academicJournals

Vol. 14(22), pp. 1846-1853, 3 June, 2015
DOI: 110.5897/AJB2015.14484
Article Number: 9FC921453395
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Genetic diversity among some productive genotypes of tomato (*Lycopersicon esculentum* Mill.)

Rukhsar Ahmad Dar[1], J. P. Sharma[1] and Mushtaq Ahmad[2]*

[1]Division of Vegetable Science and Floriculture, Sher-e- Kashmir University of Agricultural Sciences and Technology, FOA, Main Campus Chatha-180009 Jammu, India.
[2]Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar–191 121, India.

Received 7 February, 2015; Accepted 1 June, 2015

This research was done at Vegetable Experimental Farm, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu during spring and summer seasons, 2007-2009. D^2-statistics revealed that β-carotene contributed maximally towards the genetic divergence followed by ascorbic acid, total soluble solids, alcohol insoluble solids, pericarp thickness, lycopene content and polygalacturonase activity. The 60 genotypes were grouped into 20 clusters. Fourteen (14) clusters were monogenotypic and cluster I possessed highest number of genotypes numbering 25. Out of 20 clusters, cluster VII is promising for minimum polygalacturonase activity and high average fruit weight, cluster VIII had highest number of locules per fruit, fruit yield per plant and yield per hectare and cluster XVII was superior for ascorbic acid. However, cluster XX was found promising for lycopene content, β-carotene and number of fruits per plants. The highest inter cluster D^2 values were estimated between clusters XII and XX, followed by clusters XI and XX, clusters VII and XX, and clusters XV and XX, indicating that there is enough scope for the improvement of tomato crop by hybridization and selection.

Key words: Genetic variability, genetic gain, heritability, tomato.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is the world's major vegetable crop and known as protective food because of its special nutritive value. Tomato crop has wider adaptability, high yielding potential and multipurpose uses in fresh as well as processed food industries. An improvement in yield and quality in self pollinated crops like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization (Reddy et al., 2013). It is considered as important commercial and dietary vegetable crop. Tomato is the most popular vegetable grown throughout the world with the production of 126.24 million tonnes. According to FAOSTAT (2007), the top producers of tomatoes in 2007 were China with a production of 33.64 million tonnes, followed by USA with 11.5 million tonnes, Turkey with

*Corresponding author. E-mail: drmushtaqdarskuastk@rediffmail.com.

9.91 million tonnes, India with 8.85 million tonnes and Egypt with 7.55 million tonnes. The annual production of tomato in India during 2007-2008 (NHB, 2008) was 10261 thousand metric tons from 572000 ha of land. The leading tomato producing states are Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab and Bihar. In Jammu, the area under tomato is 1824 ha and production is 36650 metric tons with productivity of 20.08 tonnes per hectare (Anonymous, 2008, 2009). Genetic divergence refers to the genetic distance between species or between populations within a species. A variety of parameters are used to measure the genetic distance. Smaller genetic distances indicate a close genetic relationship whereas large genetic distances indicate a more distant genetic relationship. Genetic distance can be used to compare the genetic dis-similarity between different species. Within a species, genetic distance can be used to measure the divergence between different sub-species or different varieties of a species. The importance of genetic diversity is evident in terms of survival and adaptability of a species. For instance, a species with high genetic diversity will tend to produce a wider variety of offspring, where some of them may become the fit variants. In contrast, a species that has little or no genetic diversity will produce offspring that are genetically similar and, therefore, will likely be susceptible to diseases or problems like those of their parent. Hence, little or lack of genetic diversity reduces biological fitness and increases the chances of species extinction (Gadekar et al., 1992). Genetic divergence studies have helped in designing the hybridization programmes in crop plants effectively to generate noble variants having adaptation and yielding potential far better than parental types (Sekhar et al., 2008). In vegetable crops like tomato, estimates of genetic divergence have been proposed to provide diverse parents for getting high yielding hybrids (Sharma et al., 2008). Tomato pulp and juice is digestible mild aperients, a promoter of gastric secretion and blood purifier. It is reported to have antiseptic properties against intestinal infestations. Apart from these, lycopene is valued for its anticancer property. It acts as an antioxidant (scavenger of free radicals), which is often associated with carcinogenesis. An improvement in yield and quality in self-pollinated crops like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization (Reddy et al., 2013).

