DOI : 10.5958/0974-0112.2020.00031.6

Indian J. Hort. 77(2), June 2020: 227-236

Genetic variability studies for various morphological and quality traits in apple

J.I. Mir, Aarifa Jan*, Megna Rashid, D.B. Singh, W.H. Raja, O.C. Sharma, A. Sharma, S. Lal, K.L. Kumawat, Sajad Un Nabi and Lal Chand

ICAR-Central Institute of Temperate Horticulture, Old Air Field, Rangreth, Srinagar 190 007, Jammu & Kashmir

ABSTRACT

The present investigation was carried out to study the genetic variability among 120 apple cultivars for qualitative and quantitative traits. The apple cultivars showed a considerable genetic diversity with respect to qualitative and quantitative characters. Spreading type of growth habit was found in 84.16% of cultivars while 55% cultivars showed mixed bearing habit, *i.e.* on both shoots and spurs. Flower traits like color at balloon stage, position of anthers with respect to stigma and arrangement of petals varied among the apple cultivars. The highest average fruit weight (340.10 g) was recorded in Maharaji (White Dotted Red), while the lowest fruit weight of 1.30g was recorded in CITH-A-MB-03. Fruit firmness ranged from 44.59 RI in Tydeman's Early Worcester to 91.70 RI in *M. simcoe* and TSS ranged from 9.50°B in Winter Commercial to 28.80°B in CITH-A-MB-01. With respect to fruit colour, "*L*" values ranged from 22.05 (CITH-A-MB-03) to 76.55 (Anannas Retrine) and 55 cultivars were found to possess light colour with '*L*' values less than 50. Negative "*a*" values were recorded in 19 apple cultivars and all the green cultivars with negative 'a' values had higher *L, *b** and hue values. The cluster analysis grouped 120 genotypes into five distant clusters at 0.70 average distances. Cluster I included three genotypes (Maharaji, Kirkitchoo, EC-239451), whereas maximum number of genotypes (45) were represented by Cluster II and cluster IV, comprising six wild apple cultivars. Correlation studies revealed that fruit weight was positively correlated with firmness but showed negative correlation with TSS where as firmness showed positive correlation with fruit weight and TSS. Principal component analysis (PCA) revealed the variability contribution of PC1, PC2 and PC3 to be 46, 35 and 18%, respectively, with PC1 mainly represented by fruit weight and firmness, PC2 by firmness and TSS and PC3 by fruit weight and TSS. The PCA and clustering analysis in this study indicated a high level of diversity in the apple genotypes.**

Key words: *Malus* × *domestica*, cluster analysis, correlation, genetic variability, PCA.

INTRODUCTION

Apple (*Malus* × *domestica* Borkh.) is the most ubiquitous, well-adapted species of temperate fruit crops, and belongs to genus *Malus* and family Rosaceae. It was originated in Central Asia and its progenitor is *M. sieversii* (Janick *et al.*, 8). Genetic diversity in crop species can be determined using morphological, agronomical, biochemical characteristics and DNA markers (Liu, 10). The genetic variability in apple has allowed adapted types to be selected for different environments and selection for new cultivars continues to extend apple cultivation in both temperate and subtropical regions. Maintenance of apple germplasm and diversity are important to all future breeding programmes as genetic diversity gives species the ability to adapt to varying climatic conditions Bull and Wichmann (1) and also provide the raw material to breed new cultivars either *via* selection Dzhangaliev (4) or hybridization (Doebley *et al.* (3). Worldwide production of apples in 2017-18 was 77.3 million tonnes, with China accounting for 49% of the total production. In India, apple is most important temperate fruit of the north western Himalayan region like J&K, HP, Uttarakhand, and partly in Arunachal Pradesh, Sikkim and Nagaland having an area of 0.32 Mha and ranks fifth in production all over the world with 1.89MTs. In India J&K is having largest area (0.163 M ha) and production (1.17MT), as it has an ideal climate for its cultivation and constitutes the back bone of rural economy. The average productivity of Jammu and Kashmir is 10.2 t/ha, followed by Himachal Pradesh 6.9 t/ha and Uttarakhand 2.6 t/ha (NHB 2015-16). Although, commercial Apple cultivation is limited to only a few varieties, there is a tremendous diversity in apple germplasm and varieties having potential for higher productivity and quality remains to be exploited. Characterization of genetic resources for deciphering the variability to utilize these resources in breeding and conservation programme is required. Therefore, the aim of the present study was to study the variability of 120 apple germplasm conserved in the field gene bank of ICAR-Central Institute of Temperate Horticulture Srinagar.

*Corresponding author's Email: aarifa711@gmail.com

MATERIALS AND METHODS

The present study was carried out on 120 apple cultivars, maintained on seedling rootstocks in the field gene bank of ICAR-CITH, Srinagar. Observations were recorded for vegetative, floral and fruit parameters in all 120 apple cultivars. During 2015-2016 observations were recorded in three replicates both for qualitative traits as well as for quantitative traits as per the DUS descriptors developed by PPV&FRA (UPOV, 16). Fruit firmness (RI) was determined on two opposite checks as the equatorial zone using a hand held fruit firm tester (Model No. 63776) with 0.25 mm tip. TSS measurement was done using a digital refractometer (model: PR-32α, ATAGO, CO., LTD. Tokyo, Japan) which provided the °Brix value with an accuracy of +/- 0.1%. The surface colour of apple in terms of Hunter *L*, *a*, *b* values and yellowness index (Yi) were determined using Hunter lab Miniscan XE plus colorimeter (Model No. 45/0-L, Hunter lab, USA). '*L*' denotes the lightness or darkness (0 = black, 100= white), *a** indicates chromaticity on a green (-) to red (+) and *b** indicates chromaticity on a blue (-) to yellow axis (+). Numeric values of a* and b* were converted into hue angle ($H^o = \tan^{-1}(b^*/a^*)$) and chroma ($C = (a^* + b^{*2})^{1/2}$).

Fruit characteristics recorded were analyzed by comparing means using one way ANOVA and the significance was determined by Duncan's Multiple Range Test using SAS (v. 9.2). The clustering of cultivars was performed using an Unweighted Pair Group Method Analysis (UPGMA) cluster analysis and computed through SPSS-17 software.

RESULTS AND DISCUSSION

Vegetative characters including tree and leaf traits showed significant variation across 120 apple genotypes. The summary of frequency distribution for the parameter is given in the Table 1. The growth habit of the tree revealed that 84.16% cultivars were spreading and only 15.83% cultivars were upright in nature. Mratinic and Aksic (12), while evaluating apple germplasm in South Serbia reported 16.67% upright, 38.29% spreading, 33.34% spreading to drooping and only 11.11% drooping habit. The distribution curve revealed a predominance of the plants with intermediate to vigorous accessions.

Out of 120 apple varieties studied, maximum (60.83%) varieties were having medium (6.0-8.0 cm) leaf length, 30 per cent of varieties were having large leaves (>8.0 cm) and 9.16% were having small leaf length. Similarly, leaf width varied from narrow to broad, as highest percentage (58.33%) of cultivars were having medium leaf width (4-6

Table 1. Summary of frequency qualitative traits of 120 apple genotypes.

