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MORPHOMETRIC CHARACTERIZATION OF DIFFERENT MANGO VARIETIES CULTIVATED IN TEHSIL BERNALA DISTRICT BHIMBER AZAD KASHMIR, PAKISTAN

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Abstract

Mangifera indica L. is called king of fruits which provides lot of nutrients to human beings for better health. District Bhimber is a hub of different indigenous as well invasive varieties of Mango. In this analysis, seven local mango varieties (Langra, Moota, Peela, Kala, Sanduri, Khakharia and Gola) were explored for their morpho-genetic assessment by using numerical approaches. Results were expressed in form of dendrogram by using dedicated softwares i.e., MSVP and SPSS. The variety "Mota" was separated as one unit in cluster I while other six varieties were aggregated in cluster II. The varieties "Peela, Sanduri and Khakharia" were re-shuffled in sub-cluster "a" while three varieties "Gola, Kala and Langra" were grouped in sub-cluster "b". Two broad groups and various sub-clusters established due to genetic dissimilarities among Mango varieties. The variety "Mota" showed genetic distance (GD) of 5.7 from all other analyzed varieties. Other two varieties "Sandori and Khakharia" depicted most closeness with GD 1.9. After fruit ripening, quantity of each variety was also measured and it was found that "Mota" variety was better with 90 Kg/ft^2. Area wise analysis indicated that "Watala" area was more suitable for better growth and good yield of Mango due to better adaptability of climatic conditions and suitable soil texture. This research will be proved a good initial model data for researchers, horticulturist and agriculturist in future further study.

Key words: *Mangifera indica,* Genetic distance, Soil texture, Morphometric characters, Climatic conditions, Bhimber.

Introduction

Mango fruits have become a fundamental and important part of human diet as they are tasty and provide vitamins and also minerals which are much important for human health (Mumzuroglu *et al*., 2003). Mango (*Mangifera indica* L.), had given a famous name which is called as "King of the Fruits, and it has been reputable as a rising tropical celling foriegn crop, which is playing an important role in the economy of mango exporting countries. It is produced in almost more than ninety countries worldwide.

It is most famous fruit in the world (Karishna *et al*., 2009). Pakistan is producing approximately one million tons per year of mango and it is called the 5th largest mango producing country. Hence, Pakistan has a significant role in the world fruit market (Khan *et al*., 2015).

Major mango producing areas in Pakistan are Hyderabad, Multan, Mirpur, Sukkur Khas, Nawab Shah, Muzaffargarh, Faisalabad, Karachi and D.I. Khan (Jilani *et al*., 2010; Rajwana *et al*., 2011). Multan is called the heart of mango. It is the 6th largest city of mango production in Pakistan (Tahir *et al*., 2012).

Morphological characteristics of Mango have been playing pivotal role in study and cultivation of mango trees around the world. Similar work related to morphometric was conducted in Brazil which consisted on 103 morphometric characteristics of mango accessions grown in field germplasm of Embrapa and results outcomes were applied to help in the production of new mango varieties with better yield for Brazil (Ribeiro *et al*., 2013).

Mango trees are cultivated on a widespread soil range but it has such a nice production that derived from the drained sandy loam soil around 150 to 180 cm deep (Malik & Mitra, 2001). Soil type, climate, cultivar, planting distance, age of plants, including developmental stages and climate conditions are also play an important role in the yield of Mango (Gawankar *et al*., 2010 and Dhake *et al*., 2011).

Plantation of mango is taking place in more than 87 countries of the world, so it has his importance commercially in few countries and only around 3 percent of the world mango production is traded internationally. Its trade is increasing which is observed during recent years. World mango export has reached 912,853 metric tons annually with cost about US$ 543.10 million (Alam & Khan, 2003; Evans, 2008).

The demand for processed mango fruit has also increased worldwide beside the fresh mangoes. Processed fruit products include chutneys, puree and mango juice including mango drinks, mango flour and pickles are also produced. Ripe mango fruits are considered a delicacy around the world; and the un-marketable surplus is utilized for squashes including syrups, marmalades with jams, jellies and candies. Fine brushes are also produced by Mango stone fibers (Jilani *et al*., 2010).

