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Assessment of genetic divergence of mango genotypes using multivariate techniques

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Authors Info

S. Lal^{1*}, S.K. Singh², A.K. Singh³
and N.K. Singh⁴

¹ICAR-Central Institute of Temperate Horticulture, Srinagar-191 134, India

²Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India

³Horticultural Sciences, ICAR, New Delhi-110 012, India

⁴ICAR-National Research Centre on Plant Biotechnology, New Delhi-110 012, India

*Corresponding Author Email : shivcith@gmail.com

Edited by

Dr. R.B. Raizada

Reviewed by

Dr. Ramajayam Devarajan
Dr. Ritesh Kumar Choudhary

Abstract

Aim : The study was carried out to assess the overall genetic variability of 60 mango (*Mangifera indica*) genotypes for important fruit quality and yield characteristics to select better parents for mango breeding programme.

Methodology : A total of 17 variables were scored and subjected to multivariate analysis. ANOVA, descriptive statistics, cluster analysis and principal component analysis were used to investigate variability among the genotypes for the selected traits.

Results : Significant phenotypic variability was observed for studied traits. Cluster analysis classified all genotypes into two major groups according to shared similarity. Principal component analysis revealed that traits like fruit weight, fruit diameter, pulp content and pulp : stone ratio contributed positively, while fruit shape index, TSS:acid ratio, stone and peel traits contributed negatively for a large proportion of the observed variability.

Interpretation : Pusa Arunima, Pusa Shresth, Pusa Lalima, Mallika, Ramkela, Amrapali, Extreema, Neelum, Gulab Jamun, S.B. Alibagh, Tommy Atkins, Primor-de-Amoreira genotypes were found unique for fruit and yield attributing traits, thus making them potential donor parent for fruit weight, fruit color, fruit diameter, fruit shape, pulp and pulp : stone traits in mango hybridization programme.

Key words: Genetic divergence, Mango genotypes, Multivariate analysis, Techniques

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Introduction

Mango (*Mangifera indica* L.), the 'National Fruit of India', is grown throughout the country, except in temperate regions (Shinde *et al.*, 2001). India is the largest producer of mango contributing nearly 56% of the total global mango production of 18 million tones from an area of 2.50 million ha (NHB, 2014). It is also known as the 'King of fruits' due to its excellent flavor, delicious taste, attractive colour and nutraceutical properties (Rathore *et al.*, 2007). Mango is believed to be originated in Indo-Malayan region stretching from India to the Philippines and Papua New Guinea. It belongs to family Anacardiaceae and comprises 69 species of genus *Mangifera*, which are distributed throughout the world (Kostermans and Bompard, 1993). Most of the existing mango varieties are chance seedling selections made from naturally occurring open-pollinated population (Dinesh *et al.*, 2015), except for few man made hybrids. In spite of sustained research efforts for increasing the production and productivity over the past four decades, the productivity of mango orchards in India is still low and rarely meets the requirements of consumers, as well as export standards (Singh and Kumari, 2011). Genetic variability is the prerequisite for any plant breeding program (Khush, 2002; Srivastava *et al.*, 2017). The development of new fruit cultivars are generally based on genetic resources. Germplasm collection and characterization are essential stages of breeding programs. Mainly germplasm collection and characterization are performed by describing phenological and morphological characteristics such as tree vigour and growth habit, fruit shape, size, peel colour, time of maturity, stone size and pulp content. Selection of genetically diverse parents is mandatory for exploitation of transgressive segregation and further securing useful heterosis in progeny (Arunachalam, 1981). The multivariate analysis techniques are most frequent genetic diversity assessment method while securing relative basic differences between the germplasm. The main objective of this study was to assess the potential genetic diversity among mango genotypes using multivariate analysis methods for selection of parents for hybridization programmes to obtain desirable segregants in advanced generations.

Materials and Methods

The present study was conducted during the year 2014 and 2015 on 60 mango genotypes viz., Alphan (1), Alphanso (2), Amnesia Hyderabad (3), Ametista (4), Amrapali (5), Bhadauran (6), Bombay Green (7), Chausa (8), Dashehari (9), Edward (10), Elard (11), Extrema (12), Ferandin (13), Gulab Jamun (14), GulabKhas (15), Hardil Aziz (16), Husnara (17), Hybrid 165 (18), Irwin (19), Iturba (20), Janardan Pasand (21), Kala (22), Kaleped (23), Khasulkhas (24), Kurrakan (25), Dashehari Sabour (26), Langra (27), Lucknow Safeda (28), Machli (29), Mahmood Vikarabad (30), Mallika (31), Mombasa (32), Neelum (33), Nissar Pasand (34), Olour (35), Primor-de-Amoreira (36), Pusa Arunima (37), Pusa Lalima (38), Pusa Peetamber (39), Pusa Pratibha (40), Pusa Shresth (41), Pusa Surya (42), Ramkela (43), Ratna (44), Rataul (45), Rosari (46), S.B. Alibagh (47), Safdar Pasand (48),

Xavier (49), Saint Alexandrina (50), Sensation (51), Smith (52), Sonatol (53), Tephala (54), Tommy Atkins (55), Totapari (56), Vanraj (57), Willard (58), Zardalu (59) and Zill (60) at Mango Germplasm Block of Division of Fruits and Horticultural Technology of ICAR-Indian Agricultural Research Institute, New Delhi, India. Morphological and physico-chemical parameters of the fruits were recorded in the laboratory. Twenty fruits from each genotype were randomly selected and measured. The peel colour of each genotype at ripening was measured using calibrated Hunter Lab UltraScan PRO colorimeter attached with Easy Match QC software (Hunter Associate Laboratory, Inc., Reston, USA) and expressed as L^* (lightness; 0 = black, 100 = white), a^* ($-a$ = greenness, $+a$ = redness), and b^* ($-b$ = blueness, $+b$ = yellowness) values. Based on L^* , a^* , b^* data the Hue and chroma value was calculated. Fruit shape was determined by calculating fruit shape index as the ratio of fruit length and diameter, whereas fruit weight was measured using Sartorius electric balance. The digital Vernier caliper was used to measure the fruit length and diameter. The measurement of fruit length was made on the polar axis i.e., between the apex and stylar end.

The stone were manually separated from the ripe fruits and peel, pulp and stone contents were weighted. The yield per plant was recorded over the study period by counting the number of fruits and multiplying with average fruit weight. Total soluble solids (TSS), titratable acidity and ascorbic acid were determined as per AOAC (1994). The experiment was conducted under randomized block design with three replications, and pooled data of two years (age of tree 15 years) were analyzed following the method suggested by Gomez and Gomez (1984). To explore the diversity and relationship among 60 genotypes, their vital morphological characteristics were studied by multivariate factor analysis. To find the significance level, ANOVA was performed using PROC GLM, clustering of genotypes into similarity groups was performed using the method tree procedure PROC CLUSTER based on average distance. In order to identify the patterns of variation in fruit chromatic, physico-chemical and contribution of traits, principal component analysis (PCA) was conducted as PROC PRINCOP in the SAS 9.3 software (SAS Institute, 2012 Cary, NC).

Results and Discussion

The analyzed data pertaining to 17 fruit quality traits of 60 mango genotypes revealed significant differences and is presented in Table 1a, b. The visual appearance of fresh fruits is one of the first quality determinants made by the consumers, especially fruit peel color. Therefore, in the present study fruit peel color was recorded among the genotypes, and the results revealed that brightness L^* value was measured maximum for genotypes Primor-de-Amoreira which was statistically at *par* with Dashehari, Irwin followed by Chausa, Husnara. Bright color fruits are much preferred over dull colour by consumers, and the current findings suggest that these brightest genotypes can be utilized for specialized consumer preferences. The value of chromaticity parameter a^* indicates high blush colour, affecting

the cosmetic appearance of fruits, and the maximum a^* value was exhibited by genotype Tommy Atkins followed by Vanraj, Pusa Arunima, Janardan Pasand and Pusa Pratibha. Hence, these genotypes were considered as most attractive, suitable and superior over other mango genotypes for international trade. These findings are also supported by Sethi *et al.* (2011) who emphasized that sufficient red blushes on the peel are preferred in the international trade. The value of b^* which indicates the yellowness of fruit, is desirable for higher consumer acceptance and cosmetic appearance. It was exhibited highest by genotype Extreema, which was at par with Lucknow Safeda, Totapari Red Small and Alphonso. The current findings about variation in fruit peel color of particular genotypes would certainly provide an idea, which could be utilized for trade purpose besides the selection of desirable fruit color parent genotypes in future mango breeding programs and could enable possible selection of desired types.