Trait	Category	No. of cultivar(s)	Percentage
Tree habit	Upright	19	15.83
	Spreading	101	84.16
Leaf length (cm)	Small (<6.0 cm)	11	9.16
	Medium (6-8.0 cm)	73	60.83
	Large (>8.0 cm)	36	30
Leaf width (cm)	Narrow (4 cm)	23	19.16
	Medium (>4-6 cm)	70	58.33
	Broad (>6 cm)	27	22.5
Leaf shape	Oval	15	12.5
	Ovate	40	33.33
	Broad elliptic	55	45.83
	Narrow elliptic	10	8.33
Pubescence on lower side of leaf	Present	74	61.66
	Absent	46	38.33
Bearing Habit	On shoots	21	17.5
	On spurs	33	27.5
	Mixed	66	55.0
Predominant colour at balloon stage	Light pink	44	36.66
	Pink	28	23.33
	Dark pink	48	40.00
Position of anthers *w.r.t.* stigma	Above	45	37.5
	Below	40	33.33
	At same level	35	29.16
Arrangement of petals	Free	39	32.5
	Intermediate	36	30.0
	Overlapping	45	37.5
Fruit shape	Ovoid	26	21.66
	Cylindrical	22	18.33
	Globose	39	32.5
	Conic	26	21.66
	Obloid	5	4.16
	Ellipsoid	2	1.66
Fruit base	Narrow (<1.0 cm)	23	19.16
	Medium (1.0-2.0 cm)	36	30.00
	Broad (>2.0 cm)	61	50.83
Fruit base cavity depth	Shallow (< 0.5 cm)	19	15.83
	Medium (0.5-1.5 cm)	75	62.5
	Deep (> 1.5 cm)	26	21.66

Contd...

Table 1 Contd...

Trait	Category	No. of cultivar(s)	Percentage
Fruit apex	Smooth	83	69.16
	Grooved	37	30.83
Fruit peel lenticels	Few (<10/ cm^2)	33	27.5
	Medium (10-20/ cm^2)	39	32.5
	High (>20/ cm^2)	48	40.0
Fruit ground colour	Yellow green	31	25.83
	Green	37	30.83
	Red	13	10.83
	Cream white	12	10.0
	Yellow	13	10.83
	Orange	14	11.66

cm), 23% having narrow (<4 cm) and 27% having broad leaf width (>6 cm). Regarding the leaf shape a wide range of variation was observed and majority of cultivars (45.83%) were having broad elliptic leaf shape, (33.33%) ovate leaf shape, (12.5%) oval leaf shape and only 8.33% of cultivars were having narrow elliptic shape of leaves. The variability with respect to leaf length in different genotypes might be due to their genetic makeup and interaction with the environment. On the basis of pubescence on lower side of leaves, 61.66% of apple genotype showed pubescence and 38.33% cultivars does not showed pubescence on lower side of leaves. Reim *et al*. (14) also found diverse pattern of pubescence in apple genotype. In present study 55% of the genotype were found to be mixed bearers while 27.5% cultivars exhibited spur bearing tendency and 17.5% were shoot bearers. Predominant colour at balloon stage varied among 120 apple cultivars and it was found to be light pink in 36.66%, pink in 23.33% and dark pink in 40.00% of apple cultivars. Position of anthers with respect to stigma was found above in 45 genotype, below in 40 genotype and at the same level among 35 cultivars. The arrangement of petals was found overlapping among 45, intermediate in 36 and free in 39 genotype. Dar *et al*. (2) reported that the position of stigma with respect to anthers showed interesting trend in apple cultivars and found that six genotype under study exhibited a tristyly type of floral structure. Present study revealed predominance of globose fruit shape (32.5%) followed by ovoid (21%), conic (21%), cylindrical (18.3%), obloid (4.16%) and ellipsoid (1.66%). Fruit base size also showed variation and maximum genotype (50.83%) had broad fruit base followed by medium (30.00%) and narrow base (22.5%). In addition fruit base cavity depth grouped the 120 apple cultivars into shallow, medium and deep categories represented by 19, 75 and 26 cultivars, respectively. Fruit apex was either smooth or grooved represented by 83 and 37 cultivars, respectively. The density of fruit skin lenticels also showed varietal variation and grouped 120 genotype into three groups *viz*., few, medium and high with lenticel density of 10, 10-20 and >20/cm^2 respectively, In present study six fruit ground colour categories, *viz*., yellow green, green, red, cream white, yellow and orange were represented by 31, 37, 13, 12, 13 and 14 cultivars respectively. Fruit colour is significantly influenced by temperature, location of plant, light penetration and growth habit of tree.

The magnitude of variability present in various quantitative traits under study revealed existence of wide range of variability among all the traits. The fruit quality traits among 120 apple genotype revealed significant variability (Table 2). Since some cultivars were wild type with small fruit size, fruit weight ranged from 1.30-340.10 g with the mean of 152.84 g. The highest fruit weight of 340 g was recorded in Maharaji while the lowest fruit weight of 1.30 g was recorded in wild apple cultivar (CITH-A-MB-03). Fruit size is also an important parameter for selection of superior genotypes in breeding programmes (Westwood and Blaney, 17). Fruit firmness ranged from 44.59-91.70 RI with an average of 65.88 RI. The highest firmness was recorded in *M. simcoe and* lowest in Tydeman's Early Worcestor. Kaya *et al*. (9) on their studies on fruit quality characters and genetic variability of apple germplasm in Turkey reported fruit flesh firmness range of 3.99-14.05 $kgcm^{-2}$. The highest TSS was recorded in CITH-A-MB-01 and lowest in Winter Commercial. Fruit colour evaluation of 120 apple genotype revealed "*L*" values ranging from 22.05 (CITH-A-MB-03) to 76.55 (Anannas Retrine). Out of 120 apple 55 were found to be light coloured with '*L*' values less than 50. Negative "*a*" values were recorded in 19 apple indicating that these genotype were green in colour at the time of harvesting. Values for '*b*' scale ranged from -0.93 (CITH-A-MB-03) to 43.18 (Apple Queen) and no other accession except CITH-A-MB-03 showed negative "*b*" value indicated that all genotype are yellow in colour. Hue^o values ranged from 5.43 in Summer Red to 171.78 in CITH-A-MB-03. Chroma ranged from 6.49 (CITH-Apple-MB-03) to 51.67 (June Eating) with an average of 30.91 across 120 apple. All the green with negative *a** values had higher *L**, *b** and hue values. Henriquez *et al.* (7) reported that Red Delicious was darker red with red (lower L*, b* and Hue values and higher a* values) while Granny Smith was green and lighter (higher *L**, *b** and Hue values and negative *a** values), which is in accordance to our results. Our

Table 2. Variability of fruit quality traits in 120 apple genotypes.