Morphological properties like plant growth, tree height, canopy spread, bark characters, leaf thickness and color were assessed in previous studies (Joshi *et al*., 2013; Majumder *et al*., 2013). The performance of 10 mango varieties in a private mango orchard at Muzaffargarh District, Pakistan was elaborated by calculating the parameters included time of flowering, fruit weight, days to fruit maturity, days to fruit setting and yield (Iqbal *et al*., 2012). The genetic diversity based on morphological characters of 60 mango genotypes through principal component analysis (PCA) was catalogued into eight clusters (Majumder *et al*., 2013).

In Pakistan, 250 varieties are grown in different areas of the country. Most commonly grown varieties are "Chaunsa, Langra, Sindhri, Anwar Ratole, Fajri, Samar Bahisht, Shah Pan, and Sensation" (Dhake *et al*., 2011). Mango is an important fruit of tropics and milder sub-tropics. It is thought to be one of the most important fruit after citrus fruit.

Pakistan is situated in South Asia, with an area of 7,96,096 km^2 and it lies between 60^0 55' to 75^0 30' E longitude ranges from 0 to 8611m with mixture of climatic zones and a tremendous biodiversity of climatic zones (Barui and Ghosh,. 2002). Pakistan has landlocked soil, with mountainous ranges having adjustable climatic habitats. Average yield of mango is not really appreciable and the reason is negligence, carelessness and uneducated farmer's practices. It has also been attacked by different diseases and adverse climatic variations (Jiskani *et al*., 2007).

The present research work was conducted in Tehsil Bernala, District Bhimber of Azad Jammu and Kashmir (AJK). Barnala is a prominent destination and it is a business market point of whole Mirpur Division, AJK which combine both Mirpur and Bhimber consisting of 2526 Square kilometer. This sub- division is also very famous for mango fruit cultivation. In this tehsil Watala has very historical and indigenous mango varieties that were grown in pre-partition time of the sub-continent. Watala mango orchard is called "Raani ka Bagh" the garden of princess who was emperior of Dogra ruler.

The objectives of this research article were following: i) To measure morphometric characteristics of different local mango varieties grown naturally in forest areas of Tehsil Bernala, District Bhimber, AJK; ii) To explore genetic diversity of mango varieties by plotting dendrogram among different local mango varieties by cluster analysis and iii) To calculate yield of mango varieties for better assessment of their morphogenetic parameters and recommend the best Mango variety from the study area to grow better and propagate effectively in the area (Fig. 1).

Materials and Methods

Field survey: Survey of different mango fields were conducted during different seasons for observation of different morphological characteristics of local mango varieties. Some characteristics of different mango varieties were directly measured during field survey. These morpho-characterization supported for further analysis of genetic diversity among mango cultivars. The genetic variation of mango species explored in the form of dendrogram as mentioned in result section. After survey of field, samples of all observed mango varieties were collected for further studies in laboratory.

Collection of samples: The samples of Mango were collected and put in sterile polythene bags during the field survey. A semi-structured questionnaire was filled according to the local inhabitant's information and pre-tested with trained enumerators made accordingly. The mango data were also gathered through local farmer's interviews that supported the prepared questionnaire and field observations. It involved socio-economics, existing farmers' cultivars, pre- and post-production practices. These collected samples were brought to Department of Botany (Lab.), Mirpur University of Science and Technology, Bhimber Campus, AJK for further experimental work.

