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RESEARCH ARTICLE

GENETIC DIVERGENCE AND CLUSTER ANALYSIS IN TOMATO (*Solanum lycopersicum* L.).

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Abstract

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Present investigation was carried out at AICRP on Vegetable Crops, OUAT, Bhubaneswar, Odisha to assess the value and magnitude of genetic divergence among the genotypes using Mahalanobis D^2 statistics. About fifty five genotypes were evaluated for 17 growth, yield and quality traits which were grouped into nineteen clusters. Cluster V topped in having maximum of 11 genotypes followed by cluster I with nine and cluster XVIII with three genotypes while cluster II, III, IV, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII and XIX were monotypic. The maximum inter-cluster distance was noticed between cluster XIII and XVIII (D^2=15603.23) followed by cluster XI and cluster XVIII (D^2=13232.33). Therefore, selection of divergent parents of tomato based on these cluster distances would be useful in formulating a comprehensive strategy to develop superior hybrids or better segregants in tomato. On the basis of the present study, superior hybrids or variety (s) may be expected by crossing parents selected from cluster XIII (BT-19-1-1-1 X BT-22-4-1, BT-22-4-1) with parents of cluster XVIII (Utkal Kumari X BT-19-1-1-1, Utkal Kumari X BT-317, Utkal Kumari X BT-3).

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Introduction:-

Tomato (*Solanum lycopersicum* L.) is one of the important vegetable grown throughout the world. The cultivated tomato originated in a wild form in the Peru-Ecuador-Bolvia area of the Andes (Vavilov, 1951). Despite its wide cultivation and high yield potential the average yield is very low due to non-availability of improved varieties or hybrids. Diversity in parents is a pre-requisite in the development of variety or hybrid. Systematic study and evaluation of germplasm is of great importance for future genetic improvement of the crop. Furthermore, evaluation of germplasm is imperative, in order to understand the genetic background and breeding value of the available germplasm (Singh *et al.*, 2002). Success of crop improvement programme depends on the extent of variability, choice of parents for hybridization and selection procedure. Multivariate analysis is a potent tool for measuring

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divergence among a set of populations based on multiple characters. D^2 statistic proposed by Mahalanobis (1936) has been generally used as an efficient tool in the quantitative estimation of genetic diversity for a breeding programme. For the first time use of this technique for assessing the genetic variability in plants was suggested by Rao (1952). Moreover, grouping of different genotypes of a particular crop by adopting Tocher's method will be more useful in choosing suitable parents for heterosis breeding. Keeping in view the above facts present investigation was undertaken with an objective to study of genetic diversity in fifty five genotypes of tomato based on seventeen important traits, to help in selecting promising and genetically diverse parents for desired improvement.

Materials and Methods:-

The experimental materials for the present study consisted of 55 genotypes of tomato evaluated at AICRP on Vegetable Crops, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha during *Rabi*, 2016. The experiment was laid out in the randomized block design with three replications at spacing of 60cm x 45cm. The crop was raised by adopting recommended package of practices uniformly. Observations were recorded from five randomly selected plants (excluding border rows) of each genotype in each replication, for seventeen characters. Mean values of five plants were used for statistical analysis. The data of 55 genotypes of tomato were analyzed utilizing multivariate analysis (D^2 statistic) (Mahalanobis, 1936). The original measurements were transformed to standardized uncorrelated variables by pivotal condensation.Grouping of genotypes into different clusters was carried out by adopting Tocher's method and the relative contribution of different characters towards total divergence was calculated (Singh and Choudhary, 1985).