Therefore, the present investigation was aimed at ascertaining the nature and magnitude of genetic diversity among 60 of tomato genotypes for quality and yield attributing traits, to help the breeders in selecting promising and genetically diverse parents for desired improvement.

MATERIALS AND METHODS

The materials used for the present investigation comprised of 60 genotypes of tomato, which were collected from IIVR, Varanasi and nearby Jammu area during 2007-2009. The local germplasm was collected by approaching the farmers of different areas and making sure that the seeds collected for the investigation were the ones which the farmers were growing on their own for several years, in order to maintain the native flavour and taste. The experimental area is located in the sub-tropical zone of Jammu and Kashmir at 32° 40/ N latitude and 74° 58/ E longitude at an elevation of 332 m above mean sea level. The experiment was laid out in randomized block design with three replications with painting distance of 60 x 45 cm, total number of plots of 180 and total number of plants in experimental field of 4860. All the recommended cultural practices were followed during the growth and development period of the crop in order to raise a healthy crop. Observations were recorded on 16 physical and chemical qualities and yield related traits from ten randomly selected plants from each genotype in each plot and replications and their means were worked out for statistical analysis as per formulae given by Panse and Sukhatme (1989). Ten competitive representative plants were selected at random from each experimental plot in each replication and tagged for recording the observations.

Statistical analysis

The diversity of the competitive representative plants was estimated by using D^2 - statistics (Mahalanobis, 1936) between genotypes. The analysis of variance and covariance of 60 lines was carried out for all the characters. Using the common error dispersion matrix, the D^2 between all possible combinations were computed. The lines were grouped into different clusters. Intra and inter-cluster distances were calculated as per the method envisaged by Rao (1952). After recording data analysis of the genetic diversity and Mahalonobis, D^2 analysis was done by using Torcher's method (Figure 1) as suggested by Rao (1952).

RESULTS AND DISCUSSION

Genetic divergence

The pooled results pertaining to the contribution of each character towards the genetic divergence are presented in Table 1. Each character was ranked on the basis of their contribution (percentage) to divergence of that character. The pool depicted in Table 1 shows that the β-carotene contributed maximally (49.49%), followed by ascorbic acid (16.44%), total soluble solids (7.57%), alcohol insoluble solids (7.12%), pericarp thickness (5.82%), lycopene content (4.80%) and polygalacturonase activity (3.73%), whereas, average fruit weight (2.15%), fruit pH (1.64%), number of fruits per plant (0.85%) and fruit yield per plant (0.40%) contributed minimally towards total divergence. However, the number of locules per fruit and yield in quintals per hectare had insignificant contribution towards the total genetic divergence in tomato genotype.

The D^2 values of intra and inter cluster distance for 60 genotypes of tomato (*L. esculentum* Mill.) are presented in Table 2. The D^2 technique measures the forces of differentiation at two levels, namely intracluster and intercluster level and thus helps in the selection of genetically divergent parents for exploitation in