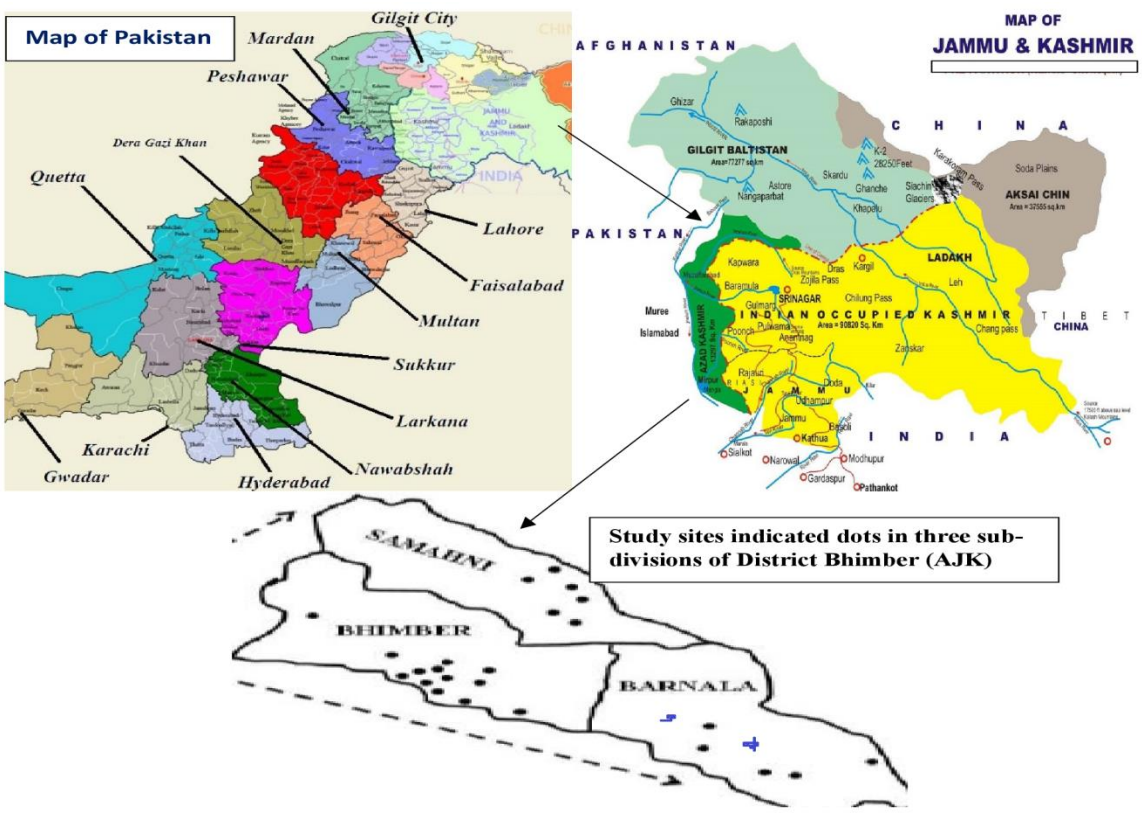

Fig. 1. Map of the District Bhimber, Azad Jammu and Kashmir Pakistan indicated study areas.

Measurement of morphometric characteristics in laboratory: The collected or preserved samples were further assessed by measurement of following morphometric characters which includes leaves width, leaves length including both petiole length and petiole width, more over rachis width and length by using a scale in centimeter. During morphometric investigation, replicated values were arranged in a table and then statistically evaluated by using a SPSS (Statistical Package for Social Sciences) (Malik & Raza, 1985).

Assessment of Genetic diversity among mango varieties: After complete morphometric analysis of each mango variety, genetic diversity among mango lines were explored and documented in the form of dendrogram. Cluster analysis was performed on the basis of squared Euclidean distance (ED) by Ward's method (WM) to form the distance matrix. The inter-cluster distance was also explored for the clustering (Khodadadi *et al*., 2011). This method joined the both clusters and reduced the sum of squared errors (SSE). In this way, different clusters were drawn in the dendrogram on the basis of morphometric characterizations of mango varieties. It was also followed to the Khan *et al*., (2015) protocol for dendrogram preparation with some modifications.

Results

Morphometric study of different varieties of Mango were assessed in three selected areas of Tehsil Bernala, District Bhimber, Azad Jammu and Kashmir (AJK). This investigation explored following characteristics as; petiole size, leaf length, leaf width, including fruit width, pulp thickness, fruit length, seed length, seed width, inflorescence length, inflorescence width, stem length, stem diameter and canopy size. This study is considered beneficial addition in genetic diversity knowledge about seven local varieties of mangoes in the study area (Goala, Sandoori, Kala, Khakria, Moota, Peela and Langra).