Sl. No.	Genotype	Fruit weight (g)	Firmness (RI)	TSS (°Brix)	Colour parameter				
					L	*a*	*b*	*Hue*	*Chroma*
1.	Anna	116.20 ± 2.42	53.10 ± 1.10	16.59 ± 0.34	47.41 ± 0.98	33.01± 0.68	19.71 ± 0.41	30.82± 0.64	38.44 ± 0.80
2.	Annanas Retrine	112.40 ± 2.34	58.40 ± 1.21	14.70 ± 0.30	76.55 ± 1.59	-3.24 ± 0.06	38.10 ± 0.79	94.85 ± 1.98	38.24 ± 0.79
3.	AAS-GP-BSP-04	231.30 ± 4.81	64.30 ± 1.33	14.50 ± 0.30	50.21± 1.04	11.67 ± 0.24	17.28 ± 0.35	55.97 ± 1.16	20.85 ± 0.43
4.	AAS_GP_BSP-09	68.90 ± 1.43	65.50 ± 1.36	16.30 ± 0.33	57.67± 1.20	11.77 ± 0.24	28.77 ± 0.59	67.75 ± 1.41	31.08 ± 0.64
5.	AAS-GP-BSP-11	130.30 ± 2.71	82.30 ± 1.71	19.70 ± 0.41	56.92 ± 1.18	-0.01 ± 0.00	27.39 ± 0.57	90.00 ± 1.88	27.39 ± 0.57
6.	AAS-GP-BSP-12	126.40 ± 2.63	78.10 ± 1.62	15.50 ± 0.32	70.72± 1.47	-6.42 ± 0.13	35.34 ± 0.73	100.30 ± 2.08	35.92 ± 0.74
7.	AAS-GP-BSP-13	150.30 ± 3.12	57.10 ± 1.18	13.80 ± 0.28	63.16 ± 1.31	-8.17 ± 0.17	30.46 ± 0.63	105.04 ± 2.17	31.53 ± 0.65
8.	Akbar	186.40 ± 3.88	78.40 ± 1.63	15.10 ± 0.31	46.21 ± 0.96	19.50 ± 0.40	15.97 ± 0.57	39.29 ± 0.82	25.20 ± 0.52
9.	Amartara Pride	164.30 ± 3.42	77.40 ± 1.61	16.80 ± 0.34	40.57 ± 0.84	14.46 ± 0.30	12.12 ± 0.25	39.99 ± 0.82	18.86 ± 0.39
10.	Ambri	181.70 ± 3.78	54.00 ± 1.12	14.40 ± 0.30	53.56 ± 1.11	18.23 ± 0.38	19.75 ± 0.41	47.29 ± 0.97	26.87 ± 0.55
11.	American Apirouge	87.30 ± 1.81	77.30 ± 1.60	16.40 ± 0.34	47.10 ± 0.97	24.61 ± 0.51	15.61 ± 0.32	32.39 ± 0.67	29.15 ± 0.60
12.	Antinovika	185.70 ± 3.86	60.50 ± 1.25	17.20 ± 0.35	44.58 ± 0.92	13.88 ± 0.29	12.43 ± 0.25	41.84 ± 0.87	18.63 ± 0.38
13.	Apple Queen	99.59 ± 2.07	51.00 ± 1.06	19.30 ± 0.40	64.25 ± 1.33	2.86 ± 0.05	43.18 ± 0.9	86.18 ± 1.80	43.27 ± 0.90
14.	Baba Nagri	118.50 ± 2.46	70.50 ± 1.46	15.90 ± 0.33	47.36 ± 0.98	13.11 ± 0.27	17.14 ± 0.35	52.59 ± 1.09	21.57 ± 0.44
15.	Bell de Bescope	250.10 ± 5.20	89.00 ± 1.85	14.90 ± 0.31	60.00 ± 0.57	3.39 ± 0.07	39.88 ± 0.05	94.85 ± 1.97	40.02 ± 0.83
16.	Benoni	55.40 ± 1.15	53.50 ± 1.11	14.40 ± 0.30	56.63 ± 1.18	31.42 ± 0.65	19.20 ± 0.40	31.43 ± 0.65	36.82 ± 0.76
17.	Black ben Davis	82.90 ± 1.72	69.50 ± 1.44	14.20 ± 0.29	48.20 ± 1.00	2.50 ± 0.05	24.09 ± 0.50	84.08 ± 1.74	24.22 ± 0.50
18.	Breaburn	155.40 ± 3.23	53.10 ± 1.10	14.00 ± 0.29	42.21 ± 0.88	29.83 ± 0.61	15.03 ± 0.31	26.73 ± 0.56	33.40 ± 0.69
19.	Bropokfield Gala	101.40 ± 2.11	60.10 ± 1.24	18.59 ± 0.38	44.16 ± 0.91	23.25 ± 0.48	17.70 ± 0.36	37.29 ± 0.76	29.22 ± 0.60
20.	CITH-Apple-MS-05	65.59 ± 1.36	61.70 ± 1.28	18.90 ± 0.39	41.03 ± 0.85	18.75 ± 0.39	12.15 ± 0.25	32.95 ± 0.67	22.34 ± 0.46
21.	CITH-Apple-MS-11	137.59 ± 2.86	69.70 ± 1.45	14.59 ± 0.30	43.23 ± 0.90	18.39 ± 0.38	9.94 ± 0.20	28.37 ± 0.60	20.90 ± 0.43
22.	CITH-Apple-SR-01	119.20 ± 2.48	63.40 ± 1.32	19.90 ± 0.41	44.93 ± 0.93	34.01 ± 0.70	18.63 ± 0.39	28.72 ± 0.58	38.77 ±0.80
23.	CITH-Apple-SR-03	252.10 ± 5.24	69.59 ± 1.44	15.80 ± 0.32	42.78 ± 0.88	22.56 ± 0.47	13.75 ± 0.28	31.33 ± 0.65	26.4 ± 0.55
24.	CITH-Apple-MB-01	1.89 ± 0.04	68.59 ± 1.42	28.80 ± 0.59	42.16 ± 0.87	11.77 ± 0.24	25.31 ± 0.52	65.05 ± 1.35	27.91 ± 0.58
25	CITH-Apple-MB-03	1.30 ± 0.02	64.10 ± 1.33	27.50 ± 0.57	22.05 ± 0.45	6.43 ± 0.13	-0.93 ± 0.02	171.78 ±3.57	6.49 ± 0.13
26.	CITH-Apple-MB-05	6.90 ± 0.14	72.70 ± 1.51	25.50 ± 0.52	40.51 ± 0.84	30.61 ± 0.63	13.48 ± 0.27	23.73 ± 0.50	33.45 ± 0.69
27.	CITH-Apple-MB-06	103.50 ± 2.15	85.40 ± 1.77	17.50 ± 0.36	69.73 ± 1.45	6.39 ± 0.13	33.38 ± 0.69	79.17 ± 1.64	33.99 ± 0.70
28.	CITH-Apple-MB-07	6.30 ± 0.13	72.50 ± 1.50	23.00 ± 0.47	65.29 ± 1.35	9.40 ± 0.19	42.49 ± 0.88	77.54 ± 1.61	43.51 ± 0.90
29.	Chanapora Selection	182.30 ± 3.79	76.50 ± 1.59	16.80 ± 0.34	71.38 ± 1.48	-4.93 ± 0.10	34.45 ± 0.71	98.15 ± 2.04	34.80 ± 0.72
30.	Chaubattia Ambrose	141.59 ± 2.94	52.40 ± 1.09	17.00 ± 0.35	48.42 ± 1.00	36.56 ± 0.76	24.60 ± 0.51	33.93 ± 0.71	44.08 ± 0.91

Contd...

