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Genetic Variability and D^2 Analysis for Yield and Quality Traits in Tomato (*Solanum lycopersicum* L.)

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A B S T R A C T

Forty two genotypes of tomato including four check cultivar (GT-2, GT-6, JT-3 and Pusa Ruby) were planted in Randomized Block Design, during *rabi* 2018 and were assessed to know the nature and magnitude of variability and genetic divergence for twelve traits. The experimental results revealed a wide range of variability for all the traits under study. High heritability coupled with high genetic advance was observed for number of fruits per plant, plant height, fruit length, fruit girth, shelf life of fruits, tomato leaf curl virus incidence, average fruit weight, fruit borer damage and number of locules per fruit which offers the better scope for improvement through selection. Based on the Mahalanobis D^2 statistics, forty two genotypes of tomato were grouped into three clusters. Maximum number of genotypes were accommodated in the cluster-I (40) followed by cluster-II (1) and cluster-III (1). Highest inter cluster distance of 273.83 was recorded between cluster I and III, hence, crossing between the genotypes of these cluster is expected to yield more heterotic hybrids. On the other hand, six genotypes *viz.*, NTL-72, NTL-81, NTL-84, NTL-53, NTL–65 and NTL-31 performed better for important traits under study. These genotypes need further testing to be released as a substitute of already existing tomato varieties or these can be crossed with diverse genotypes of other clusters for the development of superior hybrids in tomato.

Introduction

Tomato (*Solanum lycopersicum* L., 2n=24) is a member of solanaceae family, grown throughout the year in all over the world. It has wider adaptability, high yielding potential and multipurpose uses in fresh as well as processed food industries. Therefore, identification and development of new cultivars is important to improve production and productivity of tomato (Kumar *et al.*, 2013a). Planning and execution of a breeding programme for the improvement of quantitative traits depends, to a great extent, upon magnitude of genetic variability (Kumar *et al.*, 2013b). Genetic variability for yield and its component traits is essential in the base population for successful crop improvement (Allard, 1960). Tomato has a wide range of variability, which provides a tremendous scope for genetic improvement of its economic traits (Singh and Ramanujam,

1981). An improvement in yield and quality of tomato is normally achieved by selecting the genotypes with desirable trait combinations existing in nature or by hybridization. The crop improvement also depends upon the extent to which desirable traits are heritable. Heritable variation can effectively be studied in conjunction with genetic advance. High heritability alone is not enough to make efficient selection in segregation, unless the information is accompanied for substantial amount of genetic advance (Johnson *et al.,* 1955). Further, information on genetic diversity is used to identify the promising diverse genotypes, which may be used in further breeding programmes. Therefore, keeping in view the above facts in mind the present study has been conducted to obtain information on the extent of genetic variability and divergence among forty two genotypes of tomato and to assess their utility in developing heterotic combinations for commercial use.

Materials and Methods

The present experiment was conducted at NMCA college farm, Navsari Agricultural University, Navsari, during Rabi 2018-19. The soil of the experimental plot was black cotton soil with pH 7.4. Navsari is situated at 72º 54' East longitude and 20º 57' North latitude and at an altitude of 11.89 m above the mean sea level. This region falls under "South Gujarat Heavy Rainfall Zone, AES – III". The climate of this zone is typically tropical and monsoonic. The average rainfall of the zone is about 1500 mm and is normally received by second fortnight of June and ceases by September end. Winter starts from November and ends by the middle of February. The experimental materials comprised of 42 genotypes of tomato (NTL-7, NTL-10, NTL-19, NTL-22, NTL-24, NTL-25, NTL-26, NTL-28, NTL-31, NTL-38, NTL-41, NTL-45, NTL-50, NTL-52, NTL-57, NTL-58, NTL-63, NTL-64, NTL-65, NTL-66, NTL-68, NTL-71, NTL-72, NTL-73, NTL-77, NTL-81, NTL-84, NTL-85, NTL-87, NTL-89, NTL-91, NTL-96, NTL-99, NTL-105, NTL-17, NTL-21, NTL-48, NTL-53, GT-2, GT-6, JT-3, Pusa Ruby) collected from different indigenous and exotic sources. The experiment was laid out in Randomized Block Design at a spacing of 90 cm × 45 cm in the plots with 3 replications. The standard agronomic practices were followed to maintain healthy crop stand. Except days to 50 % flowering, fruit borer damage, tomato leaf curl virus damage, all other characters *viz.*, plant height, branches per plant, no. of fruits per plant, fruit length, fruit girth, no. of locules per plant, shelf life of fruits, average fruit weight and fruit yield per plant observations were recorded on five randomly selected plants per plot excluding border plants. The mean values of data were subjected to the analysis of variance as per the procedure described by Panse and Sukhatme (1978). The genotypic and phenotypic co-efficient of variation were calculated as per formulae given by Burton and De-Vane (1953). Heritability and genetic advance were calculated according to Allard (1960) and genetic gain was estimated as per the method given by Johnson *et al.*, (1955). Multivariate analysis was done utilizing Mahalanobis D^2 statistics and genotypes were grouped into different clusters following Tochers method as described by Rao (1952) and Mahalanobis (1936).