Table 1:-Clustering pattern of 55 tomato genotypes

Cluster No.	Number of genotypes	Name of genotypes
I	9	BT-1 X Utkal Dipti, BT-1 X Utkal Kumari, BT-1 X BT-19-1-1-1, BT-1 X BT-317, BT-1 X BT-22-4-1, BT-1 X BT-3, BT-1 X BT-17-2, BT-19-1-1-1 X BT-21, BT-317 X BT-21
II	2	BT-1, Utkal Dipti
III	2	BT-22-4-1 X BT-3, BT-22-4-1 X BT-507-2-2
IV	2	Utkal Dipti X BT-21, BT-3 X BT-507-2-2
V	11	BT-1 X BT-507-2-2, BT-1 X BT-21, Utkal Dipti X Utkal Kumari, Utkal Dipti X BT-19-1-1-1, Utkal Dipti X BT-317, Utkal Dipti X BT-22-4-1, Utkal Dipti X BT-3, Utkal Dipti X BT-17-2, Utkal Dipti X BT-507-2-2, Utkal Kumari X BT-22-4-1, BT-3 X BT-17-2
VI	2	Utkal Kumari X BT-21, BT-19-1-1-1 X BT-317
VII	2	BT-19-1-1-1 X BT-507-2-2, BT-317 X BT-3
VIII	2	BT-3 X BT-21, BT-507-2-2 X BT-21
IX	2	BT-317 X BT-507-2-2, BT-507-2-2
X	2	BT-19-1-1-1 X BT-17-2, BT-17-2 X BT-507-2-2
XI	2	BT-3, BT-21
XII	2	Utkal Kumari X BT-507-2-2, BT-22-4-1 X BT-21
XIII	2	BT-19-1-1-1 X BT-22-4-1, BT-22-4-1
XIV	2	BT-317 X BT-22-4-1, BT-17-2 X BT-21
XV	2	Utkal Kumari X BT-17-2, BT-317
XVI	2	BT-19-1-1-1, BT-17-2
XVII	2	BT-19-1-1-1 X BT-3, BT-317 X BT-17-2
XVIII	3	Utkal Kumari X BT-19-1-1-1, Utkal Kumari X BT-317, Utkal Kumari X BT-3
XIX	2	BT-22-4-1 X BT-17-2, Utkal Kumari

Table 2:-Intra (Diagonal) and Inter cluster average (D^2) corresponding D ($\sqrt{D^2}$) values (in parenthesis) among groups.

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	1615.75 (40.20)	1038.84 (32.23)	953.29 (30.86)	777.37 (27.88)	2248.10 (47.41)	1441.94 (37.67)	1495.63 (38.67)	1466.71 (38.29)	1813.98 (42.59)	1082.99 (32.91)
II		38.09	585.50	239.87	2156.53	270.97	258.96	227.90	528.99	174.15

		(6.17)	(24.20)	(15.49)	(46.44)	(16.46)	(16.09)	(15.10)	(23.00)	(13.20)
III			45.39 (6.74)	248.88 (15.78)	1708.85 (41.34)	940.84 (30.67)	693.82 (26.34)	828.29 (28.78)	909.06 (30.15)	430.64 (20.75)
IV				56.12 (7.49)	1618.42 (40.23)	623.65 (24.97)	623.97 (24.98)	589.32 (24.28)	904.77 (30.08)	328.76 (18.13)
V					2997.95 (54.75)	2885.09 (53.71)	2785.64 (52.78)	2819.68 (53.10)	3227.80 (56.81)	2253.13 (47.47)
VI						67.65 (8.23)	270.53 (16.45)	129.79 (11.39)	307.20 (17.53)	276.76 (16.65)
VII							67.84 (8.24)	147.13 (12.13)	150.66 (12.28)	193.36 (13.91)
VIII								68.67 (8.29)	214.72 (14.65)	275.29 (16.59)
IX									70.48 (8.40)	350.06 (18.71)
X										73.28 (8.56)
XI										
XII										
XIII										
XIV										
XV										
XVI										
XVII										
XVII										
XIX										

Table 2:-Intra (Diagonal) and Inter cluster average (D^2) corresponding D ($\sqrt{D^2}$) values (in parenthesis) among groups.