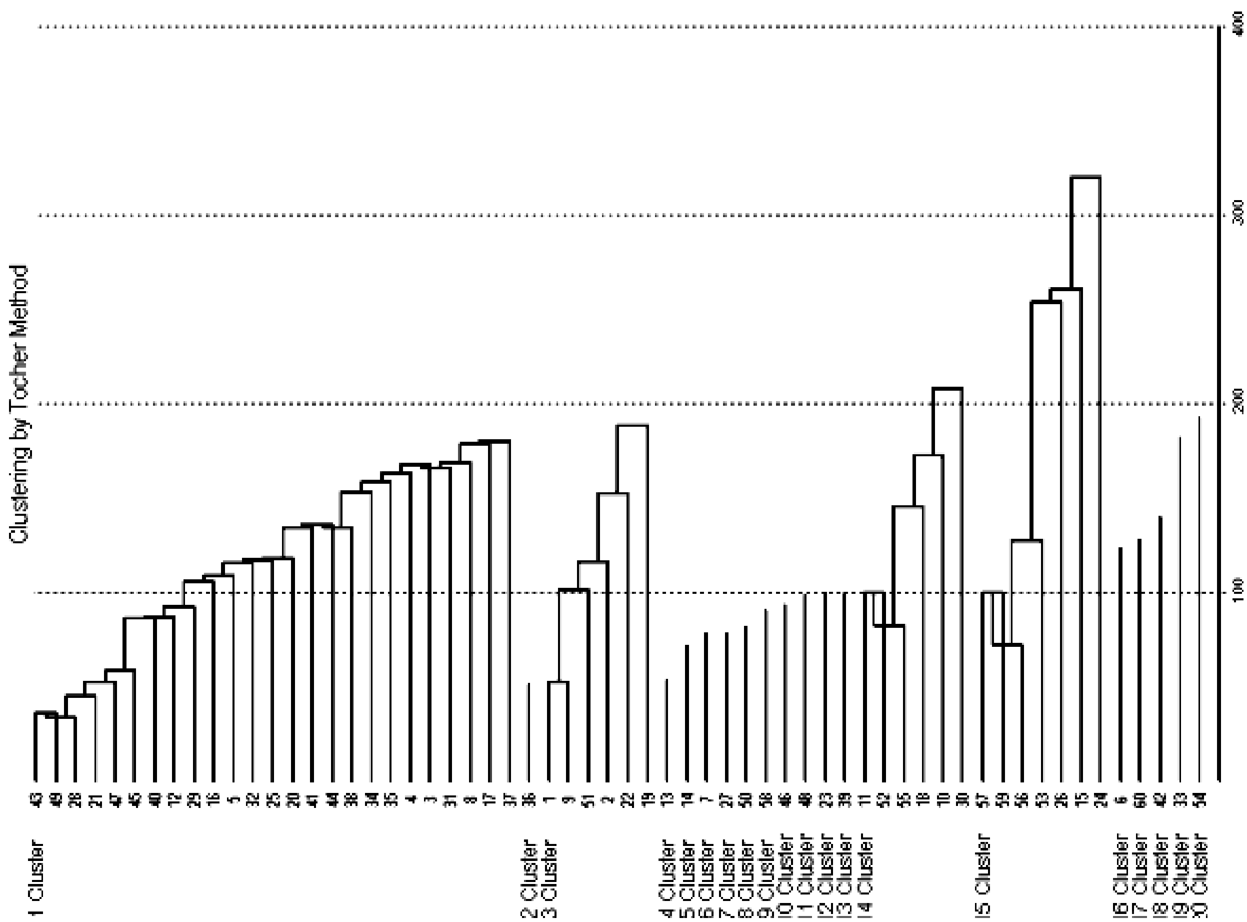

Figure 1. Clustering of 60 genotypes of tomato by Torcher's method.

Table 1. Contribution of characters towards genetic diversion.

Source	Times ranked 1st	Contribution (%)
Lycopene	85	4.80
β-Carotene	876	49.49
Polygalacturonase activity	66	3.73
Ascorbic acid	291	16.44
Fruit pH	29	1.64
Total soluble solids	134	7.57
Alcohol insoluble solids	126	7.12
Pericarp thickness	103	5.82
Number of locules	0	0.00
Number of fruits per plant	15	0.85
Fruit yield per plant	7	0.40
Average fruit weight	38	2.15
Yield in quintals per hectare	0	0.00

hybridization programmes. The intracluster distance shows divergence among the genotypes within a cluster, whereas the intercluster distance expresses relative divergence among the clusters. The genotypes were grouped into 20 clusters. 14 clusters were monogenotypic and cluster I possessed highest number of genotypes,