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized as under.

The analysis of variance revealed significant genotypic differences for all twelve characters under study (Table 1). A wide range of

variability was observed for different quantitative as well as qualitative traits indicating the scope for selection of suitable initial breeding material for further improvement. The mean performance of different genotypes as given in Table 2 revealed a wide range of variability for all the horticultural traits under study *viz.*, Days to 50 per cent flowering (30.06% to 46.26%), plant height (69.87cm to 263.87cm), branches per plant (6.29 to 11.74), number of fruits per plant (15.34 to 138.32), fruit length (3.85cm to18. 86cm), fruit girth (0.69cm to 4.85cm), number of locules per fruit (1.70 to 4.97), shelf life of fruits (2.15days to 8.08days), average fruit weight (1.06g to 86.54g), fruit yield per plant (1.71kg to 2.73kg), fruit borer damage (1.89% to 26.45%) and tomato leaf curl virus incidence (10.00% to 53.33%), which again revealed the existence of good deal of variability in the germplasm and offers the opportunity for improvement in yield and quality traits of tomato. The analysis of components of variance (Table 3) revealed that the genotypic variance followed the trend of phenotypic variance and was greater than environmental variance for all the characters except fruit yield per plant indicating that influence of environment on the expression of traits was lower or negligible. The genotypic variance was observed high in plant height, number of fruits per plant, average fruit weight, fruit borer damage and tomato leaf curl virus incidence, moderate in days to 50 % flowering and Low in number of branches per plant, fruit length, fruit girth, number of locules per fruit, shelf life of tomato and yield per plant. Earlier workers like Dhanker and Dhanker (2006), Ghosh *et al.*, (2010), Taisa *et al.*, (2011), Madhurima and Amitava (2012), Ayush *et al.*, (2012), Mohamed *et al.*, (2012), Kumari and Sharma (2013), Patel *et al.*, (2013), Khapte and Jansirani (2014), Rai *et al.*, (2016), Das *et al.*, (2017), Ligade *et al.*, (2017) and Dutta *et al.*, (2018) had also reported similar genotypic co-efficient of variation trends for different traits. The genotypic co-efficient of variation does not offer full scope to estimate the variations that are heritable and therefore, estimation of heritability becomes necessary. The estimates of heritability (broad sense) varied from 52.20% to 93.30% for different traits under study (Table 3). Further, genetic gain (expressed as per cent of population mean) was found low to high in nature and ranged from 8.42% to 113.20% for different traits (Table 3). In the present studies, high heritability with high genetic advance as percent of mean was recorded for number of fruits per plant, plant height, fruit length, fruit girth, shelf life of fruits, tomato leaf curl virus incidence, average fruit weight, fruit borer damage and number of locules per fruit. The result of the present study was in agreement with finding of Dhanker and Dhanker (2006), Ghosh *et al.*, (2010), Madhurima and Amitava (2012), Ayush *et al.*, (2012), Reddy *et al.*, (2013), Hasan *et al.*, 2016), Rai *et al.*, (2016), Das *et al.*, (2017) and Ligade *et al.*, (2017), Thapa *et al.*, (2018) and Dutta *et al.*, (2018). It indicates the predominance of additive gene action and thus more reliable for selection. Moderate heritability with moderate genetic advance observed for days to 50% flowering and number of branches per plant indicated that these characters are under non-additive gene effects and selection for these characters will be less effective. Such traits are more under the influence of environment and do not respond to selection.

Genetic divergence: Information on genetic diversity is used to identify the promising diverse genotypes, which may be used in further breeding programmes. Based on the Mahalanobis D^2 statistics, 42 genotypes of tomato were grouped into three clusters (Table 4). Maximum number of genotypes were accommodated in the cluster-I (40) followed by cluster-II (1) and cluster-III (1).