	XI	**XII**	**XIII**	**XIV**	**XV**	**XVI**	**XVII**	**XVIII**	**XIX**
I	2899.49 (53.85)	1842.96 (42.93)	3995.03 (63.21)	1124.50 (33.53)	1492.31 (38.63)	1015.23 (31.86)	995.02 (31.54)	6226.31 (78.91)	2438.54 (49.38)
II	1017.19 (31.90)	505.04 (22.47)	2006.36 (44.79)	331.40 (18.20)	219.99 (14.83)	551.31 (23.48)	189.98 (13.78)	7602.19 (87.29)	1292.06 (35.95)
III	2102.43 (45.85)	1034.96 (32.17)	2858.38 (53.46)	401.41 (20.04)	863.92 (29.39)	492.56 (22.19)	340.03 (18.44)	5900.49 (76.81)	1724.63 (41.53)
IV	1879.46 (43.35)	953.87 (30.89)	2942.58 (54.25)	400.51 (20.01)	621.85 (24.94)	255.67 (15.99)	227.10 (15.07)	5892.97 (76.77)	1591.55 (39.89)
V	4655.60 (68.23)	3339.08 (57.79)	5961.61 (77.21)	2309.98 (48.06)	2856.47 (53.45)	1615.09 (40.19)	1910.46 (43.71)	5447.75 (73.81)	3677.78 (60.65)
VI	639.07 (25.28)	215.83 (14.69)	1277.81 (35.75)	314.36 (17.73)	158.93 (12.61)	1229.14 (35.06)	621.22 (24.92)	9571.23 (97.83)	1385.08 (37.22)
VII	468.65 (21.65)	191.14 (13.83)	1038.10 (32.22)	313.77 (17.71)	109.20 (10.45)	1091.85 (33.04)	361.27 (19.01)	9323.12 (96.56)	1177.77 (34.32)
VIII	497.84 (22.31)	144.96 (12.04)	1147.08 (33.87)	362.67 (19.04)	112.33 (10.60)	1033.01 (32.14)	493.77 (22.22)	9446.96 (97.20)	1288.25 (35.89)
IX	431.99 (20.78)	129.62 (11.39)	766.75 (27.69)	350.77 (18.73)	204.99 (14.32)	1553.23 (39.41)	686.47 (26.20)	10305.93 (101.52)	1350.50 (36.75)
X	985.03 (31.39)	395.82 (19.90)	1657.30 (40.71)	149.35 (12.22)	223.55 (14.95)	826.13 (28.74)	211.73 (14.55)	7956.45 (89.20)	1217.84 (34.90)
XI	105.46 (10.27)	359.66 (18.97)	338.45 (18.40)	1162.40 (34.09)	465.40 (21.57)	2547.43 (50.47)	1405.35 (37.49)	13232.33 (115.03)	1704.30 (41.28)
XII		134.43 (11.59)	733.89 (27.09)	408.67 (20.22)	193.89 (13.93)	1578.00 (39.72)	776.57 (27.87)	10627.63 (103.09)	1395.89 (37.36)

XIII			135.38 (11.64)	1768.52 (42.05)	1107.67 (33.28)	3865.28 (62.17)	2343.31 (48.41)	15603.23 (124.91)	2331.34 (48.28)
XIV				154.98 (12.45)	340.78 (18.46)	992.35 (31.50)	393.78 (19.84)	7998.23 (89.43)	1413.90 (37.60)
XV					158.10 (12.57)	1137.16 (33.72)	447.72 (21.16)	9508.57 (97.51)	1230.54 (35.08)
XVI						166.67 (12.91)	424.68 (20.61)	5081.04 (71.28)	2017.04 (44.91)
XVII							187.23 (13.68)	6727.65 (82.02)	1344.66 (36.67)
XVIII								3996.71 (63.22)	9883.71 (99.42)
XIX									4414.61 (66.44)

Table 3:-Cluster wise mean values of 17 characters of tomato genotypes

Character Cluster	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
I. (	**57.389**	**65.850**	**16.450**	**5.572**	**4.339**	**53.251**	**5.623**	**14.351**	**0.406**	**3.783**	**73.414**	**8.022**	**46.265**	**5.739**	**277.333**	**4.127**	**1.239**
II. (	**55.550***	**65.475**	**18.575****	**5.675**	**4.725**	**53.325**	**6.387**	**14.908**	**0.363**	**3.625**	**77.375**	**10.825****	**28.050***	**4.653**	**238.500**	**4.253**	**0.838***
III. (	**56.775**	**65.875**	**14.025**	**5.375**	**4.550**	**42.275**	**5.997**	**15.285**	**0.442**	**4.425**	**78.848**	**6.850**	**90.665**	**5.530**	**269.750**	**4.292**	**2.277**
IV. (	**57.800**	**67.850**	**14.675**	**5.275**	**4.275**	**54.252****	**5.645**	**15.110**	**0.293**	**2.650***	**82.270**	**7.725**	**52.082**	**5.102**	**269.500**	**4.068**	**1.233**
V. (	**57.000**	**66.373**	**15.964**	**5.841**	**4.736**	**47.645**	**5.704**	**14.546**	**0.379**	**4.009**	**76.319**	**7.914**	**56.039**	**5.303**	**311.455**	**4.184**	**1.299**
VI. (	**58.175**	**67.575**	**13.100**	**5.400**	**4.700**	**43.250**	**5.573**	**13.542**	**0.435**	**3.275**	**90.115****	**8.600**	**42.923**	**5.517**	**204.000**	**4.068**	**1.010**
VII. (	**59.125**	**65.375**	**14.325**	**5.725**	**4.575**	**36.625***	**6.057**	**13.892**	**0.303**	**4.575**	**79.595**	**8.175**	**58.433**	**4.427**	**207.750**	**4.438**	**1.535**
VIII. (	**57.900**	**67.775**	**14.050**	**5.825**	**4.750**	**49.950**	**6.550**	**11.255***	**0.398**	**4.100**	**72.147**	**9.000**	**62.370**	**4.750**	**207.750**	**3.990***	**1.222**
IX. (	**57.250**	**65.800**	**10.800***	**6.525****	**5.350****	**42.875**	**6.410**	**13.278**	**0.288***	**3.125**	**87.997**	**6.525**	**94.210**	**4.915**	**191.250**	**4.370**	**1.322**
X. (	**57.475**	**65.675**	**17.625**	**5.600**	**4.800**	**50.450**	**3.675***	**14.298**	**0.320**	**4.200**	**73.542**	**8.525**	**61.688**	**5.295**	**234.000**	**4.345**	**1.332**
XI. (	**58.175**	**66.375**	**14.150**	**4.850***	**3.550**	**45.925**	**6.618***	**13.735**	**0.365**	**3.900**	**71.940**	**7.225**	**47.000**	**3.895***	**154.250**	**4.313**	**1.442**