Table 2 contd...

Sl. No.	Genotype	Fruit weight (g)	Firmness (RI)	TSS (°Brix)	Colour parameter				
					L	*a*	*b*	*Hue*	*Chroma*
31.	Cheapnest	168.40 ± 3.50	57.30 ± 1.19	20.40 ± 0.42	69.92 ± 1.45	8.63 ± 0.18	34.85 ± 0.72	76.08 ± 1.59	35.91 ± 0.74
32.	Coe Red Fuji	130.00 ± 2.70	60.10 ± 1.24	14.70 ± 0.30	55.30 ± 1.15	6.24 ± 0.13	26.57 ± 0.55	76.78 ± 1.59	27.30 ± 0.56
33.	Coop-13	184.70 ± 3.84	59.30 ± 1.23	17.80 ± 0.36	64.99 ± 1.35	-2.20 ± 0.04	28.95 ± 0.60	94.34 ± 1.96	29.03 ± 0.60
34.	Check Ambri	157.59 ±3.28	79.80 ± 1.66	15.10 ± 0.31	53.2 ± 1.109	12.28 ± 0.25	18.48 ± 0.38	56.38 ± 1.17	22.19 ± 0.46
35.	Commercial -7	128.30 ± 2.67	63.46 ± 1.32	14.70 ± 0.30	66.66 ± 1.38	-7.99 ± 0.16	35.55 ± 0.74	102.65 ± 2.13	36.44 ± 0.75
36.	Cooper IV	237.59 ± 4.94	53.90 ± 1.12	15.30 ± 0.31	45.82 ± 0.95	19.17 ± 0.40	11.07 ± 0.22	30.00 ± 0.62	22.13 ± 0.46
37.	EC-38735	146.30 ± 3.04	61.20 ± 1.27	15.30 ± 0.31	37.37 ± 0.77	23.43 ± 0.48	8.90 ± 0.18	20.81 ± 0.42	25.06 ± 0.52
38.	EC-83683	108.10 ± 2.24	58.00 ± 1.20	14.70 ± 0.30	44.15 ± 0.91	33.91 ± 0.70	15.08 ± 0.31	23.97 ± 0.49	37.11 ± 0.77
39.	EC-239451	307.20 ± 6.39	82.20 ± 1.71	15.59 ± 0.32	55.73 ± 1.16	7.83 ± 0.16	31.69 ± 0.66	76.12 ± 1.59	32.64 ± 0.68
40.	EC-539446	219.50 ± 4.56	52.20 ± 1.08	13.40 ± 0.27	42.11 ± 0.87	23.83 ± 0.49	14.11 ± 0.29	30.61 ± 0.63	27.70 ± 0.57
41.	EC-539449	224.10 ± 4.66	64.90 ± 1.35	13.70 ± 0.28	64.17 ± 1.33	-8.80 ± 0.18	35.79 ± 0.74	103.8 ± 2.1	36.85 ± 0.76
42.	EC-539450	218.59 ± 4.55	74.50 ± 1.54	13.90 ± 0.29	48.32 ± 1.00	14.72 ± 0.30	13.76 ± 0.28	43.06 ± 0.89	20.15 ± 0.42
43.	EC-539452	144.90 ± 3.01	87.00 ± 1.81	15.20 ± 0.31	62.50 ± 1.29	-8.2 ± 0.17	30.86 ± 0.64	104.96 ± 2.2	31.96 ± 0.66
44.	EC-349914	195.59 ± 4.07	69.30 ± 1.44	22.5 ± 0.4	45.11 ± 0.93	22.06 ± 0.45	13.84 ± 0.28	32.13 ± 0.66	26.05 ± 0.54
45.	EC-34197	240.00 ± 4.99	62.40 ± 1.29	16.20 ± 0.33	70.81 ± 1.47	8.12 ± 0.16	41.77 ± 0.8	78.98 ± 1.65	42.55 ± 0.88
46.	EC-539457	170.59 ± 3.55	55.20 ± 1.15	15.50 ± 0.32	68.11 ± 1.41	2.17 ± 0.04	35.50 ± 0.74	86.48 ± 1.80	35.57 ± 0.74
47.	EC-43906	119.59 ± 2.48	75.00 ± 1.56	16.40 ± 0.34	68.54 ± 1.42	-6.9 ± 0.14	22.34 ± 0.46	107.39 ±2.22	23.40 ± 0.48
48.	Fanny	89.30 ± 1.85	50.00 ± 1.04	13.40 ± 0.27	36.83 ± 0.76	25.7 ± 0.53	8.51 ± 0.17	18.27 ± 0.39	27.15 ± 0.56
49.	Firdous	184.80 ± 3.84	70.50 ± 1.46	17.20 ± 0.35	37.84 ± 0.78	20.96 ± 0.43	7.29 ± 0.15	19.18 ± 0.40	22.19 ± 0.46
50.	Fuji	196.50 ± 4.08	75.00 ± 1.56	20.10 ± 0.41	40.65 ± 0.84	22.34 ± 0.46	7.60 ± 0.15	18.78 ± 0.40	23.59 ± 0.49
51.	Golden Delicious	161.30 ± 3.35	68.40 ± 1.42	19.59 ± 0.40	66.70 ± 1.38	-0.6 ± 0.01	39.78 ± 0.82	90.93 ± 1.90	39.78 ± 0.82
52.	Gala	150.30 ± 3.12	74.30 ± 1.54	19.59 ± 0.40	56.82 ± 1.18	24.29 ± 0.50	29.36 ± 0.60	50.40 ± 1.04	38.10 ± 0.79
53.	Gala Beauty	144.80 ± 3.01	69.80 ± 1.45	14.80 ± 0.30	56.65 ± 1.18	20.40 ± 0.42	26.11 ± 0.54	51.99 ± 1.09	33.13 ± 0.69
54.	Gala Mast	188.10 ± 3.91	70.30 ± 1.46	15.90 ± 0.33	42.33 ± 0.88	37.93 ± 0.79	17.75 ± 0.36	25.06 ± 0.53	41.87 ± 0.87
55.	Gold spur	144.30 ± 3.00	59.90 ± 1.24	12.40 ± 0.25	34.90 ± 0.72	18.82 ± 0.39	5.39 ± 0.11	15.97 ± 0.33	19.57 ± 0.40
56.	Green Sleeves	152.59 ± 3.17	66.20 ± 1.38	19.30 ± 0.40	75.93 ± 1.58	-0.43 ± 0.00	49.39 ±1.02	90.50 ± 1.88	49.39 ± 1.02
57.	Granny Smith	66.90 ± 3.47	76.70 ± 1.59	11.90 ± 0.25	60.46 ± 1.25	-6.47 ±0.13	32.04 ± 0.66	101.42 ± 2.10	32.68 ± 0.67
58.	Hardiman	168.59 ± 3.50	70.40 ± 1.46	15.80 ± 0.32	46.47 ± 0.96	19.84 ± 0.41	13.08 ± 0.27	33.37 ± 0.69	23.77 ± 0.49
59.	Ingrid Marie	212.59 ± 4.42	80.10 ± 1.66	17.59 ± 0.36	54.28 ± 1.13	21.21 ± 0.44	17.43 ± 0.36	39.39 ± 0.82	27.45 ± 0.57
60.	Jonica	220.40 ± 4.58	79.70 ± 1.66	17.90 ± 0.37	56.73 ± 1.18	19.70 ± 0.41	30.31 ± 0.63	56.98 ± 1.18	36.15 ± 0.75