Table 2. Intra and inter cluster distance of 60 genotypes of tomato.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX
I	**151.44**	205.32	559.97	209.82	276.24	447.68	259.12	229.65	267.5	216.5	257.29	256.71	335.09	901.35	340.61	436.89	559.25	802.95	393.08	1694.03
II		**0**	290.13	65.48	97.38	78.9	296.96	82.74	136.32	198.13	341.32	490.02	100.04	396.15	386.14	280.34	172.98	454.01	181.97	874.99
III			**181.86**	403.12	502.96	266.54	836.33	248.81	440.51	312.32	845.82	1015.22	488.39	348.96	1014.44	353.88	651.48	382.1	439.28	776.5
IV				**0**	84.92	154.98	280.66	129.05	237.07	315.82	288.81	492.45	235.86	571.42	354.18	504.44	198.58	634.76	240.1	1179.16
V					**0**	203.65	171.27	143.45	333.14	443.79	301.42	568.23	200.49	671.95	409.28	606.29	185.56	680.86	288.97	1160.57
VI						**0**	531.97	169.51	269.93	402.82	597.55	849.38	191.95	273.7	638.67	419.88	128.45	494.34	293.5	589.91
VII							**0**	325	571.65	552.03	217.05	380.35	381.47	1189.91	399.95	867.55	482.67	1039.08	495.18	1966.96
VIII								**0**	246.9	215.41	377.22	531.79	248.71	492.56	508.9	334.68	343.92	477.8	240.91	1029.55
IX									**0**	200.98	437.4	353.25	186.4	555.37	343.92	156.75	375.27	691.98	372.81	1027.62
X										**0**	554.51	469.82	306.48	609.16	557.28	123.7	709.39	529.93	383.53	1272.25
XI											**0**	197.51	603.1	1202.27	403.83	849.68	579.5	974.01	447.06	2088.75
XII												**0**	589.23	1424.73	311.41	656.96	858.08	1257.8	659.98	2403.86
XIII													**0**	502.87	405.76	274.66	219.64	658.89	346.41	875.41
XIV														**203.29**	1212.03	470.57	523.57	311.59	413.54	356.78
XV															**281.79**	703.87	519.78	1280.35	607.19	1926.49
XVI																**0**	720.96	536.96	483.02	899.86
XVII																	**0**	776.8	347.67	804.79
XVIII																		**0**	196.85	763.5
XIX																			**0**	1008.49
XX																				**0**

numbering 25. Clusters III, XIV and XV had six, six and seven genotypes, respectively. The highest inter cluster D^2 value was observed between clusters XII and XX (2403.86), followed by XI and XX (2088.75), VII and XX (1966.96), XV and XX (1926.49), I and cluster XX (1694), X and XX (1272.25), XIV and XV (1212.03), IV and XX (1179.16), V and XX (1160.57), VIII and XX (1029.55), IX and XX (1027.62), III and XII (1015.22), and XIX and XX (1008.49); indicating that genetic material is diverse and there is enough scope for the improvement of tomato crop by hybridization and selection. The lowest inter cluster distance was observed between clusters II and IV (65.48), II and VI (78.9), II and VIII (82.74), and II and V (97.38). However, the intra cluster distance was found to be maximum within cluster XV (281.79) followed by cluster XIV (203.29), whereas clusters III and I showed lower value (181.86) and 151.44, respectively).

Cluster means for yield and quality contributing characters

Sixty (60) genotypes were placed in 20 clusters. The means of the clusters for yield and quality characters are shown in Table 3. For lycopene, top ranking clusters are XX (4.52), III (3.98 mg) and VI (3.9 mg).

Clusters XX, XIV and XVIII are rich in β-carotene with the value of 2.55, 2.36 and 2.33 mg; whereas, the cluster number VII (38.66), III (38.99) and VIII (41.05) exhibited minimum polygalacturonase activity. However, clusters number XVII (37.8 mg), VII (32.72 mg) and VI (33.41 mg) had highest values for ascorbic acid content while the clusters with greater acidity are clusters number XVIII (3.41), XI (3.42) and XIX (3.56). For total soluble solids, the highest values were observed in clusters number V (5.03), VII (4.92) and IV (4.82). Clusters XIII, XVI and XX

Table 3. Cluster means for yield and quality contributing characters of 60 genotypes of tomato.