					*		*										
XII. (	55.575	66.100	10.875	5.275	4.400	52.550	6.168	15.725	0.410	4.800**	74.527	9.775	79.610	5.120	190.000	4.160	1.515
XIII. (	58.675	68.425	12.775	5.275	4.050	43.545	4.162	14.507	0.480	3.100	77.908	5.775*	95.545**	4.360	126.000*	4.275	2.335**
XIV. (	58.900	68.500**	14.000	5.675	4.675	53.325	5.912	16.397**	0.387	4.650	76.080	7.350	73.935	6.135**	230.250	4.440**	1.263
XV. (	56.000	65.675	15.325	5.700	4.250	37.500	5.920	15.327	0.343	3.775	75.905	7.800	46.850	4.665	205.500	4.265	1.007
XVI. (	61.000**	67.650	14.225	5.900	4.925	52.925	6.210	15.220	0.498**	4.000	76.607	6.350	47.825	4.037	295.250	3.975	1.290
XVII. (	58.200	65.575	18.425	5.900	4.975	47.675	5.148	15.118	0.365	4.325	71.658*	6.775	48.275	4.405	257.500	4.430	1.308
XVIII. (	58.117	67.183	16.617	5.350	4.233	50.817	5.335	15.027	0.485	4.583	76.298	6.583	53.877	5.282	461.000**	4.328	0.857
XIX. (	57.525	64.925*	14.800	5.600	4.075	50.975	3.967	13.257	0.355	3.725	77.010	5.975	54.000	4.347	220.000	4.318	1.525

Figures in the parenthesis indicate number of cultivars in a cluster, * and ** indicate lowest and highest values respectively.

Days to first flowering (1), Days to 50% flowering (2), Number of cluster per plant (3), Number of flowers per cluster (4), Number of fruits per cluster (5), Number of fruits per plant (6), Length of fruits (7), Diameter of fruits (8), Pericarp thickness of fruits (9), Number of locules per fruit (10), Plant height (11), Total number of branches per plant (12), Average fruit weight (13), TSS of fruit (14), Ascorbic acid content (15), Acidity content of fruit (16), Yield per plant (17)

Table 4:-Relative contribution of different characters to genetic divergence in tomato genotypes**.**

Sl. No.	**Names of characters**	**Number of times ranked 1st**	**Percent contribution**
1	Days to first flowering	0	0.0000
2	Days to 50% flowering	0	0.0000
3	Number of cluster per plant	1	0.0673
4	Number of flowers per cluster	0	0.0000
5	Number of fruits per cluster	0	0.0000
6	Number of fruits per plant	1	0.0673
7	Length of fruits	2	0.1347
8	Diameter of fruits	0	0.0000
9	Pericarp thickness of fruits	0	0.0000
10	Number of locules per fruit	0	0.0000
11	Plant height	1	0.0673
12	Total number of branches per plant	1	0.0673
13	Average fruit weight	18	1.2121
14	TSS of fruit	91	6.1279
15	Ascorbic acid content	789	53.1313
16	Acidity content of fruit	100	6.7340
17	Yield per plant	481	32.3906

	Total	**1485**	**100**

Results and Discussion:-

On the basis of Mahalanobis D^2 analysis, 55 genotypes were grouped into 19 clusters (Table 1). Cluster V, the largest group included 11 genotypes followed by cluster I comprising of 9 genotypes and cluster XVIII comprising of 3 genotypes. Cluster II, III, IV, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII and XIX comprised of 02 genotypes each. When the clusters were compared for divergence, maximum inter- cluster distance was observed between clusters XIII and XVIII followed by XI and XVIII, clusters XII and XVIII, clusters XI and XVIII (Table 2). The genotypes with BT as prefix were developed at AICRP on Vegetable Crops, OUAT, Bhubaneswar. But all such genotypes were distributed among divergent clusters. This indicated that geographic distribution and genetic divergence did not follow the same trend.