The fruit shape and size is desirable trait for consumer attraction, packaging, yield and higher return. These characteristics are not only controlled genetically, but are also influenced by the environmental factors (Lal *et al.*, 2017). In the current investigation, fruit weight varied greatly and the heaviest fruit (g) was produced by genotype Primor-de-Amoreira followed by Pusa Arunima, which was at par with Pusa Surya, Elard and Extreema. Similarly lightest fruit weight was produced by Neelum, which was at par with Kurrakan and Bhadauran. High variability might be due to genetic differences among the genotypes. Uddin *et al.* (2006) also reported variable fruit weight in different mango varieties and opined that possible variation might be also due to genetic, geographical and environmental factors. The genotypes Pusa Shresth and Pusa Lalima produced longest fruit followed by Iturba, Tommy Atkins, and shortest by St. Alexandrina and Neelum. Barua *et al.* (2013) also revealed wide variation in fruit

Table 1(a) : Variation in fruit chromatic and physical characteristics of 60 mango genotypes

Genotype	L*	a*	b*	FW (g)	FL (mm)	FD (mm)	FSI
Alphan	52.66±1.016	11.99 ±0.135	40.00 ±0.258	99.25 ±0.576	60.45 ±0.890	47.05±0.592	1.49±0.015
Alphonso	56.33 ±0.526	10.62±0.035	54.46 ±0.519	140.00 ±1.955	91.76±1.995	54.76±1.004	1.68±0.000
Amnesia Hyderabad	46.00±0.868	8.18 ±0.177	52.22 ±0.839	113.49 ±0.635	83.89± 1.208	50.62±1.200	1.67±0.204
Ametista	51.69±0.564	4.06±0.038	42.84 ±0.906	151.47 ±1.926	91.74 ±0.656	59.86 ±1.121	1.53±0.015
Amrapali	42.23±0.780	-6.45±0.084	16.89 ±0.129	218.99 ±1.365	112.56±0.096	64.80±0.609	1.74±0.012
Bhadauran	55.11 ±0.322	0.46 ±0.006	37.57 ±0.642	76.20 ±0.434	66.12 ±0.920	40.40±0.640	1.40±0.006
Bombay Green	51.52 ±0.300	-1.87 ±0.019	34.12 ±0.311	189.27 ±1.417	91.05 ±0.849	63.38 ±1.121	1.44 ±0.025
Chausa	67.67±0.905	0.80±0.006	47.60 ±0.434	203.62 ±3.479	90.56 ±1.565	65.56±1.271	1.37±0.012
Dashehari	70.12±0.552	7.14 ±0.114	51.72 ±0.541	121.87 ±0.845	94.58 ±1.851	55.94 ±0.912	1.69 ±0.007
Edward	64.11±0.666	12.02 ±0.147	50.70 ±0.531	270.37 ±4.657	100.48 ±1.255	52.72 ±0.552	1.90 ±0.015
Elard	62.33±0.972	14.00 ±0.271	45.00 ±0.767	279.37 ±4.074	71.07 ±0.819	90.70±0.684	0.79 ±0.015
Extreema	62.24 ±0.874	13.32±0.127	56.66 ±0.685	273.00 ±3.109	67.83 ±0.564	94.53±1.504	0.72 ±0.006
Ferandin	50.95±0.544	-7.84±0.160	27.03 ±0.361	260.37 ±3.978	92.77 ±1.235	72.24 ±0.717	1.29±0.015
Gulab Jamun	47.33±0.225	1.49±0.021	44.33 ±0.268	184.37 ±0.859	75.01 ±1.150	63.27±0.667	1.18±0.007
GulabKhas	49.48 ±0.162	-5.21 ±0.052	20.62 ±0.117	98.05 ±2.160	78.20 ±0.228	78.33 ±0.849	1.00±0.101
Hardil Aziz	62.81±0.721	16.08±0.029	50.53 ±0.263	118.09 ±0.668	85.21 ±0.947	50.36±0.739	1.69±0.015
Husnara	63.90±0.531	14.98 ±0.195	52.97 ±0.541	83.53 ±1.551	79.11 ±1.521	45.12±0.475	1.75±0.013
Hybrid 165	52.33±0.499	11.11 ±0.142	54.26 ±0.326	169.49 ±2.958	85.85 ±0.290	68.81±0.679	1.25±0.010
Irwin	68.51±0.836	10.64 ±0.015	52.52 ±0.433	243.12 ±1.948	103.50 ±0.459	68.01 ±0.042	1.52±0.021
Iturba	57.66±0.800	13.00 ±0.100	53.00 ±0.807	167.24 ±2.083	132.00±2.142	52.00 ±0.557	2.10±0.024
Janardan Pasand	58.66±0.592	17.66 ±0.210	47.66 ±0.284	113.75 ±2.278	93.89 ±0.772	58.86 ±0.945	1.59 ±0.012
Kala	56.33±0.992	1.57±0.015	47.33 ±0.575	143.25 ±2.697	76.25 ±1.100	53.25 ±0.309	1.43±0.019
Kaleped	53.99±0.130	10.19 ±0.136	42.51 ±0.956	159.37 ±1.350	83.37 ±1.225	47.00±0.229	1.77±0.012
Khasulkhas	58.75±0.610	4.60 ±0.095	42.13 ±0.560	174.47 ±2.224	87.41 ±0.462	67.15±1.00	1.30 ±0.017
Kurrakan	47.22±0.284	2.13 ±0.020	23.24±0.295	76.11 ±1.016	75.42 ±0.835	49.46 ±0.431	1.52 ±0.021
Dashehari Sabour	51.00 ±0.561	13.99 ±0.127	42.66 ±0.534	119.87 ±0.837	80.25 ±1.564	50.75±0.468	1.58±0.015
Langra	50.59±0.608	-9.59 ±0.123	28.91 ±0.302	207.84 ±3.440	92.30 ±1.095	67.57 ±0.911	1.36±0.030
Lucknow Safeda	62.67±0.800	4.89 ±0.015	55.67 ±0.491	98.16 ±0.497	73.09 ±1.695	48.87±0.457	1.49±0.003
Machlii	56.10±0.502	-2.50 ±0.046	43.47 ±0.540	157.27 ±1.130	95.09 ±0.501	60.90 ±0.400	1.56 ±0.030
Mahmood Vikarabad	54.33±1.054	15.33 ±0.146	52.0 ±0.470	127.62 ±0.122	84.01 ±1.219	56.18±0.790	1.49±0.022
Mallika	53.26±0.449	12.76 ±0.050	46.53 ±0.361	239.16 ±1.289	109.21 ±1.392	73.74±0.090	1.48±0.009
Mombasa	51.67 ±0.503	-2.2 ±0.021	36.56 ±0.243	134.37 ±1.853	72.99 ±0.927	56.12±0.558	1.29±0.013
Neelum	58.53±0.132	17.16 ±0.226	53.14 ±0.794	72.61 ±0.877	54.13 ±0.787	49.22±0.940	1.05±0.017
Nissar Pasand	53.33 ±1.180	12.66 ±0.142	49.00 ±0.347	154.87 ±2.250	117.12 ±1.507	53.25±0.274	2.20±0.023