Cluster	lycopene	β-Carotene	Polygalacturonase activity	Ascorbic acid	Fruit pH	Total soluble solids (%)	AIS	Pericarp thickness (mm)	Number of locules	Number of fruits/plant	Fruit yield/plant (g)	Average fruit weight (g)	Yield (q/ha)
I	2.87	1.41	45.63	25.01	4.1	4.47	31.38	4.37	2.73	14.41	898.68	62.53	323.44
II	3.33	1.68	52.66	29.37	3.96	4.53	32.49	3.85	2.67	14.28	812.77	56.64	292.48
III	3.98	2.09	38.99	26.16	4.22	4.42	30.34	4.61	2.67	16.97	821.36	52.62	296.06
IV	3.22	1.6	52.52	28.92	4.04	4.82	25.32	3.85	2	14.39	677.47	47.33	243.77
V	2.98	1.5	49.61	32.05	4.06	5.03	32.18	4.17	2.5	20.72	822.29	39.58	295.97
VI	3.9	1.89	54.42	33.41	4.1	4.5	29.12	3.8	3.17	13.33	771.99	57.52	277.84
VII	2.44	1.2	38.66	32.72	4.23	4.92	35.35	4.82	2.83	12.78	968.72	75.55	348.66
VIII	3.32	1.72	41.05	28.78	4.11	4.6	30.17	4.4	3.33	24.78	1459.83	59.1	556.75
IX	3.3	1.63	58.86	26.44	4.05	3.85	31.73	3.38	2.67	18.16	593.87	32.48	213.66
X	3.43	1.68	44.27	20.04	4.03	4.32	35.38	4.07	3.33	12.97	866	65.79	311.66
XI	2.35	1.22	43.16	29.98	3.42	4.25	27.57	4.92	2.5	11.9	520.52	43.84	187.3
XII	2.05	1.16	45.09	26.01	4.23	3.67	30.49	4.42	2.33	12.05	623.72	48.62	224.48
XIII	3.15	1.66	60.18	30.42	4.59	4.48	39.13	3.33	3	12.82	725.12	56.54	260.97
XIV	3.73	2.36	59.31	29.16	3.98	4.32	31.77	3.54	2.47	14.5	771.54	54.35	279.94
XV	2.48	1.24	59.09	28.74	4.2	4.31	29.4	3.32	2.67	17.93	895.23	54.82	322.17
XVI	3.55	1.9	55.82	21.53	4.33	3.85	38.92	3.68	2.83	19.55	1120.29	57.09	403.26
XVII	3.22	1.7	63.7	37.8	3.97	4.6	28.95	3.07	2.5	14.44	671.88	50.25	260.79
XVIII	2.51	2.33	46.64	24.62	3.41	4.45	35.41	4.37	2.83	11.51	589.92	51.3	212.27
XIX	2.07	1.94	52.39	27.86	3.56	4.5	30.05	3.88	3.17	13.91	789.29	56.64	284.08
XX	4.52	2.55	64.55	34.52	3.79	4.35	38.05	2.58	2.5	24.92	875.29	35.39	315.05

had the maximum value for alcohol insoluble solids with the values of 39.13, 38.92 and 38.05 mg/100 g, respectively. The pericarp thickness was found to be highest in clusters V (4.92), XI (4.82) and VII (4.61). However, clusters VIII and X had same number of locules (3.33) followed by cluster XIX (3.17). Number of fruits per plant was observed to be maximum in clusters XX (24.92), VIII (24.78) and V (20.72). It was observed that clusters I, VII, VIII and XVI had highest values of 898.68, 968.72, 1459.83 and 1120.29 g, respectively, for fruit yield per plant. Average fruit weight was observed to be maximum in cluster number VII (75.55 g) followed by cluster number X (65.79 g) and I (62.53 g). The top ranking clusters for yield in quintals per hectare were clusters VIII (556.75q/ha), XVI (403.26), VII (348.66 q/ha) and I (323.44 q/ha). The clusters II, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XVI, XVII, XIX and XX had single genotype each, namely, EC-29914, EC 27995, EC-521041, JTP- 02-05, EC- 5888, Improved Shalimar and CGNT-12 CO-2.

Composition of cluster based on D^2 values

Composition of cluster based on D^2 values (Figure 1) indicated a lot of genetic diversity among the sixty (60) genotypes of tomato. Genetic diversity among the sixty (60) genotypes of tomato was worked as per the procedure given by Mahalanobis (1936) and presented in Table 4 and Figure 1. The results indicate that all the sixty (60) genotypes were grouped into 20 clusters. Cluster I had 25 genotypes namely, EC-381213, EC-2517, PAU-2371, CO-3, EC-52077, KS-229, VR-415, EC-521044, PAU-2372, EC-3526, EC-521056, EC-2798, EC-521079, Pant T-8, Pant T-10, KS-227, VTG-85, EC-528374, NDT-9, Pant T-7, EC-538151, EC-529081, EC-521086, EC-9046 and Local-2707, followed by cluster XV with seven genotypes,

Table 4. Composition of cluster based D^2 values of 60 genotypes of tomato.

