I (D^2 = 772.564). Cluster III (D^2 = 265.900) showed minimum intra-cluster diversity. Based on distance between clusters, *ie.*, inter-cluster distances, the maximum divergence was observed between clusters IV and VIII (D^2 = 3363.063) followed by clusters IV and VI (D^2 = 3293.227), clusters I and IV (D^2 = 2300.552), clusters IV and VII (D^2 =2300.461), clusters IV and V

(D^2 = 2106.041). Cluster I had the least inter - cluster distance (D^2 = 714.097) with the cluster III. For plant height at 60 DAT, the highest cluster means was shown by cluster IV, followed by cluster VIII, cluster II and cluster V (Table 3). Between cluster IV and VIII (D^2 =3363.063), cluster IV and V (D^2 = 2106.041), cluster II and IV (1805.740) and cluster II and VIII (1635.038) most considerable distances were observed. Hence, crosses amongst the genotypes could be a better option for the improvement of tomato under southern India conditions. (Mala and Vadivel, 1999) [10]. For days to first flowering and days to fifty per cent flowering, the lowest cluster mean was observed in cluster III followed by cluster V and cluster IX. The inter-cluster distance between cluster V and IX (D^2 =1331.087) was comparatively high. Therefore, the crosses between the genotypes belonging to these respective clusters may be tried to improve earliness characters (Kaushik et al., 2018; Kaushik, 2019) [6, 7]. Average fruit weight, fruit volume and number of fruits per plant are major yield contributing traits in tomato. For average fruit weight, the highest cluster mean (Table 3) was shown by cluster VIII followed by cluster IX, cluster VI and cluster VII. Inter-cluster distance between cluster VI and IX (D^2= 1970.350) and cluster VII and IX (D^2= 1382.736) and cluster VIII and IX (D^2= 1582.754) were comparatively high. Cluster IV followed by cluster V, cluster IX and cluster VIII were with the highest mean for the number of fruits per plant. Inter cluster distance between clusters IV and VIII (D^2 = 3363.063) followed by clusters IV and V (D^2 = 2106.041) and clusters IV and IX (D^2 = 1985.381) were comparatively high. For fruit volume, highest cluster mean was observed in the cluster VIII followed by cluster I and cluster V. Inter cluster distance between clusters V and VIII (D^2 = 1154.346) followed by clusters I and V (D^2 = 1003.849) were comparatively high.

For number of seeds per fruit, the highest cluster mean (Table 3) was shown by the cluster II followed by cluster I, cluster IX and cluster III. Inter-cluster distance between cluster I and IX (D^2= 1319.016) and cluster II and IX (D^2= 1380.728) and cluster I and II (D^2= 1104.732) were comparatively high. Hence hybridization between the genotypes of these respective clusters can be attempted to get genotypes with the high number of seeds per fruit which is necessary for seed production point of view.

For lycopene content, cluster VII followed by cluster IV and cluster IX. Inter-cluster distance between cluster IV and VII (D^2 =2300.461) was comparatively high, and hence, the hybridization can be designed between the genotypes these clusters to improve lycopene content. Similar results also reported by Das *et al*. (1998) [1] and Vijeth et al. (2019) [8].

Table 1: Classification of tomato genotypes into different clusters based on D^2 value

Clusters	Number of genotypes	Genotypes included in the cluster
I	20	TM-1, TM-2, TM-3, TM-4, TM-5, TM-6, TM-7, TM-8, TM-9, TM-10, TM-11, TM-12, TM-13, TM-14, TM-15, TM-16, TM-17, TM-18, TM-48, TM-53
II	9	TM-19, TM-20, TM-21, TM-22, TM-23, TM-24, TM-25, TM-26, TM-55
III	2	TM-34, TM-51
IV	3	TM-27, TM-28, TM-30
V	18	TM-29, TM-31, TM-32, TM-33, TM-35, TM-36, TM-37, TM-38, TM-39, TM-40, TM-41, TM-42, TM-43, TM-44, TM-45, TM-46, TM-47, TM-49
VI	2	TM-57, TM-60
VII	2	TM-56, TM-58
VIII	2	TM-54, TM-59
IX	2	TM-50, TM-52

Table 2: Average intra- and inter -cluster D^2values along with their D values (in parenthesis) for 15 characters formed by 60 genotypes of tomato

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	772.564 (27.795)	1104.732 (33.238)	714.097 (26.723)	2300.552 (47.964)	1003.849 (31.684)	986.304 (31.405)	803.117 (28.339)	904.389 (30.073)	1319.016 (36.318)
II		1264.743 (35.563)	967.875 (31.111)	1805.740 (42.494)	1276.998 (35.735)	1619.930 (40.239)	1061.979 (32.588)	1635.038 (40.436)	1380.728 (37.158)
III			265.900 (16.306)	1849.428 (43.005)	858.932 (29.308)	917.465 (30.293)	797.675 (28.243)	1053.539 (32.458)	922.555 (30.374)
IV				295.386 (17.187)	2106.041 (45.005)	3293.227 (57.387)	2300.461 (47.963)	3363.063 (57.992)	1985.381 (44.558)
V					1155.040 (33.986)	1347.036 (36.702)	1058.295 (32.531)	1154.346 (33.976)	1331.087 (36.484)
VI						418.155 (20.449)	793.049 (28.161)	791.099 (28.126)	1970.350 (44.558)
VII							481.641 (21.946)	1025.516 (32.024)	1382.736 (37.185)
VIII								592.046 (24.332)	1582.754 (39.784)
IX									1385.104 (37.217)

Table 3: Mean value of 15 characters for nine clusters in tomato

Traits	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Plant height 60 DAT (cm)	64.91	66.92	62.45	112.36	66.41	60.45	56.9	69.6	64.2
Plant height 90 DAT (cm)	78.03	81.21	78.98	123.77	77.89	75.41	69.63	78.42	77.83
Days to first flowering	34.91	35.13	30.3	33.9	33.31	34.55	33.45	33.65	32.45
Days to 50 per cent flowering	38.79	37.77	36.5	36.5	36.83	39.75	38.25	38.75	36.75
Polar diameter (mm)	47.24	39.84	44.93	27.51	43.55	57.71	48.3	52.22	42.15
Equatorial diameter (mm)	46.48	39.39	45.77	27.22	43.67	52.11	49.84	53.65	49.08
Number of locules	2.66	2.25	2.67	2.11	2.79	2	3.26	2.5	3.33
Fruit volume (cc)	38.2	28.78	32.66	6.78	38.19	35.68	33.76	51.55	35.72
Average fruit weight (g)	49.72	37.38	41.59	9.69	45.25	57.22	54.28	77.14	58.75
Number of fruits per plant	29.67	29.92	25.1	53.4	37.4	16.4	26	30.1	34.66
Yield per plant (kg)	1.44	0.93	1.05	0.51	1.57	0.94	1.39	2.39	2.03
Yield per plot (kg)	7.14	4.63	5.29	2.59	7.86	4.71	6.95	11.96	10.17
Number of seeds per fruit	104.35	109.98	97.51	88.83	79.98	64.19	87.23	82.81	103.35
Thousand seed weight (g)	2.79	3.16	2.75	2.97	2.68	3.37	2.75	3.4	2.71
Lycopene content (mg / 100 g)	6.83	9.15	8.45	11.95	7.5	6.5	12.42	5.55	9.49

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