continued to

Olour	48.77±0.332	5.89±0.096	37.51 ±0.303	105.50 ±0.760	74.75 ±0.651	63.66 ±0.904	1.17 ±0.018
Primor-de-Amoreira	71.67±1.502	4.99 ±0.055	53.14 ±0.551	327.50 ±4.056	103.91 ±1.113	85.98±0.881	1.21±0.025
Pusa Arunima	43.33±0.529	17.95 ±0.290	36.00 ±0.266	298.37±2.859	115.49 ±0.832	72.77±1.631	1.59 ±0.019
Pusa Lalima	55.17±0.822	16.20 ±0.211	48.38 ±0.210	166.77 ±1.190	134.24 ±1.207	82.92±0.709	1.68 ±0.015
Pusa Peetamber	63.50±0.832	11.64 ±0.133	51.19 ±0.397	169.50 ±2.911	115.47 ±2.434	89.15±1.968	1.34 ±0.012
Pusa Pratibha	46.21±0.255	17.28 ±0.348	31.15 ±0.268	126.01 ±1.368	85.16 ±0.293	68.30±0.325	1.27±0.012
Pusa Shresth	47.22 ±0.691	10.51 ±0.110	30.52 ±0.217	228.25 ±3.069	138.39 ±1.202	82.08±1.261	1.75±0.010
Pusa Surya	58.60±0.622	11.63 ±0.119	43.65 ±0.457	287.75 ±1.062	108.43 ±1.542	83.82 ±0.775	1.30±0.006
Ramkela	50.00 ±0.793	-10.06 ±0.110	27.16 ±0.026	123.87 ±1.803	66.36 ±0.952	60.30 ±0.293	1.11±0.010
Ratna	60.23±0.553	10.21 ±0.123	53.23 ±0.618	183.74±0.609	90.92 ±1.126	66.82±0.779	1.36±0.015
Rataul	52.87 ±0.385	-7.53 ±0.061	34.87 ±0.372	76.75 ±0.181	67.00 ±0.866	67.50±0.876	0.99±0.020
Rosari	51.33 ±0.815	11.00 ±0.133	49.00 ±0.622	173.37 1.773±	92.03 ±0.760	60.01±0.835	1.53±0.006
S.B. Alibagh	59.50±0.624	0.47±0.006	35.52 ±0.372	98.37 ±1.445	92.57 ±0.895	56.70 ±1.095	1.63±0.010
Safdar Pasand	55.00±0.613	7.08 ±0.051	48.66 ±0.488	129.25 ±2.174	78.48 ±1.282	55.36 ±0.649	1.41±0.015
Xavier	54.18 ±1.175	10.94 ±0.119	43.33 ±0.207	110.89 ±1.871	77.01 ±1.631	58.35 ±0.197	1.32 ±0.006
Saint Alexandrina	56.62 ±0.571	8.70±0.110	40.73 ±0.322	97.66 ±0.528	51.13 ±0.377	66.68 ±0.725	0.79±0.006
Sensation	50.13 ±0.431	1.50 ±0.020	34.54±0.128	175.12 ±2.185	87.45 ±2.045	62.06±0.596	1.41±0.017
Smith	55.56 ±0.286	14.59 ±0.180	49.57 ±0.517	196.25 ±0.862	116.74 ±0.780	70.41±0.749	1.65±0.013
Sonitol	47.86±0.702	3.27 ±0.032	41.97 ±0.504	137.16 ±1.347	74.41 ±0.913	55.45 ±0.138	1.70±0.030
Tephala	50.66 ±0.438	2.80 ±0.018	40.66 ±0.501	132.25 ±1.316	68.15 ±0.801	54.00±0.692	1.34±0.010
Tommy Atkins	46.60±0.680	28.54 ±0.095	33.62 ±0.680	184.37 ±1.423	122.16 ±1.568	58.09 ±0.701	2.54±0.038
Totapari	59.66±0.530	17.00 ±0.146	54.99 ±0.781	138.62 ±1.795	115.63 ±1.108	70.12 ±0.267	1.65 ±0.015
Vanraj	48.00 ±0.382	21.33 ±0.350	36.33 ±0.142	146.00 ±1.740	101.99 ±1.273	57.37±1.11	1.78±0.006
Willard	48.99±0.608	5.03±0.060	43.66 ±0.502	238.74 ±5.023	111.97 ±1.605	59.75 ±0.962	1.87±0.012
Zardalu	60.33±0.626	13.66 ±0.163	53.00 ±0.850	193.87 ±1.675	86.50 ±1.446	54.54 ±0.165	1.58 ±0.023
Zill	54.29 ±0.143	-1.56 ±0.015	37.17 ±0.566	103.62 ±1.857	113.49 ±1.536	58.74±0.662	1.93±0.029
LSD ($p \leq 0.05$)	3.52	0.85	3.09	11.88	6.33	4.63	0.09

FW: Fruit weight, FL: Fruit length, FD: Fruit diameter and FSI: Fruit shape index

length in Bari mango varieties under Chittagong region. Likewise, the maximum fruit diameter was exhibited by genotype Extreema followed by Elard, Pusa Peetabmer, Primor-de-Amoreira and Pusa Surya, whereas the minimum fruit diameter was found in genotype in Bhadauran followed by Husnara, Kaleped, Alphan, Lucknow Safeda and Neelum. The fruit shape variation provides a good entry point to investigate domestication and selection history of mango, as well as providing fundamental insights into the regulation of plant organ shape and size besides making strategy for packaging. To determine fruit shape, fruit shape index was calculated, which revealed significant variation among the selected genotypes. The maximum fruit shape index was also recorded in genotype Tommy Atkins which was at par with Nissar Pasand followed by Iturba, Zill and Edward, whereas lowest was recorded in genotypes Extreema, which was statistically at par with St. Alexendrina. Similar variation in fruit size was also noted by Singh *et al.* (2012) and Manchekar *et al.* (2011) in mango genotypes. Fruit shape and size are one of the main factors used to determine consumer acceptance. Higher premiums are paid for medium to large fruit, making fruit size an important factor when determining market returns. In selected genotypes, significant variation was observed for these particular traits and this information could be utilized in further mango improvement programme for development of desirable fruit shape and size genotypes. The results related to

wide variation in fruit shape and size traits in the current study are in conformity with the results of Barholia and Yadav (2014), Vasugi *et al.* (2013), Bhowmick and Banik (2008) and Nayak *et al.* (2013) in mango, respectively.

Mango fruit is known for its vast variability in taste, flavour, sweetness, sugar acid blend and vitamin C contents and therefore, popularly known as king of fruits (Rathore *et al.*, 2007). Most of the domestic consumers like to eat sweet mango however, in international market genotypes having better sugar acid blend is much preferred. In this case, significant variation was also recorded in all the genotypes for biochemical traits and highest TSS (°B) was recorded in genotype Chausa, which was at par with Zill, Amrapali and lowest Ramkela, followed by Lucknow Safeda and Pusa Peetamber. Likewise, maximum titratable acidity (%) was estimated in Chausa followed by Bombay Green, and minimum in Sensation followed by Ferandin. The values of titratable acidity are in accordance with the results of Kumar (1998) in different mango cultivars. Its wide range of values from 0.16 to 0.51% was also supported by Bora *et al.* (2017) and Patel *et al.* (2017). Variation in acidity in different mango varieties of mango could be due to their varietal characters.

TSS/acid ratio is considered as a symbol of better fruit quality, it is generally recognized that quality fruits benefit from a

higher sugar:acid ratio, whereas fruits of lower quality suffer from a lower sugar : acid ratio (Shi *et al.*, 2015). In this study, the highest TSS/acid ratio was recorded in genotype Gulab Jamun followed by Husnara, however, lowest was noted in Ramkela followed by Tommy Atkins. The range of TSS acidity ratios, as reported in the present study, was similar to those of Palaniswamy *et al.* (1975) who found a TSS:TA ratio for high-quality mangos for cvs. Khirsapat, Gopalbhog and Langra of 162.5, 150.0 and 131.3, respectively. Similarly, Rodríguez *et al.* (2012) also reported highest sugar acid ratios for cvs. Kent (382) and Lippens (333), which might be indicative of the effect on their flavor.

Highest ascorbic acid content was recorded in Chausa followed by Lucknow Safeda, Ramkela and Pusa Shresth, while lowest ascorbic acid content was noted in Husnara followed by Alphan and Sensation. Such variation in ascorbic acid content could be due to nature and extent of genetic variability present in the mango varieties. Similar findings have also been reported López *et al.*, 1997; Selvan *et al.*, 2010; Barhate *et al.*, 2012; Majumder *et al.*, 2012; Bora *et al.*, 2017) while working on fruit quality characters of different mango varieties under different climatic conditions. Thickness of fruit peel determines the shelf-life of fruit during transport and storage. The thickest fruit peel was found in Ramkela followed by Neelum and Sensation, however, thinnest fruit peel was observed in Pusa Arunima followed by S.B. Alibagh and Husnara. Similarly, Bora *et al.* (2017) and Patel *et al.* (2017) reported wide range of peel thickness in different mango varieties. Peel thickness provides protection against fruit fly and helps to reduce post harvest losses, however, this fact could increase the difficulty of removing peel before processing.