Cluster	Number of genotypes	Genotypes
I	25	EC-381213, EC-2517, PAU-2371, CO-3, EC-52077, KS-229, VR-415, EC-521044, PAU-2372, EC-3526, EC-521056, EC-2798, EC-521079, Pant T-8, Pant T-10, KS-227, VTG-85, EC-528374, NDT-9, Pant T-7, EC-538151, EC-529081, EC-521086, EC-9046, Local-2707.
II	1	EC-29914.
III	6	EC-164660, EC-521067, CGNT-1, EC-363942, EC-521045, Punjab Chhuhara.
IV	1	EC-27995.
V	1	EC-521041.
VI	1	JTP-02-05.
VII	1	EC-5888.
VIII	1	Improved Shalimar
IX	1	CGNT-12
X	1	CO-2
XI	1	EC-135580
XII	1	CTS-02
XIII	1	VTG-86
XIV	6	EC-521059, CGNT-2, CGNT-6, DT-2, EC-251581, EC-3668,
XV	7	CGNT-11, CGNT-13, CGNT-10, CGNT-3, EC-35293, EC-538151/3, CTS-06-19
XVI	1	EC-520059.
XVII	1	CGNT-14.
XVIII	1	EC-521054.
XIX	1	PAU-1374
XX	1	CGNT-5

CGNT-11, CGNT-13, CGNT-10, CGNT-3, EC-35293, EC-538151/3 and CTS-06-19; clusters III and XIV with six genotypes in each cluster: EC-164660, EC-521067, CGNT-1, EC-363942, EC-521045, Punjab Chhuhara and EC-521059, CGNT-2, CGNT-6, DT-2, EC-251581, EC-3668. However, the clusters II, IV, V, VI, VII, VIII IX, X, XI, XII, XIII, XVI, XVII, XIX and XX had single genotype each namely, EC-29914, EC 27995, EC-521041, JTP- 02-05, EC- 5888, Improved Shalimar, CGNT-12, CO-2, EC- 135580, CTS-02, VTG-86, EC-520059, CGNT-14, EC-521054, PAU-1374 and CGNT-5.

In the present investigation, the results pertaining to the contribution of each character towards the genetic divergence revealed that β-carotene contributed maximally, followed by ascorbic acid, total soluble solids, alcohol insoluble solids, pericarp thickness, lycopene content and polygalacturonase activity, whereas average fruit weight, fruit pH, number of fruits per plant and fruit yield per plant contributed minimally towards total divergence.

The D^2 values of intra and inter cluster distance for 60 genotypes of tomato are reported. The highest inter cluster D^2 values were estimated to be between clusters XII and XX, followed by XI and XX, VII and XX, XV and XX, I and XX, X and XX, XIV and XV, IV and XX, V and XX, VIII and XX, IX and XX, III XII, and IX and I, indicating that there is enough scope for the improvement of tomato crop by hybridization and selection. However, the lowest inter cluster distance was observed between cluster II and IV followed by clusters II and VI, II and VIII, and II and V. However, the intra cluster distance was found to be maximum within cluster XV, followed by cluster XIV, whereas clusters III and XX reported lower values, respectively. It can be concluded that if we are interested in improving lycopene content, hybridization between clusters VIII and XX is a better option. To reduce polygalacturonase activity, cluster VII and VIII is ideal. It indicates that genotype in cluster VII is better suited for long transportation. To improve ascorbic acid content, cluster XVII and VII is an ideal combination. Improving maximum yield hybridization between clusters VII and VIII is better as it also possessed important genotypes having special features which could be better exploited by double cross or their derivatives for future selection. These findings are in close conformity with those of Kumar and Tewari (1999), Parthasarathy and Aswath (2002) and Sekhar et al. (2008).

Means of yield and quality contributing characters of different clusters reveal considerable variation for important characters such as yield, fruit weight, fruit colour and lycopene content. In the present investigation, cluster means were worked out from the pooled data on the basis of mean performance of genotypes for different traits studied. The pooled data depicted in Table 3 revealed that cluster 5 was observed to be promising for total soluble solids. Whereas, cluster VII is promising for minimum polygalacturonase activity and high average fruit weight, cluster VIII had highest number of locules, cluster VIII was also found promising for fruit yield per plant and yield quintals per hectare, cluster XI was found superior for pericarp thickness, cluster XIII is promising for fruit pH and alcohol insoluble solids, cluster XVII was superior for ascorbic acid. However, cluster XX was found promising for lycopene content, β-carotene and number of fruits per plants. Similarly, Parthasarathy and Aswath (2002) also recorded same trend for fruit weight and yield.