Morphometric characterization of Mango varieties from Watala: Morphometric study of different varieties showed significant difference among varieties grown in Watala area as observed in fruit width in Moota variety (20.5±0.31). Inflorescence of all Mango varieties also showed significant differences in three selected study areas. The maximum size of inflorescence was observed in Goola variety (22.2±0.11). Similarly, other varieties of Mango showed similar results. Kala variety also showed the maximum size of Inflorescences (21.1±0.13). Maximum canopy cover was also noted in Langara variety (2190±0.64) and minimum in Sandoori variety (1551±0.93). Highest fruit length was observed in Goala variety (8.7±0.21) and lowest in Kala variety (5.2±0.21). The maximum leaf length was noted in Moota variety (22.3±0.11) and minimum in Goola variety (18.7±0.41). The largest size of petiole length was noted in Kala variety (4.3±0.23) and lowest one in Langara (2.9±0.03). Similarly, other parameters involved in this study was also showed significant difference in all Watala areas of Bernala, AJK as mentioned in Table 1. These variations or diversity in varieties exhibited due to rich in nutrients soil, climatic variations and genetic diversity in the selected areas.

Morphometric characterization of Mango species presents in Bara: Morphomet-ric parameters of seven different local varieties of Mango species present in Bara area of sub-division Bernala was also analyzed and documented in Table 2. Morphometric characteristics of different varieties showed significant difference due to genetic diversity among varieties. Maximum fruit width was measured in Langra variety (19.6±0.19). The maximum size of inflorescence was also observed in Moota variety (26.3±0.12). Similarly, other varieties of the mangoes species show the same results. Maximum canopy cover was noted in Langra variety (2230±0.31) and minimum in Khakharia (1510±0.77). Highest fruit length was observed in Gola variety (9.3±0.20) and lowest in Kala (4.5±0.16). The maximum leaf length was noted in Langra variety (21.5±0.23) and minimum in Gola (18.1±0.20). Largest size petiole length was noted in Moota variety (4.3±0.21) and lowest one in Langra (2.8±0.05) an indicated in Table 2.

Table 1. Morphometric study for the analysis of genetic diversity of Mango varieties in Watala areas of Tehsil Bernala District Bhimber, Azad Kashmir.

Parameter	Quantitative analysis of morphometric characteristics of mango varieties						
	Gola	Sandoori	Khakharia	Langra	Peela	Kala	Moota
A1	4.2 ± 0.21	3.8 ± 0.93	3.4 ± 0.25	2.9 ± 0.03	3.7 ± 0.41	4.3 ± 0.23	4.1 ± 0.21
A2	18.7 ± 0.41	19.3 ± 0.14	20.2 ± 0.29	21.5 ± 0.21	20.3 ± 0.21	19.2 ± 0.34	22.3 ± 0.11
A3	5.2 ± 0.21	5.9 ± 0.17	4.2 ± 0.18	4.5 ± 0.07	3.93 ± 0.14	4.2 ± 0.08	5.7 ± 0.35
A4	8.7 ± 0.21	7.4 ± 0.11	6.4 ± 0.11	7.63 ± 0.32	6.2 ± 0.23	5.2 ± 0.21	6.16 ± 0.12
A5	14.5 ± 0.17	18.8 ± 0.12	18.6 ± 0.14	19.5 ± 0.12	16.2 ± 0.33	19.4 ± 0.11	20.5 ± 0.31
A6	2.0 ± 0.14	1.2 ± 0.05	1.6 ± 0.09	1.8 ± 0.08	1.6 ± 0.43	1.5 ± 0.09	2.1 ± 0.08
A7	6.8 ± 0.31	5.74 ± 0.09	5.03 ± 0.28	6.9 ± 0.03	3.31 ± 0.17	5.53 ± 0.08	3.5 ± 0.06
A8	20.8 ± 0.15	10.5 ± 0.16	11.3 ± 0.32	15.8 ± 0.12	11.4 ± 0.25	20.2 ± 0.31	8.9 ± 0.07
A9	22.2 ± 0.11	18.1 ± 0.19	16.5 ± 0.22	18.5 ± 0.19	17.3 ± 0.19	21.1 ± -0.13	20.2 ± 0.16
A10	23.9 ± 0.73	22.9 ± 0.31	27.1 ± 0.29	30.3 ± 0.2	31.6 ± 0.08	31.8 ± 0.71	35.0 ± 0.31
A11	208.9 ± 0.45	212.1 ± 0.97	233.6 ± 0.71	216.9 ± 0.93	232.4 ± 0.71	217.5 ± 0.31	241.9 ± 0.13
A12	243.4 ± 0.91	205.5 ± 0.85	230.5 ± 0.54	223.4 ± 0.97	243.6 ± 0.08	252.3 ± 0.83	207.5 ± 0.42
A13	1905 ± 0.71	1551 ± 0.93	1744 ± 0.41	2190 ± 0.64	1912 ± 0.75	1907.6 ± 0.32	1617.3 ± 0.31