Stone characteristics varied significantly among different genotypes of mango under study. The maximum stone percent was recorded in S.B. Alibagh followed by Totapari Red Small and Zill, while minimum was found in Extreema followed by Ferandin and Irwin. Stone percentage is an important character of mango as it determines the edible portion in the fruit. The maximum peel percentage was recorded in the fruit of Neelum followed by Zill and Totapari Red Small, however, the lowest peel percentage was reported in Khasulkhas followed by Amrapali and Alphan. It is evident from the current findings that the mango genotypes significantly varied with respect to their pulp and peel characteristics. The pulp content showed wide variability and highest pulp content was recorded in genotypes Extreema followed by Ferandin, while lowest in Neelum followed by Totapari Red Small. Pulp stone ratio is an ideal parameter for judging the fruit quality from the consumer's point of view. Data regarding pulp:stone ratio of mango genotypes revealed remarkable variation. The maximum amount of pulp:stone ratio was noted in Extreema, Ferandin and Irwin, while minimum in Neelum followed by Totapari Red Small. An ideal mango cultivar must have higher pulp:ratio beside other yield characteristics. Singh *et al.* (2017) also found variation for pulp:stone ratio in mango varieties and concluded that a high pulp:stone ratio indicates the suitability of cultivars for fruit processing. The present findings are also in accordance with the results of Jilani *et al.* (2010) and Anila and

Radha (2005). Yield being the economic potential of plants is considered most important while making selection and further improvement. A wide range of variability was noticed among the 60 genotypes, which ranged from 13.50 to 88.00 kg per tree. The most productive genotype was Pusa Lalima followed by Pusa Arunima, Amrapali which was at par with Totapari Red Small and Mallika whereas lowest was recorded in Irwin which was at par with Ratna and Mombasa genotypes. Similar variation in traits related to fruit morphological (peel colour), physical (fruit shape and size) and biochemical constituents and yield has been previously reported) Majumder *et al.*, 2013; Kaur *et al.*, 2014; Gill and Singh, 2015) in mango genotypes under variable climate.

Descriptive statistics in Table 2 revealed the maximum standard deviation for fruit weight followed by TSS/acid ratio, fruit length and yield, however, highest coefficient of variation in a^* followed by pulp: stone and yield and least in L^* followed by TSS and ascorbic acid suggests good potential of these traits for selection in mango improvement program. Highest geometric mean and harmonic mean was found in fruit weight followed by fruit length and TSS/acid ratio, while least was noted in acidity followed by fruit shape index and peel thickness. Kurtosis tells the weight of the tails of a distribution. These results showed the distribution of quantitative traits which provides information about nature of gene action and number of genes controlling the traits, respectively.

The skewed distribution of a trait in general suggests that the trait is under the control of non-additive gene action and is influenced by environmental variables. Positive skewness is associated with complementary gene interactions while negative skewness is associated with duplicate (additive $\times$ additive) gene interactions. The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on the trait. In the current investigation, data were normally skewed to the tune of less than ± 2 . However, positive skewness was recorded for peel percent, yield, stone, pulp: stone ratio, fruit diameter, acidity, fruit weight, peel thickness, ascorbic acid, fruit length, TSS/acid ratio, fruit shape index, TSS and L^* while it was negative for a^* , b^* and pulp. In the present set of data, platykurtic distribution pattern was recorded for peel, yield, stone, pulp: stone ratio, fruit shape index, peel thickness, pulp%, fruit diameter, however, leptokurtic distribution was recorded for L^* , b^* , fruit weight, fruit length, a^* , acidity, ascorbic acid, TSS and TSS/acid ratio, respectively.

The results gives an idea about the existence of genetic variability among the selected mango genotypes and provides opportunity to the breeders for selection of parents for targeted traits besides making strategies for mango germplasm documentation, conservation and management. This variation observed in various traits studied under study might be due to different environmental interaction and genetic composition. These results are in accordance with the findings of Shi *et al.* (2015); Kaur *et al.* (2014); Gill and Singh (2015); Krishnapillai *et al.* (2016) in mango and Pandey *et al.* (2016) in aonla.

Table 1(b) : Variation in fruit physical, biochemical and yield characteristic of 60 mango genotypes

Genotype	TSS : Acid ratio	AA (mg 100g ⁻¹)	TSS (°B)	Titratable acidity (%)	PT (mm)	Stone (%)	Peel (%)	Pulp (%)	Pulp :stone ratio	Yield (kg per tree)
Alphan	95.12 ±0.658	23.00±0.166	19.50±0.351	0.21±0.004	1.30±0.012	23.50±0.358	12.67±0.062	63.83±0.018	2.78±0.018	32.50±0.555
Alphanso	60.72±0.347	25.40±0.491	20.10±0.121	0.33±0.003	1.77±0.010	19.77±0.252	17.36±0.376	62.88±0.029	3.28±0.029	20.00±0.240
Amnesia Hyderabad	97.60±2.266	27.88±0.159	17.50±0.238	0.18±0.004	1.53±0.021	19.81±0.266	20.87±0.271	59.32±0.049	3.08±0.049	17.50±0.110
Ametista	102.32±2.293	27.88±0.229	18.00±0.396	0.18±0.002	1.94±0.019	17.27±0.255	17.33±0.083	65.40±0.035	3.77±0.035	28.00±0.620
Amrapali	72.88±0.852	25.50±0.228	21.58±0.223	0.30±0.002	1.81±0.012	13.27±0.099	12.28±0.147	74.45±0.050	5.44±0.050	55.00±0.530
Bhadauran	81.16±0.403	29.67±0.268	18.50±0.232	0.23±0.003	1.35±0.012	28.57±0.265	16.41±0.235	55.02±0.007	2.03±0.007	21.50±0.278
Bombay Green	40.73±0.503	31.50±0.297	18.75±0.344	0.46±0.006	2.11±0.032	15.05±0.122	17.00±0.217	67.95±0.010	4.69±0.010	24.50±0.114
Chausa	43.09±0.480	46.72±0.635	21.75±0.256	0.51±0.006	1.86±0.021	13.60±0.099	16.87±0.186	69.53±0.046	4.98±0.046	33.00±0.364
Dashehari	55.99±0.716	34.83±0.176	20.64±0.255	0.37±0.001	1.75±0.026	21.50±0.422	24.76±0.075	53.75±0.032	2.43±0.032	26.00±0.442
Edward	69.75±0.839	38.97±0.191	17.83±0.183	0.26±0.003	2.17±0.015	14.45±0.330	14.99±0.054	70.55±0.049	4.89±0.049	28.50±0.059
Elard	90.98±0.875	32.67±0.247	19.96±0.144	0.22±0.003	2.15±0.024	13.11±0.155	14.44±0.264	72.45±0.098	5.68±0.098	18.00±0.146
Extrema	65.72±0.495	27.50±0.040	16.71±0.327	0.26±0.006	2.01±0.017	8.70±0.029	12.90±0.139	78.40±0.136	9.37±0.136	31.00±0.457
Ferandin	93.18±1.342	30.00±0.636	15.79±0.159	0.17±0.003	1.48±0.022	9.77±0.115	15.03±0.097	75.21±0.046	8.14±0.046	38.50±0.886
Gulab Jamun	110.46±1.447	25.50±0.460	18.85±0.172	0.17±0.003	1.56±0.024	19.35±0.087	17.06±0.151	63.59±0.061	3.40±0.061	19.00±0.140
Gulab Khas	67.18±0.662	27.00±0.186	14.86±0.212	0.22±0.001	1.85±0.006	23.24±0.415	19.81±0.243	56.95±0.036	2.55±0.036	28.00±0.206
Hardil Aziz	79.36±1.033	38.15±0.162	17.63±0.200	0.23±0.003	1.60±0.013	21.66±0.155	16.50±0.351	61.84±0.022	2.89±0.022	21.00±0.261
Husnara	106.84±0.347	22.67±0.310	20.56±0.074	0.20±0.002	1.21±0.027	25.54±0.387	27.24±0.572	47.22±0.025	1.94±0.025	20.50±0.107
Hybrid 165	75.02±1.002	25.83±0.323	18.25±0.202	0.25±0.004	1.64±0.030	14.93±0.100	15.56±0.279	69.51±0.031	4.78±0.031	39.50±0.381
Irwin	86.12±1.027	30.00±0.556	21.36±0.318	0.25±0.003	2.12±0.015	12.02±0.107	15.90±0.204	72.08±0.064	6.15±0.064	13.50±0.130
Iturba	72.56±1.457	32.67±0.086	20.00±0.135	0.28±0.003	2.17±0.026	19.85±0.213	22.96±0.165	57.19±0.036	2.97±0.036	19.50±0.119
Janardan Pasand	45.89±0.635	40.50±0.235	16.28±0.115	0.36±0.004	1.82±0.040	25.19±0.148	27.46±0.324	47.35±0.021	2.03±0.021	51.50±0.578
Kala	59.28±1.125	37.87±0.461	15.56±0.112	0.26±0.003	1.32±0.012	18.88±0.232	19.31±0.107	61.81±0.025	3.33±0.025	17.00±0.201
Kaleped	53.75±0.086	31.83±0.324	14.89±0.026	0.28±0.002	1.46±0.015	14.20±0.188	18.54±0.212	67.25±0.048	4.83±0.048	17.00±0.170
Khasulkhas	55.67±0.644	28.67±0.318	13.69±0.125	0.24±0.003	1.69±0.017	17.31±0.127	11.43±0.093	71.26±0.048	4.26±0.048	31.50±0.471
Kurakan	47.26±0.611	38.83±0.410	15.63±0.061	0.33±0.004	1.28±0.015	32.39±0.510	27.58±0.245	40.03±0.012	1.24±0.012	27.00±0.241
Dashehari Sabour	78.89±0.994	37.33±0.178	17.75±0.123	0.23±0.003	1.54±0.012	24.58±0.595	24.27±0.152	51.15±0.017	2.13±0.017	19.00±0.122
Langra	53.73±0.629	35.00±0.431	20.75±0.293	0.38±0.005	1.73±0.012	15.43±0.168	12.73±0.127	71.84±0.049	4.69±0.049	48.00±0.646
Lucknow Safeda	67.03±0.880	43.67±0.462	13.21±0.143	0.20±0.003	1.89±0.022	20.77±0.180	24.44±0.119	54.79±0.015	2.82±0.015	22.00±0.236
Machli	52.76±0.536	31.50±0.137	13.64±0.085	0.26±0.003	1.63±0.017	16.42±0.159	25.53±0.098	58.05±0.031	3.59±0.031	27.50±0.332
Mahmood Vikarabad	99.39±1.445	27.00±0.067	20.83±0.334	0.21±0.003	1.83±0.020	21.55±0.461	20.84±0.188	57.62±0.035	2.67±0.035	19.00±0.317
Malika	56.36±0.456	26.33±0.389	17.70±0.156	0.32±0.002	1.71±0.007	14.90±0.121	14.81±0.122	70.30±0.067	4.92±0.067	52.50±0.602
Mombasa	52.82±0.374	34.22±0.242	16.25±0.131	0.31±0.003	1.55±0.018	21.99±0.372	20.67±0.074	57.33±0.026	2.67±0.035	15.00±0.118
Neelum	75.03±1.362	26.30±0.280	18.00±0.258	0.24±0.004	2.40±0.029	27.35±0.468	58.92±0.439	13.74±0.001	0.45±0.001	45.00±0.791