Table.1 Analysis of variance for various traits in tomato

Source of variation	Replication	Genotypes	Error
Degree of freedom	2	41	82
Days to 50 per cent flowering	25.95	52.79**	9.96
Plant height (cm)	197.17	3395.10**	179.97
Branches per plant	2.00	3.71**	0.86
No. of fruits per plant	63.69	1132.71**	26.46
Fruit length (cm)	0.68	23.68**	1.39
Fruit girth (cm)	0.06	1.45**	0.09
No. of locules per fruit	0.01	1.97**	0.24
Shelf life of fruits (Days)	0.17	3.88**	0.27
Average fruit weight (g)	163.88	766.15**	69.44
Fruit yield per plant(kg)	0.22	0.28*	0.16
Fruit borer damage (%)	14.51	100.19**	9.43
Tomato leaf curl virus incidence (%)	7.14	410.63**	36.41

Table.2 Mean values of genotypes for twelve characters of tomato (*Solanum lycopersicum* L.)

Sr. No.	Genotypes	Days to 50 % flowering	Plant height (cm)	Branches per plant	No. of fruits per plant	Fruit length (cm)	Fruit girth (cm)	No. of locules per fruit	Shelf life of fruits (Days)	Average fruit weight (g)	Fruit yield per plant(kg)	Fruit borer damage (%)	Tomato leaf curl virus incidence (%)
1	**NTL-7**	38.06	75.80	6.73	31.01	16.35	4.17	4.37	6.18	55.91	2.20	20.24	13.33
2	**NTL-10**	42.06	112.80	8.10	33.01	13.53	3.15	2.70	5.25	38.45	2.43	23.74	30.00
3	**NTL-19**	33.73	111.74	8.18	37.67	14.08	4.05	2.83	5.78	50.80	2.59	22.00	26.67
4	**NTL-22**	36.40	122.07	8.66	45.34	17.24	3.33	4.90	6.38	66.59	1.76	23.21	36.67
5	**NTL-24**	44.06	74.60	9.26	45.34	12.96	4.01	2.83	5.63	41.11	1.83	15.34	36.67
6	**NTL-25**	30.73	92.81	7.52	31.34	14.31	3.82	3.17	6.85	47.52	2.43	26.31	36.67
7	**NTL-26**	35.73	106.94	7.63	30.34	14.49	3.71	2.83	5.88	49.31	2.65	14.55	26.67
8	**NTL-28**	34.39	100.54	8.47	26.01	14.00	3.45	2.83	5.55	43.91	1.74	14.19	33.33
9	**NTL-31**	30.39	91.60	8.96	20.34	14.14	3.55	3.30	6.21	43.61	2.13	13.41	43.33
10	**NTL-38**	32.40	110.21	8.47	15.34	12.77	4.11	2.50	5.88	42.66	1.73	25.89	36.67
11	**NTL-41**	36.06	119.74	6.45	26.01	16.78	3.88	3.63	5.98	65.47	1.73	17.34	36.67
12	**NTL-45**	43.40	96.21	7.41	28.67	14.12	3.25	3.10	5.95	41.47	2.10	16.52	13.33
13	**NTL-50**	36.06	123.07	8.16	26.34	14.29	3.95	3.50	6.42	47.39	1.76	26.39	16.67
14	**NTL-52**	35.06	79.54	7.70	32.01	15.77	3.69	3.63	5.47	59.25	2.06	20.45	10.00
15	**NTL-57**	38.40	114.74	6.29	23.34	16.71	3.77	4.17	6.21	60.07	2.17	16.63	36.67
16	**NTL-58**	43.06	84.81	8.81	25.34	15.91	3.48	3.70	5.14	55.77	2.26	24.59	23.33
17	**NTL-63**	34.40	93.41	8.59	43.01	14.47	3.28	3.83	4.11	44.13	1.81	24.23	20.00
18	**NTL-64**	41.40	77.94	7.67	54.33	7.57	2.63	2.56	2.15	10.81	2.13	7.51	13.33
19	**NTL-65**	38.40	69.87	7.86	26.01	16.21	3.29	4.17	6.65	56.38	2.42	23.56	46.67
20	**NTL-66**	37.40	77.21	6.57	39.34	15.03	3.45	3.50	6.87	51.21	2.70	20.41	26.67
21	**NTL-68**	40.73	86.00	8.39	32.68	11.98	3.59	2.50	4.81	34.47	2.40	17.03	53.33
22	**NTL-71**	41.73	134.67	7.33	30.34	15.00	3.67	3.64	5.14	50.72	2.02	20.15	36.67
23	**NTL-72**	40.06	72.94	6.60	33.34	16.93	4.85*	2.70	6.01	66.05	2.73	25.82	13.33

Contd...