Contd...

Table 2 contd...

Sl. No.	Genotype	Fruit weight (g)	Firmness (RI)	TSS (°Brix)	Colour parameter				
					L	*a*	*b*	*Hue*	*Chroma*
61.	June Eating	58.40 ± 1.21	49.90 ± 1.04	13.50 ± 0.27	69.20 ± 1.44	7.98 ± 0.16	51.05 ± 1.06	81.12 ± 1.68	51.67 ± 1.07
62.	Kesari	65.00 ± 1.35	60.30 ± 1.25	16.50 ± 0.34	57.92 ± 1.20	16.38 ± 0.34	35.51 ± 0.74	65.25 ± 1.35	39.11 ± 0.81
63.	Kindal Snap	90.50 ± 1.88	62.40 ± 1.29	21.30 ± 0.44	63.31 ± 1.31	-5.63 ± 0.11	34.25 ± 0.71	99.33 ± 2.06	34.71 ± 0.72
64.	King Lucious	263.50 ± 5.48	77.90 ± 1.62	16.59 ± 0.34	57.78 ± 1.20	0.18 ± 0.00	33.68 ± 0.70	89.69 ± 1.86	33.68 ± 0.70
65.	Kirkitchoo	302.10 ± 6.28	83.10 ± 1.72	18.10 ± 0.37	48.64 ± 1.01	7.270 ± 0.15	25.59 ± 0.53	74.13 ± 1.54	26.61 ± 0.55
66.	Lal Ambri	212.10 ± 4.41	70.50 ± 1.46	19.70 ± 0.41	53.58 ± 1.11	20.89 ± 0.43	17.68 ± 0.36	40.21 ± 0.84	27.36 ± 0.56
67.	Laxton ‘s Fortune	171.40 ± 3.56	57.70 ± 1.20	15.70 ± 0.32	63.73 ± 1.32	9.99 ± 0.20	33.13 ± 0.69	73.21 ± 1.52	34.60 ± 0.72
68.	Lemon Guard	121.59 ± 2.53	53.00 ± 1.10	16.40 ± 0.34	65.55 ± 1.36	6.58 ± 0.13	40.47 ± 0.84	80.72 ± 1.69	41.00 ± 0.85
69.	*M.baccata* Kharot	150.00 ± 3.12	63.90 ± 1.33	18.10 ± 0.37	65.15 ± 1.35	-1.47 ± 0.03	41.76 ± 0.86	92.03 ± 1.90	41.78 ± 0.87
70.	Maharaji	340.10 ± 7.07	77.50 ± 1.61	15.30 ± 0.31	51.57 ± 1.07	27.77 ± 0.57	19.90 ± 0.41	35.65 ± 0.72	34.16 ± 0.71
71.	M.baccata	46.90 ± 0.97	61.80 ± 1.28	18.00 ± 0.37	68.99 ± 1.43	-8.07 ± 0.16	39.21 ± 0.81	101.63 ± 2.11	40.03 ± 0.83
72.	M. floribunda	11.40 ± 0.23	66.10 ± 1.37	19.40 ± 0.40	28.92 ± 0.60	19.30 ± 0.40	17.60 ± 0.36	42.39 ± 0.87	26.12 ± 0.54
73.	M. Manchurian	11.50 ± 0.23	63.80 ± 1.32	23.59 ± 0.49	24.17 ± 0.50	29.63 ± 0.61	13.93 ± 0.29	25.16 ± 0.53	32.74 ± 0.68
74.	M. simcoe	272.59 ± 5.67	91.70 ± 1.91	15.20 ± 0.31	54.56 ± 1.13	18.59 ± 0.38	21.24± 0.44	48.78 ± 1.02	28.23 ± 0.58
75.	Mayan	100.40 ± 2.09	53.59 ± 1.11	15.80 ± 0.32	54.47 ± 1.13	19.00 ± 0.39	23.00± 0.47	50.42 ± 1.06	29.83 ± 0.62
76.	Michal	257.40 ± 5.35	55.80 ± 1.16	13.20 ± 0.27	51.63 ± 1.07	20.91 ± 0.43	20.18± 0.42	43.98 ± 0.91	29.06 ± 0.60
77.	Mollies Delicious	249.00 ± 5.18	51.20 ± 1.06	16.20 ± 0.33	42.03 ± 0.87	32.08 ± 0.66	16.63 ± 0.34	27.40 ± 0.56	36.13 ± 0.75
78.	Neip Early Stainy	160.90 ±3.35	56.59 ± 1.17	14.30 ± 0.29	53.21 ± 1.10	1.94 ± 0.04	23.83 ± 0.49	85.35 ± 1.77	23.92 ± 0.50
79.	Orange Val	164.50 ± 3.42	70.00 ± 1.45	18.30 ± 0.38	71.59 ± 1.49	-1.35 ± 0.02	46.36 ± 0.96	91.67 ± 1.90	46.38 ± 0.96
80.	Oregon Spur	223.90 ± 4.66	58.30 ± 1.21	15.70 ± 0.32	40.00 ± 0.83	18.97 ± 0.39	6.90 ± 0.14	19.99 ± 0.41	20.18 ± 0.42
81.	Parkin’s Beauty	76.40 ± 1.59	61.59 ± 1.28	15.40 ± 0.32	56.37 ± 1.17	7.91 ± 0.16	26.01± 0.54	73.10 ± 1.51	27.18 ± 0.56
82.	Pink Lady	96.80 ± 2.01	55.90 ± 1.16	16.70 ± 0.34	54.75 ± 1.13	12.33 ± 0.25	21.13 ± 0.44	59.70 ± 1.25	24.46 ± 0.50
83.	Prima	243.30 ± 5.06	66.70 ± 1.38	13.59 ± 0.28	55.70 ± 1.16	19.00 ± 0.39	23.00 ± 0.47	50.42 ± 1.06	29.83 ± 0.62
84.	Prince Noble	93.90 ± 1.95	76.80 ± 1.59	11.80 ± 0.24	51.88 ± 1.08	14.77 ± 0.30	22.39 ± 0.46	56.58 ± 1.17	26.82± 0.56
85.	Razakwari	140.59 ± 2.92	49.59 ± 1.03	15.80 ± 0.32	52.68 ± 1.09	45.96 ± 0.95	22.77± 0.47	26.37 ± 0.54	51.29 ± 1.06
86.	Red Baron	89.10 ± 1.85	70.40 ± 1.46	13.70 ± 0.28	53.44 ± 1.11	13.98 ± 0.29	27.39 ± 0.57	62.96 ± 1.30	30.75 ± 0.64
87.	Red Chief	211.70 ± 4.40	68.00 ± 1.41	16.40 ± 0.34	41.71 ± 0.86	22.47 ± 0.46	9.50± 0.19	22.91 ± 0.48	24.39 ± 0.50
88.	Red Delicious	248.59 ± 5.17	64.20 ± 1.33	16.40 ± 0.34	48.86 ± 1.01	19.77 ± 0.41	18.33 ± 0.38	42.85 ± 0.88	26.96 ± 0.56
89.	Red Fuji	170.40 ± 3.54	78.30 ± 1.62	17.50 ± 0.36	48.78 ± 1.01	12.53 ± 0.26	17.71± 0.36	54.73 ± 1.12	21.70 ± 0.45
90.	Red Gold	123.59 ± 2.57	56.50 ± 1.17	19.10 ± 0.39	43.72 ± 0.91	25.10 ± 0.52	11.11± 0.22	23.87 ± 0.49	27.45 ± 0.57
91.	Red Spur	173.30 ± 3.60	75.90 ± 1.58	16.30 ± 0.33	51.56 ± 1.07	15.91 ± 0.33	16.72± 0.34	46.42 ± 0.97	23.08 ± 0.47