continued to

Nissar Pasand	97.05±1.398	35.37±0.363	17.33±0.182	0.18±0.002	1.69±0.031	15.34±0.189	25.10±0.150	59.56±0.045	3.93±0.045	29.00±0.320
Olour	41.79±0.576	25.50±0.186	14.00±0.221	0.34±0.004	1.57±0.015	29.83±0.456	26.12±0.081	44.05±0.021	1.38±0.021	36.00±0.269
Primor-de-Amoreira	44.05±0.537	27.83±0.177	14.89±0.255	0.34±0.002	1.79±0.026	14.93±0.182	13.22±0.291	71.86±0.70	4.37±0.070	39.50±0.707
Pusa Arunima	43.22±0.780	33.00±0.465	19.38±0.260	0.45±0.005	0.94±0.015	12.28±0.084	16.87±0.292	70.86±0.061	5.88±0.061	64.50±0.543
Pusa Lalima	43.90±0.698	40.83±0.401	13.88±0.150	0.32±0.003	1.75±0.009	22.99±0.191	29.14±0.407	47.87±0.010	1.39±0.010	88.00±0.817
Pusa Peelamber	56.53±0.322	40.33±0.434	13.63±0.119	0.24±0.003	1.85±0.027	22.87±0.247	29.38±0.135	47.75±0.026	1.53±0.026	42.50±0.301
Pusa Pratibha	87.01±0.822	39.67±0.522	18.00±0.064	0.21±0.004	1.76±0.010	28.18±0.270	36.11±0.495	35.72±0.006	0.81±0.006	37.50±0.727
Pusa Shresth	97.55±1.231	42.33±0.895	18.50±0.129	0.19±0.004	1.70±0.009	16.77±0.042	18.84±0.127	64.39±0.029	3.47±0.029	43.50±0.259
Pusa Surya	47.45±0.448	40.50±0.157	13.81±0.300	0.29±0.004	2.09±0.010	15.10±0.320	14.76±0.087	70.14±0.038	4.80±0.038	31.50±0.640
Ramkela	34.91±0.436	42.50±0.232	12.50±0.084	0.36±0.004	2.85±0.049	21.47±0.292	17.66±0.248	60.87±0.032	2.86±0.032	28.50±0.153
Ratna	38.44±0.117	25.65±0.254	15.84±0.131	0.42±0.006	1.84±0.020	15.92±0.087	26.72±0.225	57.36±0.085	3.69±0.085	14.50±0.047
Rataul	60.36±0.377	26.68±0.136	17.75±0.127	0.29±0.004	1.51±0.021	26.85±0.361	25.78±0.295	47.37±0.017	1.98±0.017	24.00±0.144
Rosari	39.46±0.170	28.22±0.199	13.69±0.242	0.35±0.001	1.78±0.019	23.61±0.102	26.15±0.195	50.24±0.026	2.14±0.026	21.50±0.315
S.B. Alibagh	103.74±1.243	34.23±0.187	17.86±0.162	0.18±0.002	1.13±0.012	48.05±0.368	25.14±0.489	26.80±0.025	3.32±0.025	15.50±0.091
Safdar Pasand	82.89±0.893	26.67±0.170	18.06±0.122	0.22±0.005	1.30±0.015	20.05±0.319	19.01±0.256	60.95±0.020	3.20±0.020	23.00±0.139
Xavier	85.65±0.518	32.67±0.287	16.00±0.192	0.19±0.002	1.23±0.025	22.17±0.280	24.52±0.289	53.32±0.028	2.46±0.028	39.50±0.351
Saint Alexandrina	86.48±0.796	31.67±0.334	14.74±0.112	0.18±0.002	2.18±0.028	20.59±0.184	28.76±0.280	50.66±0.029	2.43±0.029	25.00±0.286
Sensation	87.64±1.057	24.33±0.289	13.75±0.162	0.16±0.002	2.34±0.023	33.45±0.409	18.49±0.196	48.06±0.012	1.31±0.012	43.50±0.599
Smith	64.08±1.300	32.48±0.205	14.61±0.118	0.23±0.002	1.73±0.015	12.78±0.134	15.98±0.236	71.24±0.065	5.77±0.065	18.50±0.075
Sonatal	60.34±1.005	31.33±0.211	16.75±0.231	0.28±0.003	1.54±0.006	22.82±0.244	21.33±0.210	55.85±0.025	2.53±0.025	32.00±0.136
Tephala	39.87±0.380	28.00±0.331	17.95±0.261	0.45±0.002	1.75±0.006	20.74±0.239	20.58±0.283	58.68±0.035	2.95±0.035	29.50±0.251
Tommy Atkins	35.65±0.244	34.05±0.324	13.70±0.155	0.38±0.004	1.57±0.027	26.48±0.216	22.94±0.297	50.58±0.030	1.86±0.030	31.00±0.145
Totapari	36.57±0.225	32.10±0.537	15.63±0.160	0.43±0.006	1.42±0.010	37.93±0.160	38.03±0.649	24.05±0.010	0.54±0.010	53.00±0.567
Vanraj	47.76±0.497	32.67±0.274	21.38±0.250	0.45±0.002	1.61±0.020	28.28±0.259	28.63±0.318	43.09±0.010	1.44±0.010	37.00±0.373
Willard	57.60±0.469	35.77±0.180	20.13±0.230	0.35±0.001	1.46±0.021	21.01±0.042	18.50±0.052	60.50±0.026	2.92±0.026	21.00±0.225
Zardalu	106.33±1.167	40.17±0.645	21.25±0.172	0.20±0.002	1.51±0.021	22.13±0.204	23.91±0.182	53.96±0.031	2.35±0.031	35.50±0.243
Zill	80.11±0.831	32.50±0.240	21.67±0.132	0.28±0.003	1.87±0.010	34.20±0.436	38.53±0.289	27.27±0.012	0.89±0.012	19.00±0.231
LSD($p \leq 0.05$)	4.39	5.43	1.23	0.05	0.20	2.54	3.67	4.23	1.10	3.21

TSS: Total soluble solids, AA: Ascorbic acid and PT: Peel thickness

Table 2 : Descriptive statistics for 17 fruit quality and yield traits of 60 mango genotypes