Sr. No.	Genotypes	Days to 50 % flowering	Plant height (cm)	Branches per plant	No. of fruits per plant	Fruit length (cm)	Fruit girth (cm)	No. of locules per plant	Shelf life of fruits (Days)	Average fruit weight (g)	Fruit yield per plant (kg)	Fruit borer damage (%)	Tomato leaf curl virus incidence (%)
24	**NTL-73**	37.06	137.87	8.30	27.67	14.33	3.22	3.70	4.80	44.24	2.14	23.40	20.00
25	**NTL-77**	31.39	82.07	8.08	22.34	12.51	2.83	2.90	3.80	31.28	2.16	23.82	23.33
26	**NTL-81**	33.06	172.14	11.74	74.01	7.00	1.72	2.03	2.81	6.44	1.71	5.48	40.00
27	**NTL-84**	44.06	263.87	10.49	138.32	3.85	0.69	1.70	3.82	1.06	2.22	1.89	46.67
28	**NTL-85**	46.26	114.87	7.74	31.01	16.35	3.17	4.77	6.21	53.93	2.29	14.52	13.33
29	**NTL-87**	36.40	125.07	8.11	31.01	14.84	3.44	2.83	7.46	52.04	2.47	23.75	23.33
30	**NTL-89**	32.06	137.27	8.74	27.01	15.63	3.36	3.44	6.14	51.52	2.03	16.08	13.33
31	**NTL-91**	30.73	93.94	7.67	23.01	16.97	3.20	4.44	5.49	57.97	2.58	22.00	26.67
32	**NTL-96**	35.40	130.54	6.82	25.34	13.51	3.82	2.57	6.67	44.61	2.45	20.66	33.33
33	**NTL-99**	35.06	105.07	9.59	18.01	17.15	4.51	3.03	6.63	86.55	1.80	25.15	30.00
34	**NTL-105**	38.73	115.14	9.82	24.68	14.07	3.53	2.10	6.65	44.50	2.21	10.42	43.33
35	**NTL-17**	39.06	112.80	7.22	33.68	16.42	3.71	2.97	6.37	57.49	2.52	22.97	40.00
36	**NTL-21**	42.06	115.07	8.17	36.67	15.87	3.90	2.03	6.57	61.20	2.22	26.45	40.00
37	**NTL-48**	35.40	91.74	7.74	23.01	13.67	4.03	2.03	5.77	42.37	2.18	18.04	43.33
38	**NTL-53**	33.06	115.27	6.92	22.34	14.58	3.91	2.90	8.08	54.84	2.17	22.97	53.33
39	**GT-2**	37.73	83.14	7.23	24.68	18.86	3.77	4.97	6.41	71.01	2.30	17.26	36.67
40	**GT-6**	34.07	77.40	6.33	34.68	16.81	3.96	3.37	5.47	62.81	2.70	22.59	40.00
41	**JT-3**	30.06	82.27	8.40	29.34	14.34	4.32	2.17	5.80	52.48	2.61	21.41	33.33
42	**Pusa Ruby**	38.06	140.74	7.63	34.34	16.71	4.20	3.63	6.47	62.68	1.77	18.52	23.33
Mean		**37.00**	**107.75**	**8.01**	**33.75**	**14.48**	**3.56**	**3.20**	**5.76**	**49.10**	**2.20**	**19.45**	**30.71**
S.Em±		**1.82**	**7.75**	**0.54**	**2.97**	**0.68**	**0.17**	**0.28**	**0.30**	**4.81**	**0.23**	**1.77**	**3.48**
C.D at 5%		**5.13**	**21.79**	**1.51**	**8.36**	**1.92**	**0.48**	**0.79**	**0.85**	**13.53**	**0.66**	**4.99**	**9.80**
C.V %		**8.53**	**12.45**	**11.62**	**15.24**	**8.16**	**8.38**	**15.25**	**9.10**	**16.97**	**18.43**	**15.79**	**19.65**