Contd...

Table 2 contd...

Sl. No.	Genotype	Fruit weight (g)	Firmness (RI)	TSS (°Brix)	Colour parameter				
					L	*a*	*b*	*Hue*	*Chroma*
92.	Rich a Red	153.50 ± 3.19	64.00 ± 1.33	17.59 ± 0.36	53.46 ± 1.11	17.91 ± 0.37	23.30± 0.48	52.45 ± 1.08	29.38 ± 0.61
93.	Rome Beauty	211.90 ± 4.41	63.59 ± 1.32	15.90 ± 0.33	34.85 ± 0.72	24.18 ± 0.50	8.90± 0.18	20.20 ± 0.42	25.76 ± 0.53
94.	Royal delicious	235.59 ± 4.90	65.10 ± 1.35	14.00 ± 0.29	41.70 ± 0.86	23.98 ± 0.50	9.25± 0.19	21.11 ± 0.42	25.70 ± 0.53
95.	Royal Gala	95.90 ± 1.99	72.80 ± 1.51	19.80 ± 0.41	45.06 ± 0.93	32.55 ± 0.67	17.41± 0.36	28.15 ± 0.58	36.92 ± 0.77
96.	Sarapol	120.59 ± 2.51	58.59 ± 1.21	14.70 ± 0.30	58.91 ± 1.22	17.94 ± 0.37	26.57± 0.55	55.97 ± 1.16	32.07 ± 0.66
97.	Scarlet Gala	114.30 ± 2.39	78.59 ± 1.63	17.90 ± 0.37	44.84 ± 0.93	34.46 ± 0.71	15.34± 0.31	24.02 ± 0.49	37.72 ± 0.78
98.	Shireen	125.40 ± 2.61	54.20 ± 1.13	16.00 ± 0.33	43.80 ± 0.91	21.73 ± 0.45	10.98± 0.22	26.79 ± 0.56	24.34 ± 0.50
99.	Silver Spur	175.40 ± 3.65	84.20 ± 1.75	14.59 ± 0.30	40.13 ± 0.83	21.37 ± 0.44	7.15± 0.14	18.48 ± 0.39	22.53 ± 0.47
100.	Skyline Supreme	175.59 ± 3.65	77.20± 1.60	15.8 ± 0.3	47.02 ± 0.97	22.06 ± 0.45	12.11 ± 0.25	28.76 ± 0.60	25.16 ±0.52
101.	Shalimar -01	145.40 ± 3.02	58.59 ± 1.21	17.20 ± 0.35	48.50 ± 1.00	27.97 ± 0.58	21.48 ± 0.44	37.52 ± 0.77	35.26 ± 0.73
102.	Snow Drift	121.59 ± 2.53	68.70 ± 1.43	19.50 ± 0.40	76.96 ± 1.60	-3.03 ± 0.06	42.81 ± 0.88	94.03± 1.96	42.91 ± 0.89
103.	Spartan	124.50 ± 2.59	57.80 ± 1.20	18.50 ± 0.38	44.54 ± 0.92	17.22 ± 0.36	6.50 ± 0.13	20.71 ± 0.43	18.41 ± 0.38
104.	Star summer Gold	172.30 ± 3.58	65.50 ± 1.36	16.70 ± 0.34	71.03 ± 1.47	2.74 ± 0.05	36.02 ± 0.74	85.65 ± 1.78	36.12 ± 0.75
105.	Stark Cardinal	72.59 ± 1.511	50.20 ± 1.04	20.50 ± 0.42	72.10 ± 1.49	8.20 ± 0.17	45.11 ± 0.57	86.52 ± 1.80	42.50 ± 0.88
106.	Stark Earliest	187.59 ± 3.90	53.80 ± 1.11	19.90 ± 0.41	53.59 ± 1.11	8.27 ± 0.17	16.95 ± 0.35	63.99 ± 1.33	45.84 ±0.95
107.	Starking Delicious	135.90 ± 2.83	66.10 ± 1.37	17.20 ± 0.35	44.42 ± 0.92	19.14 ± 0.39	10.80 ± 0.22	29.43 ± 0.61	21.98 ± 0.45
108.	Starkrimson	202.40 ± 4.21	62.50 ± 1.29	15.80 ± 0.32	40.03 ± 0.83	17.89 ± 0.37	5.70 ± 0.11	17.67 ± 0.36	18.77 ±0.39
109.	Starkrimson Gold	46.10 ± 0.95	63.00 ± 1.31	18.50 ± 0.38	52.29 ±1.08	18.57 ± 0.38	18.12 ± 0.37	44.28 ± 0.92	25.95 ± 0.54
110.	Summer Queen	107.30 ± 2.23	51.00 ± 1.06	15.40 ± 0.32	35.18 ± 0.73	29.00 ± 0.60	10.05 ± 0.20	19.11 ± 0.39	30.69 ± 0.63
111.	Summer Red	244.10 ±5.07	70.90 ± 1.47	15.90 ± 0.33	46.16 ± 0.96	30.27 ± 0.63	2.88 ± 0.06	5.43 ± 0.11	30.40 ± 0.63
112.	Tallisare	113.20 ± 2.35	72.70 ± 1.51	13.40 ± 0.27	67.26 ± 1.40	0.83 ± 0.01	44.99 ± 0.93	88.94 ± 1.85	45.00 ± 0.93
113.	Tropical Beauty	220.10 ±4.57	78.80 ± 1.63	16.80 ± 0.34	70.29 ± 1.46	5.34 ± 0.11	39.65 ± 0.82	82.33 ± 1.71	40.01 ± 0.83
114.	Top Red	187.40 ± 3.90	69.50 ± 1.4	16.40 ± 0.34	44.77 ± 0.93	23.28 ± 0.48	10.98 ± 0.22	25.25 ± 0.52	25.74 ± 0.53
115.	Tydeman's Early Worcester	181.70 ± 3.78	44.59 ± 0.92	14.90 ± 0.31	42.30 ± 0.88	26.76 ± 0.55	14.34 ± 0.29	28.18 ± 0.58	30.36 ± 0.6.0
116.	Vance Delicious	197.50 ± 4.10	53.300 ± 1.10	16.50 ± 0.34	43.52 ± 0.90	21.00 ± 0.43	9.59 ± 0.19	24.56 ± 0.51	23.09 ± 0.47
117.	Vista Bella	197.50 ± 4.11	53.30 ± 1.10	14.40 ± 0.30	56.63 ± 1.18	31.42 ± 0.65	19.20 ± 0.40	31.43 ± 0.65	36.82 ± 0.76
118.	Well Spur	162.59 ± 3.38	68.59 ± 1.42	16.70 ± 0.34	43.83 ± 0.91	13.92 ± 0.29	10.08 ± 0.20	35.91 ± 0.74	17.18 ± 0.35
119.	Winter Commercial	102.40 ± 2.13	74.59 ± 1.55	9.50 ± 0.40	51.42 ± 1.07	20.41 ± 0.42	15.22 ± 0.31	36.71 ± 0.76	25.46 ± 0.52
120.	Yellow Transparent	164.50 ± 3.42	57.90 ± 1.20	15.30 ± 0.31	63.44 ±1.32	-4.76 ± 0.09	36.28 ± 0.75	97.49 ± 2.01	36.59 ± 0.76
	$CD_{0.05}$	3.90	3.86	0.98	3.10	1.13	1.44	3.64	1.88
	CV	1.58	3.64	3.65	3.70	4.64	3.99	4.10	3.75