Trait	Minimum	Maximum	Mean±SEm	Standard deviation	Variance	CV (%)	Skewness	Kurtosis	Geometric mean	Harmonic mean
L*	42.23	71.67	54.96±0.85	6.61	43.75	0.12	0.49	-0.21	54.58	54.21
a*	-10.06	28.54	7.67±1.06	8.22	67.50	1.07	-0.26	-0.30	7.12	6.07
b*	16.89	56.66	43.09±1.23	9.49	90.10	0.22	-0.72	-0.13	41.86	40.36
Fruit weight (g)	72.61	327.50	163.16±8.04	62.29	3879.79	0.38	0.71	-0.22	152.10	141.83
Fruit length (mm)	51.13	138.39	90.64±2.53	19.59	383.87	0.22	0.40	-0.29	88.57	86.52
Fruit diameter (mm)	40.40	94.53	62.53±1.54	11.96	143.09	0.19	0.78	0.19	61.47	60.47
Fruit shape index	0.72	2.54	1.49±0.04	0.33	0.11	0.22	0.24	1.25	1.45	1.41
TSS (°B)	12.50	21.75	17.32±0.34	2.62	6.87	0.15	0.01	-1.11	17.12	16.92
Titrate acidity (%)	0.16	0.51	0.28±0.01	0.09	0.01	0.31	0.72	-0.33	0.27	0.26
TSS/acid ratio	34.91	110.46	67.85±2.83	21.93	480.73	0.32	0.26	-1.15	64.33	60.90
Ascorbic acid (mg 100g ⁻¹)	22.67	46.72	32.32±0.75	5.84	34.09	0.18	0.43	-0.72	31.82	31.33
Peel thickness (mm)	0.94	2.85	1.72±0.04	0.33	0.11	0.19	0.57	1.22	1.68	1.65
Stone (%)	8.70	48.05	21.05±0.92	7.16	51.23	0.34	1.10	2.15	19.95	18.90
Peel (%)	11.43	58.92	21.74±1.02	7.94	63.02	0.37	1.98	6.48	20.60	19.64
Pulp (%)	13.74	78.40	57.21±1.73	13.41	179.90	0.23	-1.02	1.12	55.09	51.92
Pulp:stone ratio	0.45	9.37	3.28±0.23	1.75	3.06	0.53	1.02	1.54	2.81	2.28
Yield (kg tree ⁻¹)	13.50	88.00	30.84±1.79	13.84	191.57	0.45	1.55	3.47	28.33	26.23

By constructing a similarity tree, based on average cluster distance using 17 fruit quality and yield traits, the whole set of 60 mango genotypes were classified into two major groups. The grouping of genotypes was based on the basis of the traits in which the genotypes share the similarity. The First group was further categorized into two clusters. Of these, the first cluster consisted a total of 19 genotypes contributing 31.66 % of the total

genotypes (Ametista, Nissar Pasand, Gulab Jamun, Zardalu, Sensation, Bombay Green, Chausa, Langra, Hybrid 165, Khasulkhas, Ratna, Rosari, Iturba, Smith and Tommy Atkins, Vanraj, Pusa Pratibha, Pusa Lalima and Totapari Red Small). This first cluster was further divided into two sub-clusters and first sub-cluster included 4 genotypes (Vanraj, Pusa Peetamber, Pusa Lalima and Totapari Red Small) characterized by higher yield and

Table 3 : Principal component analysis of 60 mango genotypes using six principal component axes

Trait	PC1	PC2	PC3	PC4	PC5	PC6
L*	0.078	0.016	0.369	-0.447	0.189	0.089
a*	-0.057	0.259	0.434	-0.057	-0.176	-0.244
b*	0.024	0.042	0.531	-0.332	0.123	-0.174
Fruit weight (g)	0.415	0.166	0.071	0.025	-0.129	-0.035
Fruit length (mm)	0.124	0.431	0.182	0.270	-0.202	0.178
Fruit diameter (mm)	0.286	0.175	-0.151	-0.248	-0.413	-0.110
Fruit shape index	-0.091	0.266	0.304	0.459	0.129	0.239
TSS (°B)	0.019	-0.102	0.266	0.293	0.120	-0.255
Titrate acidity (%)	0.059	0.393	-0.184	0.011	0.515	-0.293
TSS/ acid ratio	-0.061	-0.407	0.297	0.147	-0.429	0.123
Ascorbic acid (mg 100g ⁻¹)	0.007	0.288	0.019	-0.061	0.052	0.670
Skin thickness (mm)	0.098	0.028	-0.081	-0.402	-0.012	0.331
Stone (%)	-0.419	0.058	-0.077	0.015	-0.074	0.011
Peel (%)	-0.370	0.176	0.044	-0.224	-0.137	-0.093
Pulp (%)	0.443	-0.135	0.015	0.125	0.120	0.049
Pulp:stone ratio	0.429	-0.130	0.045	0.041	0.021	-0.039
Yield (kg tree ⁻¹)	0.051	0.364	-0.174	0.031	-0.410	-0.252
Eigenvalue	4.300	2.625	2.119	1.915	1.365	1.067
Variability (%)	25.296	15.444	12.465	11.268	8.032	6.277
Cumulative (%)	25.296	40.740	53.205	64.472	72.504	78.782

PC: Principal component

Fig. 1: Dendrogram of 60 mango genotypes obtained by average distance between cluster analyses based on 17 fruit quality and yield traits.

Genotype code: Alphan (1), Alphanso (2), Amnesia Hyderabad (3), Ametista (4), Amrapali (5), Bhadauran (6), Bombay Green (7), Chausa (8), Dashehari (9), Edward (10), Elard (11), Extreema (12), Ferandin (13), Gulab Jamun (14), GulabKhas (15), Hardil Aziz (16), Husnara (17), Hybrid 165 (18), Irwin (19), Iturba (20), Janardan Pasand (21), Kala (22), Kaleped (23), Khasulkhas (24), Kurrakan (25), Dashehari Sabour (26), Langra (27), Lucknow Safeda (28), Machlli (29), Mahmood Vikarabad (30), Mallika (31), Mombasa (32), Neelum (33), Nissar Pasand (34), Olour (35), Primor-de-Amoreira (36), Pusa Arunima (37), Pusa Lalima (38), Pusa Peetamber (39), Pusa Pratibha (40), Pusa Shresth (41), Pusa Surya (42), Ramkela (43), Ratna (44), Rataul (45), Rosari (46), S.B. Alibagh (47), Safdar Pasand (48), Xavier (49), Saint Alexandrina (50), Sensation (51), Smith (52), Sonatol (53), Tephala (54), Tommy Atkins (55), Totapari (56), Vanraj (57), Willard (58), Zardalu (59) and Zill (60).

lower titratable acidity, however, the second cluster consisted a total of 15 genotypes (Amitista, Nissar Pasand, Gulab Jamun, Zardalu, Sensation, Bombay Green, Chausa, Langra, Hybrid 165, Khasulkhas, Ratna, Rosari, Iturba, Smith and Tommy Atkins). Likewise, the second cluster of group I was further categorized into two sub-clusters and consisted a total of 29 genotypes contributing 48.33% of the total genotypes. Of these first sub-cluster consisted only one genotype, i.e., Neelum characterized by lower pulp:stone ratio and fruit size, however,

the second sub-cluster consisted of rest of 28 genotypes. The second sub-cluster was further divided into two sub cluster (a&b) and the first sub-cluster (a) consisted of total of 11 genotypes (Alphanso, Dashehari, Kala, Mombasa, Sonatol, Tephala, Kaleped, Machlli, Ramkela, Janardan Pasandand, Olour) and second sub-cluster (b) consisted 17 genotypes (Alphan, St. Alexendrina, Bhadauran, Husnara, Amnesia Hyderabad, Mahmood Vikarabad, Hardil Aziz, Dashehari Sabour, Safdar Pasand, Xavier, Lucknow Safeda, Pusa

Fig. 2 : Segregation of 60 mango genotypes according to their fruit quality and yield characteristics determined by principal component analysis (PCA). Vectors represent the loadings of fruit quality and yield traits data along with the principal component scores.