If genotypes possessing high genetic divergence are involved in hybridization programmes, it is expected that more heterotic hybrids and transgressive segregants may be produced in segregating generations. Present results are in agreement with the findings of Mahesh *et al.* (2006) and Singh *et al.* (2008).It is evident from Table 2 that cluster II had the minimum intra-cluster distance (6.17) whereas maximum intra-cluster distance (66.44) was observed in cluster XIX.

Since improvement in yield and other related traits is a basic objective in any breeding programme, cluster means for fruit yield plant^{-1} and its major components need to be considered for selection of parents. The cluster means of 17 quantitative and qualitative characters for groups of tomato genotypes are presented in Table 3. Cluster II containing two tomato genotypes showed the highest values in respect of number of cluster plant^{-1} (18.575) and total number of branches plant^{-1} (10.825) whereas lowest values for days to first flowering (55.550), average fruit weight (28.050) and yield plant^{-1} (0.838). Cluster IV contains two tomato genotypes with highest value in number of fruits plant^{-1} (54.252) and lowest value in number of locules fruit^{-1} (2.650). Cluster VI with two genotypes showed the highest values for plant height (90.115). Cluster VII containing two genotypes, showed the lowest value in respect of number of fruits plant^{-1} (36.625). Cluster VIII with two genotypes had the lowest value of diameter of fruits (11.255) and acidity content of fruit (3.990). Cluster IX containing two genotypes showed the lowest values in number of cluster plant^{-1} (10.800) and in pericarp thickness of fruits(0.288) whereas had the highest values in number of flowers cluster^{-1} (6.525) and number of fruits plant^{-1} (5.350). Lowest value of cluster X was observed for length of fruits (3.675). Highest values of Cluster XI were observed in length of fruits (6.618) whereas lowest values were in number of flowers cluster^{-1} (4.850), number of fruits plant^{-1} (3.550) and TSS of fruit (3.895). Cluster XII showed highest value for number of locules fruit^{-1} (4.800). Highest values for average fruit weight (95.545), yield plant^{-1} (2.335) and lowest values for total number of branches plant^{-1} (5.775) and ascorbic acid content (126.000) were observed in Cluster XIII. Cluster XIV comprising of two genotypes showed highest values for days to 50% flowering (68.500), diameter of fruits (16.397), TSS of fruit (6.135) and acidity content of fruit (4.440). Highest values for days to first flowering (61.000) and pericarp thickness of fruit (0.498) were observed in Cluster XVI and for ascorbic acid content (461.000) in Cluster XVIII.

The relative contribution of 17 quantitative and qualitative traits to genetic divergence among the 55 genotypes of tomato have been presented in Table 4, by rank average of individual character over all 1485 paired combinations. Among the yield contributing quantitative characters, the maximum contribution towards divergence was made by yield plant^{-1} (32.3906) followed by average fruit weight (1.2121 %), length of fruits (0.1347 %), plant height (0.0673), total number of branches plant^{-1} (0.0673), number of fruits plant^{-1} (0.0673) and number of cluster plant^{-1} (0.0673). Rest of the qualitative characters contributing to divergence in descending order were ascorbic acid content (53.1313), acidity content of fruit (6.7340) and TSS of fruit (6.1279). It was observed that in the characters days to first flowering, days to 50% flowering, number of flowers cluster^{-1}, number of fruits cluster^{-1}, diameter of fruits, pericarp thickness of fruits and number of locules fruit^{-1} contribution to divergence was 0%.

Previous workers Jag Paul Sharma *et al.* (2011) and Rajeev and Reddy (2012) also reported similar kind of results. Average fruit weight was shown to have substantial contribution to divergence by several researchers (Veershety, 2004; Singh *et al.*, 2008).Singh *et al.* (2008) corroborated the importance of number of fruits/plant while numerous researchers (Mahesh *et al.*, 2006; Singh *et al.*, 2008) confirmed high contribution of fruit yield plant^{-1} towards divergence. The characters like average fruit weight and number of fruits plant^{-1} will offer a good scope for improvement throughselection and directselection can be adopted effectively for achievingdesirable results. In order to achieve high heterosis or superior recombinants in future, hybridization between genotypes in clusters XIII and XVIII or between clusters XI and XVIII, would be more desirable.

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