studies provide detailed colour characterization of 120 apple genotype providing sufficient details for cultivar identification and quality prediction.

It is evident from the Table 3 that fruit weight was positively correlated with firmness but showed negative correlation with TSS while firmness showed positive correlation with fruit weight and TSS. Therefore, fruit weight on one hand is important character for deciding the quality of apple but on the other hand is showing negative correlation with the fruit quality, *i.e.* TSS. The best quality fruit is one which is having appropriate fruit size with optimum TSS. PC1, PC2 and PC3 accounted for 46, 35 and 18% trait variability, respectively (Table 4). In particular, the first component was positively and strongly associated with 'fruit weight (0.72) and firmness (0.36), but negatively associated with TSS (-0.57). The second component showed positive associated to all the three characters but a strong association with fruit firmness (0.81). The third component explained positive association with fruit weight (0.68) and TSS (0.57) and negative association with firmness (-0.44). Principal component analysis has been used previously to evaluate germplasm of apple (Pereira-Lorenzo *et al*., 13) and one of the multivariate statistical procedures which has been used to study correlations among fruit traits and to establish genetic relationships among genotypes within sets of apple genotypes Mir *et al*. (11). The 120 apple genotype on the basis of variability were grouped into five distinct clusters at 0.70 average distances (Fig. 1), with varying number

Table 3. Correlation matrix among different fruit quality traits in apple.

Trait	Weight	Firmness	TSS
Weight	1.00	0.24	-0.34
Firmness		1.00	0.05
TSS			1.00

Table 4. Correlation between original three variables and the first three principal components (PC) and contributions to the total variation (%) in 120 apple genotype.

Trait	PRIN 1	PRIN 2	PRIN 3
Fruit weight	0.728343	0.045158	0.683723
Fruit firmness	0.367593	0.816337	-0.445498
TSS	-0.578266	0.575807	0.577974
Eigen value	1.39	1.05	0.54
% Variation	46.59	35.13	18.28
% Cumulative	46.59	81.72	100.00

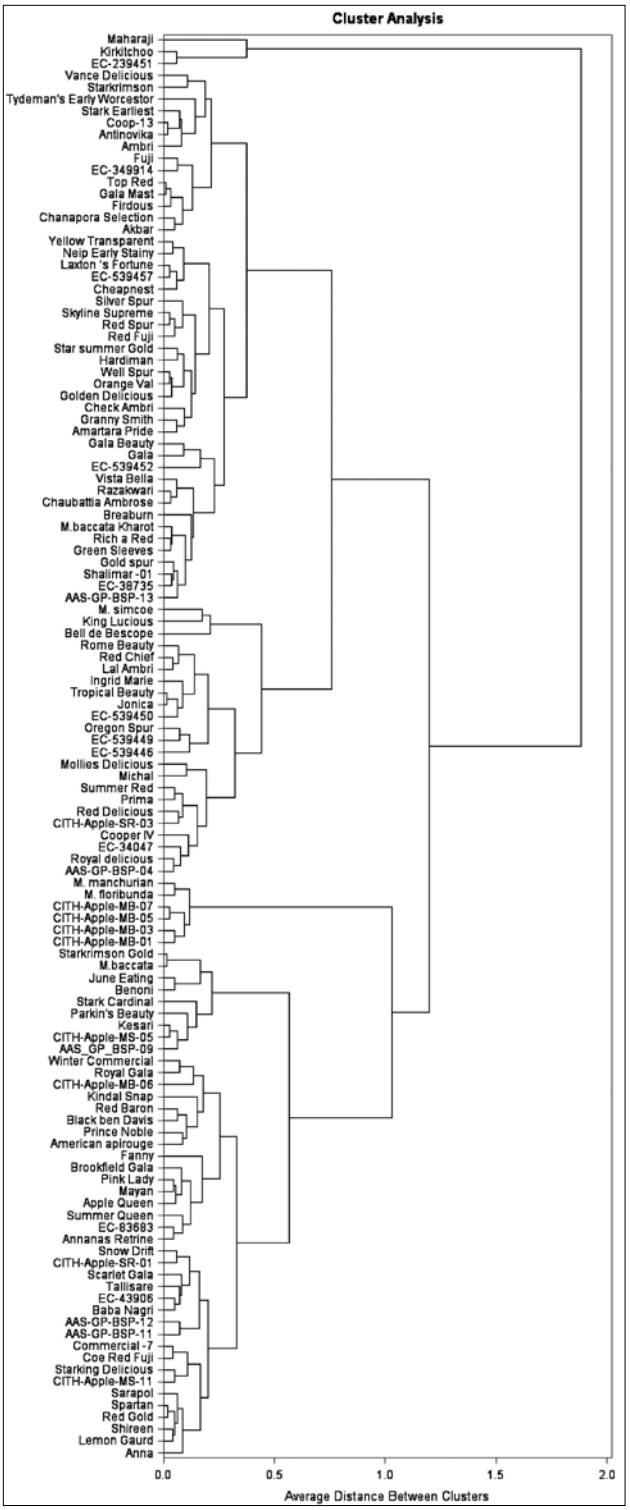

Fig. 1. Dendrogram based on fruit quality traits of 120 apple genotypes (*Malus* × *domestica* Borkh.).