Genotype code: Alphan (1), Alphanso (2), Amnesia Hyderabad (3), Ametista (4), Amrapali (5), Bhadauran (6), Bombay Green (7), Chausa (8), Dashehari (9), Edward (10), Elard (11), Extreema (12), Ferandin (13), Gulab Jamun (14), Gulab Khas (15), Hardil Aziz (16), Husnara (17), Hybrid 165 (18), Irwin (19), Iturba (20), Janardan Pasand (21), Kala (22), Kaleped (23), Khasul khas (24), Kurakkan (25), Dashehari Sabour (26), Langra (27), Lucknow Safeda (28), Machlli (29), Mahmood Vikarabad (30), Mallika (31), Mombasa (32), Neelum (33), Nissar Pasand (34), Olour (35), Primor-de-Amoreira (36), Pusa Arunima (37), Pusa Lalima (38), Pusa Peetamber (39), Pusa Pratibha (40), Pusa Shresth (41), Pusa Surya (42), Ramkela (43), Ratna (44), Rataul (45), Rosari (46), S.B. Alibagh (47), Safdar Pasand (48), Xavier (49), SaintAlexandrina (50), Sensation (51), Smith (52), Sonatol (53), Tephala (54), Tommy Atkins (55), Totapari (56), Vanraj (57), Willard (58), Zardalu (59) and Zill (60).

Pratibha, S.B. Alibagh, Zill, Gulabkhas, Kurakkan, Rataul). These findings reveal that the genotypes in different clusters have wide genetic diversity in terms of traits studied.

Further, the second group of two major group included 12 genotypes (Pusa Surya, Pusa Arunima, Primor-de-Amoreira, Extreema, Elard, Ferandin, Willard, Mallika, Irwin, Edward, Pusa Shresth and Amrapali) contributing 20% of the total genotypes studied. The second group was further divided into two major clusters. In first cluster, there were 5 genotypes contributing 8.33% of the total genotypes, which was further divided in to two-sub-clusters in which first sub-cluster comprised 3 genotypes, however, second sub-cluster consisted only two genotypes, i.e., Elard and Extreema. The second cluster was also further divided into two sub-clusters which comprised a total of 7 genotypes (Ferandin, Willard, Mallika, Irwin, Edward, Pusa Shresth and Amrapali) contributing 11.66% of the total genotypes. The first-sub-cluster consisted of only 5 genotypes, Ferandin, Willard,

Mallika, Irwin, Edward), however, second sub-cluster comprised two genotypes (Pusa Shresth and Amrapali). Crosses involving parents belonging to more divergent clusters would be expected to manifest maximum heterosis and wide variability in genetic architecture (Singh *et al.*, 2013). In the present study, the first group comprised of high yielding genotypes and second group with high fruit quality had more divergent nature as compared to individual clusters. Therefore, the chance of getting segregates with high yield having better quality is quite high. Similarly, the diverse genotypes from different individual clusters can also be utilized as parents for promising traits.

The current findings also state that the factor(s) other than geographical separation is responsible for divergence, and the genotypes that have originated from the same place may have different genetic architecture or vice-versa. These findings are in confirmation with the previous studies carried out in mangoes (Majumder *et al.*, 2013; Sennhenn *et al.*, 2013; Mem *et*

al., 2016; Rahman et al., 2006). Therefore, selection of parents should also consider the special advantage of each group and each genotype within a group depending on specific objective of hybridization (Chahal and Gosal, 2002). Principal component analysis (PCA) was applied to identify the traits which were the main source of variability and to explain the genetic diversity among the populations (Milosevic et al., 2010; Lal et al., 2013; Verma et al., 2014). Eigenvalues of principal component axis, percent of total variation and cumulative variation accounted for them obtained from principal component analysis are presented in Table 3. Principal components analysis reduced the original seventeen characters in the experiment to six principal components (Table 3). The first six components with eigenvalues >1 explained 78.78% of variation among 60 genotypes (Table 3). Other PCs had Eigen values <1 and were not included and interpreted.

The first PC, which is the most important component, explained 25.29% of total variation and was positively related to fruit weight, fruit diameter, pulp per cent and pulp: stone ratio, while negatively related to a^* , fruit shape index, TSS/acid ratio, stone and peel percent (Fig. 2), respectively. The PC2 accounted 15.44% of the total variation and the characters with greatest weight on this component were fruit length, stone, skin and yield. The PC3 accounted for 12.46% and was positively related to L^* , a^* , b^* and TSS/acid ratio. However, PC4 accounted for 11.26% and weighted for fruit shape index and TSS.

The PC5 and PC6 accounted for 8.03 and 6.27%, and weighted for acidity peel thickness and ascorbic acid, respectively. In the current investigation, differentiation of genotypes into different components was due to high contribution of few traits rather than small contribution of each trait. The positive and negative loadings showed positive and negative correlation trends between the component and variable. Thus, above mentioned characters which load high positively or negatively contributed to more diversity.

This suggests that these principal component scores might be used to summarize 17 variables in any further analysis of data. These findings confirm the suitability of using these traits as basis for selecting parental sources; however, studies for several years must be conducted before parental selection for possible plant breeding and will provide some guidance for screening of breeding resources for improving fruit quality and serve as a base for economically valuable phenotypes (Lal et al., 2017). The first group genotypes were superior in terms of fruit yield associated traits whereas the second group genotypes were superior in fruit peel colour and quality attributes, respectively.

These results corroborate with the findings of Lopez et al. (1997) and Kundu et al. (2013) in mango. The current findings shall be useful for detecting phenotypic differences among the mango genotypes. It further assists the breeders in selecting the most diverse mango accessions (Pusa Arunima, Pusa Shresth, Pusa Lalima, Mallika, Ramkela, Amrapali, Extreema, Neelum, Gulab Jamun, S.B. Alibagh, Tommy Atkins and Primor-de-

Amoreira) with improved fruit quality and yield related traits to begin crossing for obtaining progeny with enhanced desired traits.

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References

- AOAC: Official Methods of Analysis. 16th Edn., Association of Official Analytical Chemists, Arlington, Virginia, USA (1994).
- Anila, R. and T. Radha: Physico-chemical analysis of mango varieties under Kerala conditions. *J. Trop. Agri.*, **41**, 20-22 (2005).
- Arunachalam, V.: Genetic distances in plant breeding. *Indian J. Genet. Plant Breed.*, **41**, 226-36 (1981).
- Barhate, S.G., S. Balasubramanyam, R.R. Bhalerao and P. P. Bhalerao: Genetic diversity in mango (*Mangifera indica* L.) genotypic and phenotypic characterization. *Int. J. Plant Sci.*, **7**, 85-89 (2012).
- Barholia, A.K. and S. Yadav: Fruit quality characters and their relation with weight per fruit in mango over years. *Orient. J. Chem.*, **30**, 34-39 (2014).
- Barua, H., M.M.A. Patwary and M.H. Rahman: Performance of Bari mango (*Mangifera indica* L.) varieties in Chittagong region. *Bangladesh J. Agril. Res.*, **38**, 203-209 (2013).
- Bhowmik, N. and B. C. Banik: Genetic variability and correlation studies for fruit physico-chemical properties of some mango cultivars grown under new alluvial zone of West Bengal. *The Asian J. Hort.*, **3**, 346-349 (2008).
- Bora, L., A.K. Singh and C.P. Singh: Characterization of mango (*Mangifera indica* L.) genotypes based on physio-chemical quality attributes. *J. App. Nat. Sci.*, **9**, 2199-2204 (2017).
- Chahal, G.S. and S. S. Gosal: Principles and procedures of plant breeding: Biotechnological and conventional approaches. Alpha Science International, Harrow, UK, p. 604 (2002).
- Dinesh, M.R., K.V. Ravishankar, B. Sthapit, V.A. Parthasarathy, B.S. Sandya, P. Nischita and B. Lavanya: Genetic diversity studies in certain indigenous mango (*Mangifera indica* L.) varieties. *Indian J. Plant Genet. Resour.*, **28**, 153-160 (2015).
- Gill, M.S. and N. Singh: Genetic parameters, character association and path analysis for fruit yield and its component characters in mango (*Mangifera indica* L.). *Indian J. Plant Genet. Resour.*, **28**, 292-295 (2015).
- Gomez, K.A. and A.A. Gomez: Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., N.Y., U.S.A. (1984).
- Jilani, M. S., F. Bibi, K. Waseem and M.A. Khan: Evaluation of physico-chemical characteristics of mango (*Mangifera indica* L.) cultivars grown in D.I. Khan. *J. Agri. Res.*, **48**, 201-207 (2010).
- Kaur, M., J.S. Bal, L.K. Sharma and S.K. Bali: An evaluation of mango (*Mangifera indica* L.) germplasm for future breeding programme. *African J. Agric. Res.*, **9**, 1530-1538 (2014).
- Khush, G.S.: Molecular genetics-plant breeder's perspective: In Molecular Techniques in Crop Improvement (Eds.: S.M. Jain, D.S. Brar and B.S. Ahloowalia). Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 1-8 (2002).
- Krishnapillai, N. and R.S.W. Wijeratnam: Morphometric analysis of mango