Composition of cluster based on D^2 values indicated a lot of genetic diversity among the sixty (60) genotypes of tomato. It was worked out as per the procedure given by Mahalanobis (1936) and presented in Table 4. The results indicate that all the sixty (60) genotypes were grouped into 20 clusters. Cluster I contains highest number of genotypes, that is, 25 genotypes, namely, EC-381213, EC-2517, PAU-2371, CO-3, EC-52077, KS-229, VR-415, EC-521044, PAU-2372, EC-3526, EC-521056, EC-2798, EC-521079, Pant T-8, Pant T-10, KS-227, VTG-85, EC-528374, NDT-9, Pant T-7, EC-538151, EC-529081, EC-521086, EC-9046 and Local-2707, followed by cluster XV with seven genotypes: CGNT-11, CGNT-13, CGNT-10, CGNT-3, EC-35293, EC-538151/3, CTS-06-19, clusters III and XIV with six genotypes in each cluster: EC-164660, EC-521067, CGNT-1, EC-363942, EC-521045, Punjab Chhuhara and EC-521059, CGNT-2, CGNT-6, DT-2, EC-251581, EC-3668. However the clusters II, IV, V, VI, VII, VIII IX, X, cluster XI, XII, XIII, XVI, XVII, XIX and XX had single genotype each namely, EC-29914, EC 27995, EC-521041, JTP- 02-05, EC- 5888, improved Shalimar, CGNT-12, CO-2, EC- 135580, CTS-02, VTG-86, EC-520059, CGNT-14, EC-521054, PAU-1374 and CGNT-5. Even though most of the varieties were developed in India, there was good diversity because of diverse parents used in the development of these varieties or some were introduction from other countries which could have contributed to diversity present in these genotypes. The grouping of genotypes into 20 clusters indicated the presence of wide range of genetic diversity among the genotypes. These findings are in close conformity with those of Parthasarathy and Aswath (2002), Arun and Kohli (2003) and Sharma et al. (2009).

For D^2 analysis, tomato genotypes were grouped into 20 clusters. Considerable inter and intra cluster distance were observed between and within the clusters. The highest inter cluster D^2 values were estimated to be between clusters XII and XX, followed by XI and XX, VII and XX, XV and XX, I and XX, X and XX, XIV and XV, IV and XX, V and XX, VIII and XX, IX and XX, III XII, and IX and I, indicating that there is enough scope for the improvement of tomato crop by hybridization and selection. Contribution of each character towards the genetic divergence was maximum for β-carotene followed by ascorbic acid, total soluble solids, alcohol insoluble solids, pericarp thickness, lycopene content and polygalacturonase activity. An improvement in yield and quality in self pollinated crops like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization. The success of hybridization programme depends upon selection of suitable parents of diverse origin. Thus, the results of the present study could have strong implications for breeding programs for development of tomato variety as a commercially important crop and would be helpful for future programs regarding tomato varieties genetic improvements, building a genetic map for the local tomato varieties. These findings were in general agreement with the earlier reports of Basavaraj et al. (2010), Evgenidis et al. (2011) and Thamir et al. (2014).

Conclusion

This study reveals that cluster V was promising for total soluble solids whereas, cluster VII was promising for minimum polygalacturonase activity and high average fruit weight, cluster VIII had highest number of locules per fruit, cluster VIII was also found promising for fruit yield per plant and yield per hectare, cluster XI was found superior for pericarp thickness, cluster XIII was promising for fruit pH and alcohol insoluble solids, cluster XVII was superior for ascorbic acid, However, cluster XX was found promising for lycopene content, β-carotene and number of fruits per plants. Highly diverse clusters were XII and XX, and XI and XX. Genotypes in these clusters are proposed for hybridization to get heterotic hybrids in F_1 generation and some promising transgressive segregants in F_2 generation.

Conflict of interests

The authors did not declare any conflict of interest

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