Key: A1 = Petiol size, A2 = Leaf length, A3 = Leaf width, A4 = Fruit length, A5 = Fruit width, A6 = Pulp thickness A7 = Seed length, A8 = Seed width, A9 = Inflorescence length, A10 = Inflorescence width, A11 = Stem length, A12 = Stem diameter and A13 = Canopy size

Table 2. Morphometric study for the analysis of genetic diversity mangoes species Bara area of Tehsil Bernala, AJK.

Parameter	Quantitative analysis of morphometric characteristics of mango varieties						
	Gola	Sandoori	Khakharia	Langra	Peela	Kala	Moota
A1	3.9 ± 0.32	3.6 ± 0.08	3.3 ± 0.10	2.8 ± 0.05	4.2 ± 0.14	4.0 ± 0.13	4.3 ± 0.21
A2	18.1 ± 0.20	19.5 ± 0.12	20.1 ± 0.23	21.5 ± 0.23	18.7 ± 0.24	18.9 ± 0.31	20.7 ± 0.11
A3	5.4 ± 0.25	5.6 ± 0.14	4.0 ± 0.11	4.6 ± 0.08	4.3 ± 0.18	4.0 ± 0.08	5.3 ± 0.17
A4	9.3 ± 0.20	8.2 ± 0.08	5.5 ± 0.11	8.3 ± 0.13	6.2 ± 0.25	4.5 ± 0.16	6.5 ± 0.24
A5	13.1 ± 0.34	16.4 ± 0.12	18.5 ± 0.17	19.6 ± 0.19	15.7 ± 0.21	19.6 ± 0.11	20.5 ± 0.31
A6	2.2 ± 0.21	1.2 ± 0.33	1.7 ± 0.23	1.8 ± 0.83	1.7 ± 0.41	1.6 ± 0.32	2.1 ± 0.08
A7	7.2 ± 0.18	5.33 ± 0.03	5.5 ± 0.31	7.53 ± 0.71	5.50 ± 0.05	5.6 ± 0.06	4.5 ± 0.01
A8	11.6 ± 0.71	10.5 ± 0.12	10.3 ± 0.46	11.3 ± 0.11	8.3 ± 0.41	12.4 ± 0.12	8.4 ± 0.08
A9	24.1 ± 0.14	19.9 ± 0.12	15.6 ± 0.12	18.3 ± 0.14	17.2 ± 0.13	19.7 ± 0.53	26.3 ± 0.12
A10	26.9 ± 0.93	23.2 ± 0.15	27.7 ± 0.22	29.6 ± 0.23	31.7 ± 0.19	34.0 ± 0.71	35.3 ± 0.31
A11	203.3 ± 0.34	215 ± 0.27	235.6 ± 0.7	212 ± 0.21	252 ± 0.44	216.6 ± 0.31	240.1 ± 0.12
A12	236.6 ± 0.91	203.6 ± 0.37	233.3 ± 0.5	220.3 ± 0.15	271.6 ± 0.81	250.3 ± 0.17	264.6 ± 0.13
A13	1850 ± 0.71	1545 ± 0.77	1510 ± 0.77	2230 ± 0.31	1858 ± 0.91	1914 ± 0.31	1541 ± 0.31