Table.3 Range, mean and components of variance for various traits in tomato

Sr.No.	Characters	Range	Mean	GCV %	PCV %	Heritability (b.s.%)	Genetic advance	Genetic advance % of mean
1.	**Days to 50 per cent flowering**	30.06-46.26	37.00	10.21	13.31	58.90	5.97	**16.15**
2.	**Plant height (cm)**	69.87-263.87	107.75	30.38	32.83	85.60	62.40	**57.91**
3.	**Branches per plant**	6.29-11.74	8.01	12.15	16.82	52.20	1.45	**18.09**
4.	**No. of fruits per plant**	15.34-138.32	33.75	56.89	58.90	93.30	38.21	**113.20**
5.	**Fruit length (cm)**	3.85-18.86	14.48	18.83	20.52	84.20	5.15	**35.58**
6.	**Fruit girth (cm)**	0.69-4.85	3.56	18.94	20.71	83.60	1.27	**35.67**
7.	**No. of locules per fruit**	1.70-4.97	3.20	23.77	28.24	70.80	1.32	**41.21**
8.	**Shelf life of fruits (days)**	2.15-8.08	5.76	19.03	21.09	81.40	2.04	**35.37**
9.	**Average fruit weight (g)**	1.06-86.55	49.10	31.04	35.38	77.00	27.54	**56.10**
10.	**Fruit yield per plant (kg)**	1.71-2.73	2.20	9.18	20.59	19.90	0.19	**8.42**
11.	**Fruit borer damage (%)**	1.89-26.45	19.45	28.28	32.39	76.20	9.89	**50.86**
12.	**Tomato leaf curl virus incidence (%)**	**10.00-53.33**	**30.71**	**36.36**	**41.33**	**77.40**	**20.24**	**65.90**

Table.4 Distribution of 42 genotypes of tomato into three different clusters on the basis of Mahalanobis D^2 statistics

Clusters	Number of genotypes	Genotypes
I	40	NTL-7, NTL-10, NTL-19, NTL-22, NTL-24, NTL-25, NTL-26, NTL-28, NTL-31, NTL-38, NTL-41, NTL-45, NTL-50, NTL-52, NTL-57, NTL-58, NTL-63, NTL-64, NTL-65, NTL-66, NTL-68, NTL-71, NTL-72, NTL-73, NTL-77, NTL-81, NTL-87, NTL-89, NTL-91, NTL-96, NTL-99, NTL-105, NTL-17, NTL-21, NTL-48, NTL-53, GT-2, GT-6, JT-3, Pusa Ruby
II	1	NTL-81
III	1	NTL-84

Table.5 Average inter and intra cluster (D^2) values for 42 genotypes of tomato

Clusters	I	II	III
I	19.45	91.77	273.83
II		0.00	81.68
III			0.00

Table.6 Cluster means for twelve characters in forty two tomato genotypes

Clusters	Days to 50 per cent flowering	Plant height (cm)	Branches per plant	Number of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Number of locules per fruit	Shelf life of fruits (days)	Average fruit weight (g)	Fruit yield per plant (kg)	Fruit borer damage (%)	Tomato leaf curl virus incidence (%)
I	36.92	102.24	7.86	30.13	**14.93**	**3.68**	**3.27**	**5.88**	**51.36**	2.21	**20.24**	30.08
II	33.06	172.14	**11.74**	74.01	7.00	1.72	2.03	2.81	6.44	1.71	5.48	40.00
III	**44.06**	**263.87**	10.49	**138.32**	3.85	0.69	1.70	3.82	1.06	**2.22**	1.89	**46.67**

Among different twelve traits studied tomato leaf curl virus incidence, number of fruits per plant, shelf life of fruits, fruit borer damage, fruit girth and plant height contributed very much towards genetic divergence. Based on inter-cluster distance, clusters III and I followed by II and I had maximum inter-cluster distance. Therefore, it is concluded that the genotypes belonging to these clusters should be inter-crossed in order to generate more variability and to improve tomato. Cluster I revealed maximum mean value for fruit length, fruit girth, number of locules per fruit, shelf life of fruits, average fruit weight and fruit borer damage. Cluster II revealed maximum values for number of branches per plant, while cluster III revealed maximum value for days to 50 % flowering, plant height, number of fruits per plant, fruit yield per plant and tomato leaf curl virus incidence. Similar findings have been reported by Jogi *et al.,* (2008), Meena and Bahadur (2013), Dar *et al.,* (2015), Kumar *et al.,* (2016), Hossain *et al.,* (2016) and Spaldon and Kumar (2017). Therefore, it can be concluded that the selection of parents for hybridization should not be based on geographical diversity only, but it should have a base of both geographical origin as well as genetic divergence (Table 5 and 6).

From the present investigation it can be concluded that six genotypes *viz.,* NTL - 72, NTL – 84, NTL – 81, NTL – 53, NTL – 65 and NTL - 31 performed better for important traits. These genotypes need further testing to be released as a substitute of already existing tomato varieties or these can be crossed with other genotypes for the development of superior tomato hybrids.

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