of sub clusters. Use of D^2 statistics to estimate or evaluate the net/total divergence in breeding for crop improvement has been indicated by number of workers in different fruit crops (Sharma *et al*., 15). The first cluster consisted of three cultivars (Maharaji, Kirkitchoo, EC-239451) having highest fruit weight (316.44 g), highest firmness (80.93RI) and medium TSS (16.33°B). Cluster II was comprised of 45 cultivars and further divided into two sub clusters with 14 in sub cluster I and 31 in sub-cluster II. Cluster-III is represented by 23 and consisted of two sub-clusters with three in subcluster I of 23 cultivars sub-cluster II. The Cluster- IV was characterized by 6 wild apple (*M. manchurian*, *M. floribunda*, CITH-A-MB-07, CITH-A-MB-05, CITH-A-MB-03, CITH-A-MB-01) possessing lowest fruit weight of 6.54 g. medium firmness 68.46 RI and highest TSS 24.63°B. Thus, this cluster was specifically represented by wild species of apple having small fruits. Cluster-V was represented by 43 Cluster-V was represented by two subclusters with 9 genotypes in sub cluster I and 34 genotypes in sub-cluster II. Forte *et al.* (5) constructed dendrogram of the morphological traits for the analysis of the phylogenetic relationships among the wild and cultivated apple genotypes. Different wild apple genotypes were also evaluated for the genetic variability high degree of variability for different parameters was observed among them. Hassan *et al*. (6) while studying the assessment of genetic variability of wild apple (*Malus* spp.) genotypes in Kashmir valley concluded that Jammu and Kashmir has rich germplasm of wild apple in terms of variability and genetic divergence with respect to various traits.

Present study classified 120 apple genotypes into different groups and provides sufficient data which can be used for cultivar identification and breeding programmes. Our results indicated that apple cultivars can be discriminated on the basis of various quantative and qualitative traits through cluster analysis and PCA. The characterization of apple cultivars will be useful for multiplication of desirable cultivars with useful traits. This information can also be efficiently utilized in future apple improvement programmes for evolving new and superior varieties. These 120 cultivars characterized as per the DUS descriptor will play an important role as reference cultivars for DUS testing.

REFERENCES

1. Bull, J.J. and Wichmann, H.A. 2001. Applied evolution. *Ann. Rev. Ecol. Syst.* **32**: 183-217.
2. Dar, J.A., Wani, A.A. and Dhar, M.K. 2015. Morphological, biochemical and male-meiotic characterization of apple (*Malus* × *domestica* Borkh.) germplasm of Kashmir valley. *Chromosome Bot.* **10**: 39-49.
3. Doebley, J.F., Gaut, B.S. and Smith, B.D. 2006. The molecular genetics of crop domestication. *Cell*, **7**: 1309-21.
4. Dzhangaliev, A.D. 2003. *The Wild Apple Tree of Kazakhstan*. In: Janick J, editor. Wild apple and fruit trees of central Asia. *Hort. Rev*. **29**: 63-285.
5. Forte, A.V., Ignatov, A.N., Ponomarenko, V.V., Dorokhov, D.B. and Savelyev, N.I. 2002. Phylogeny of the *Malus* (apple tree) species, inferred from the morphological traits and molecular DNA analysis. *Russ. J. Gen.* **38**: 1150-60.
6. Hassan, S., Bhat, K.M. and Rehman, H.U. 2017. Assessment of genetic variability of wild apple *(Malus* spps) genotypes in Kashmir valley. *Int. J. Plant Soil Sci.* **14**: 1-12.
7. Henriquez, C., Almonacid S., Chiffelle, I., Valenzuela, T., Araya M., Cabezas L., Simpson, R. and Speisky, H. 2010. Determination of antioxidant capacity, total phenolic content and mineral composition of different fruit tissue of five apple cultivars grown in Chile. *Chil. J. Agric. Sci*. **70**: 223-30.
8. Janick, J., Cummnis, J.N., Brown, S.H. and Hemmat, M. 1996. Apples. **In**: Janick, J. and Moore, J.N. (eds) *Fruit Breeding*, Vol. 1, *Tree and Tropical Fruits*, John Wiley and Sons, New York, pp. 1-77.
9. Kaya, T., Balta, F. and Sensoy, S. 2015. Fruit quality parameters and molecular analysis of apple germplasm resources from Van Lake Basin, Turkey. *Turkish J. Agri. Forest.* **39**: 1-12.
10. Liu, C.J. 1997. Geographical distribution of genetic variation in *Stylosanthes scabra* revealed by RAPD analysis. *Euphytica*, **98**: 21-27.
11. Mir, J.I., Ahmed N., Singh, D.B., Padder, B.A., Shafi, W., Zaffer, S., Hamid, A. and Bhat, H.A. 2017. Diversity evaluation of fruit quality of apple (*Malus* × *domestica* Borkh.) germplasm through cluster and principal component analysis. *Indian J. Plant. Physiol.* **22**: 221-26.

12. Mratinic, E. and Aksic M. F. 2012. Phenotypic diversity of apple (*Malus* sp.) germplasm in South Serbia. *Braz. Arch. Biol. Tech.* **55**: 349-58.

13. Pereira-Lorenzo, S., Ramos-Cabrer, A.M. and Diaz-Hernandez, M.B. 2007. Evaluation of genetic identity and variation of local apple cultivars (*Malus* × *domestica*) from Spain using microsatellite markers. *Gen. Res. Crop Evol.* **54**: 405-20.

14. Reim, S., Proft, A., Heinz, S. and Hofer, M. 2012. Diversity of the European indigenous wild apple *Malus sylvestris* (L.) Mill. in the East Ore Mountains (Osterzgebirge), Germany: I. Morphological Characterization. *Gen. Res. Crop Evol.* **59**: 1101-14.

15. Sharma, G., Bashir, R., Sharma, N. and Jamwal, M. 2013. Multivariate analysis and choice of parent for hybridization in apple (*Malus* × *domestica* Borkh.). *Asian J. Biosci*. **8**: 39-42.

16. UPOV 2005. International Union for the Protection of New Varieties of Plants. 2005. Apple (Fruit Varieties) UPOV Code: MALUS_ DOM (*Malus* × *domestica* Borkh.) – Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability. Geneva, TG/14/9.

17. Westwood, M.N. and Blaney, L.T. 1963. Non-climatic factors affecting the shape of apple fruits. *Nature*, **200**: 802-03.

Received : July, 2019; Revised : March, 2020;
Accepted : April, 2020