- varieties in Sri Lanka. *Aus. J. Crop Sci.*, **10**, 784-792 (2016).
- Kostermans, A.J.G.H. and J.M. Bompard: The mango: Their Botany, Nomenclature, Horticulture and Utilization. Academic Press Ltd., London (1993).
- Kumar, D.: Effect of post-harvest treatment on shelf-life and quality of mango. *Indian J. Hort.*, **55**, 134-138 (1998).
- Kundu, S., N. Sanyal, D. Mazumdar, P. Datta and B. Ghosh: Characterization and evaluation of some superior lesser-known cultivars of mango. *Acta Hort.*, **975**, 81-88 (2013).
- Lal, S., N. Ahmed, S.R. Singh, D.B. Singh, O.C. Sharma and R. Kumar: Variability of health and bioactive compounds in strawberry (*Fragaria x ananassa* Duch.) cultivars grown under an Indian temperate ecosystem. *Fruits*, **68**, 423-34 (2013).
- Lal, S., O.C. Sharma, D.B. Singh, S.A. Rather, B.A. Padder and I. Qureshi: Genetic divergence of horticultural traits among olive (*Olea europaea* L.) genotypes grown in temperate climate. *Int. J. Curr. Microbiol. App. Sci.*, **6**, 2120-2130 (2017).
- Lal, S., S.K. Singh, A.K. Singh, M. Srivastav, A. Singh and N.K. Singh: Character association and path analysis for fruit chromatic, physico-chemical and yield attributes in mango (*Mangifera indica*). *Indian J. Agric. Sci.*, **87**, 122-131 (2017).
- Lopez, V., O.V. Martinez and O.P. Lopez: Geographic differentiation and embryo type identification in *Mangifera indica* L. cultivars using RAPD markers. *Hort. Sci.*, **32**, 1105-1108 (1997).
- Majumder, D.A.N., M.A. Hassan, L. Rahim and M.A. Kabir: Correlation and path coefficient analysis of mango (*Mangifera indica* L.). *Bangladesh J. Agric. Res.*, **37**, 493-503 (2012).
- Majumder, D.A.N., M.A. Hassan, L. Rahim and M.A. Kabir: Genetic diversity in mango (*Mangifera indica* L.) through multivariate analysis. *Bangladesh J. Agric. Res.*, **38**, 343-353 (2013).
- Manchekar, M.D., M.A.N. Hegde, C.K. Venugopal and A. S. Byadg: Clonal variability studies in Alphonso mango (*Mangifera indica* L.) by genetic divergence (D^2) analysis. *Karnataka J. Agric. Sci.*, **24**, 490-492 (2011).
- Mem, T., F.K. Rimberia, A.B. Nyende and D. Sila: Morphological diversity of mango germplasm from the upper Athi river region of Eastern Kenya: An analysis based on non- fruit descriptors. *African J. Food Agri. Nutri. Dev.*, **16**, 10913-10935 (2016).
- Milošević, T., N. Milošević, I. Glišić and B. Krška: Characteristics of promising apricot (*Prunus armeniaca* L.) genetic resources in Central Serbia based on blossoming period and fruit quality. *Hort. Sci.*, **37**, 46-55 (2010).
- Nayak, D., A.K. Singh and M. Srivastava: Estimation of genetic parameters of fruit quality traits in mango hybrid population. *Indian J. Hort.*, **70**, 13-17 (2013).
- NHB: Indian Horticulture Database 2013. National Horticulture Board, Gurgaon, India (2014).
- Palaniswamy, K.P., C.R. Muthukrishnan and K.G. Shanmugavclu: Physico-chemical characteristics of some varieties of mango. *Ind. Food Packer*, **28**, 12-19 (1975).
- Pandey, G., D. Pandey, M. Tripathi, A. Singh and M. Mishra: Studies on bio-chemical profiling of Indian gooseberry (*Emblica officinalis*) for genetic diversity. *J. Environ. Biol.*, **37**, 179-184 (2016).
- Patel, M.C., B.N. Satodiya, H.R. Barot and D.A. Patel: Evaluation of mango (*Mangifera indica* L.) genotypes for fruit characters and quality attributes. *Int. J. Chem. Stud.*, **5**, 1843-1845 (2017).
- Rahaman, E.H., M.G. Rabbani and E.J. Garvey: Genetic diversity of sweet gourd through multivariate analysis. *Bangladesh J. Agril. Sci.*, **33**, 197-204 (2006).
- Rathore, H.A., T. Masud, T. Shammi and A.H. Soomro: Effect of storage on physico-chemical composition and sensory properties of mango (*Mangifera indica* L.) variety Dashehari. *Pakistan J. Nutr.*, **6**, 143-148 (2007).
- Rodríguez, C.R., V.H. Pleguezuelo, J.L. Durán Zuazo, M. Fernández, and D.F. Tarifa: Physico-chemical quality parameters of mango (*Mangifera indica* L.) fruits grown in a Mediterranean subtropical climate (SE Spain). *J. Agr. Sci. Tech.*, **14**, 365-374 (2012).
- SAS Institute: SAS Enterprise Guide, Version 9.3. SAS Inst., Cary, NC, USA (2012).
- Selvan, M.T., R. Singh and S.K. Singh: Physico-chemical characters of some newly evolved mango hybrids. *Indian J. Hort.*, **67** (Special Issue), 403-406 (2010).
- Sennhenn, A., K. Prinz, J. Gebauer, A. Whitbread, R. Jamnadass and K. Kehlenbeck: Identification of mango (*Mangifera indica* L.) landraces from Eastern and Central Kenya using a morphological and molecular approach. *Genet. Resour. Crop. Evol.* (2013) DOI 10.1007/s10722-013-0012-2.
- Sethi, S., M. Srivastav, D.V.K. Samuel, A.K. Singh, A.K. Dubey and G. Singh: Evaluation of newly developed mango (*Mangifera indica*) hybrids for their storage behavior and peel colour. *Indian J. Agric. Sci.*, **81**, 252-5 (2011).
- Shi, S., X. Ma, W. Xu, Y. Zhou, H. Wu and S. Wang: Evaluation of 28 mango genotypes for physio-chemical characters, antioxidant capacity and mineral content. *J. Appl. Bot. Food Qual.*, **88**, 264 - 273 (2015).
- Shinde, A.K., G.M. Waghmare and B.P. Patil: Exploring pollinizers for enhancing productivity in 'Alphonso' mango (*Mangifera indica*). *Indian J. Agric. Sci.*, **71**, 592-594 (2001).
- Singh, A., M. Tyagi and C.P. Singh: Studies on morphology and physical attributes of mango varieties. *Int. J. Curr. Microbiol. App. Sci.*, **6**, 2324-2330 (2017).
- Singh, V.K. and S. Kumari : Changes in biochemical and mineral constituents associated with jelly seed in mango (*Mangifera indica*) cv. Dashehari. *Indian J. Agric. Sci.*, **81**, 563-566 (2011).
- Singh, N., N. Jeerath, G. Singh and P.P.S. Gill: Physico-chemical characterization of unexploited mango diversity in sub-montane zone of Northern India. *Indian J. Plant Genet. Resour.*, **25**, 261-269 (2012).
- Singh, S. R., N. Ahmed, S. Lal, S. A. Ganie, M. Amin, N. Jan and A. Amin: Determination of genetic diversity in onion (*Allium cepa* L.) by multivariate analysis under long day conditions. *African J. Agril. Res.*, **8**, 5599-5606 (2013).
- Srivastava, S., A. D. Pathak, R. Kumar and B.B. Joshi: Genetic diversity of sugar beet genotypes evaluated by microsatellite DNA markers. *J. Environ. Biol.*, **38**, 777-783 (2017).
- Uddin, M.Z., M.A. Rahim, J.C. Barman and M.A. Wadud: A study on the physical characteristics of some mango germplasm grown in Mymensingh condition. *Int. J. Sustain. Crop Prod.*, **1**, 33-38 (2006).
- Vasugi, C., K. Sekar, M.R. Dinesh and R. Venugopalan: Studies on genetic divergence in unique indigenous mango accessions of Western Ghats. *Int. J. Cur. Res.*, **5**, 2494-2499 (2013).
- Verma, M.K., S. Lal, J.I. Mir, H.A. Bhat and M.A. Sheikh: Genetic variability among 'Kashmiri Nakh' pear (*Pyrus pyrifolia*): A local variety grown in North- Western Himalayan region of India. *African J. Biotechnol.*, **13**, 3352-3359 (2014).