Key: A1 is Petiol size, A2 is leaf length, A3 is leaf width, A4 is fruit length, A5 is fruit width, A6 is pulp thickness A7 is seed length, A8 is seed width, A9 inflorescence length, A10 inflorescence width, A11 is stem length, A12 stem diameter, and A13 is canopy size

Table 3. **Morphometric study for the analysis of genetic diversity mangos species Kadhala area of tehsil Bernala, AJK.**

Parameters	Quantitative analysis of morphometric characteristics of mango varieties						
	Gola	Sandoori	Khakharia	Langra	Peela	Kala	Moota
A1	4.4 ± 0.26	3.4 ± 0.12	2.9 ± 0.53	2.6 ± 0.05	3.3 ± 0.22	4.4 ± 0.27	4.2 ± 0.15
A2	18.1 ± 0.49	17.4 ± 0.14	18.3 ± 0.35	19.3 ± 0.21	22.3 ± 0.21	17.3 ± 0.62	22.7 ± 0.21
A3	4.9 ± 0.24	5.36 ± 0.08	3.7 ± 0.15	3.7 ± 0.01	3.8 ± 0.12	3.5 ± 0.19	5.6 ± 0.29
A4	8.2 ± 0.14	6.6 ± 0.12	7.2 ± 0.15	6.90 ± 0.21	7.13 ± 0.08	6.1 ± 0.08	5.3 ± 0.15
A5	15.8 ± 0.15	20.6 ± 0.17	16.5 ± 0.20	18.2 ± 0.15	17.9 ± 0.81	21.6 ± 0.16	20.8 ± 0.12
A6	1.8 ± 0.82	1.0 ± 0.76	1.3 ± 0.20	1.6 ± 0.02	2.0 ± 0.07	1.9 ± 0.02	1.7 ± 0.08
A7	6.6 ± 0.21	5.76 ± 0.08	4.7 ± 0.15	6.3 ± 0.25	3.2 ± 0.19	4.5 ± 0.34	3.1 ± 0.05
A8	13.6 ± 0.20	9.83 ± 0.03	12.4 ± 0.22	14.1 ± 0.05	14.16 ± 0.71	13.4 ± 0.42	9.1 ± 0.59
A9	25.1 ± 0.29	15.7 ± 0.12	17.9 ± 0.15	17.4 ± 0.15	18.7 ± 0.41	23.2 ± 0.72	26.7 ± 0.21
A10	20.43 ± 0.76	19.3 ± 0.14	24.3 ± 0.21	27.4 ± 0.17	33.1 ± 0.15	29.5 ± 0.91	32.5 ± 0.41
A11	214.3 ± 0.34	179.0 ± 0.93	208.0 ± 0.86	201.6 ± 0.91	231 ± 0.72	192.6 ± 0.21	216.6 ± 0.72
A12	223.3 ± 0.59	183.3 ± 0.32	184.3 ± 0.22	191.6 ± 0.95	250.0 ± 0.32	231.0 ± 0.91	224.3 ± 0.51
A13	1661.6 ± 0.87	1388 ± 0.54	1675 ± 0.29	1997 ± 0.02	1858 ± 0.92	1803 ± 0.92	1583 ± 0.72

Key: A1 is Petiol size, A2 is leaf length, A3 is leaf width, A4 is fruit length, A5 is fruit width, A6 is pulp thickness A7 is seed length, A8 is seed width, A9 inflorescence length, A10 inflorescence width, A11 is stem length, A12 stem diameter, and A13 is canopy size

Morphometric characterization of Mango in Kadhala area: The same morphometric characters of different varieties of Mango species were also explored in Bara area of Sub-division Bernala. Hence, this morphometric study depicted genetic diversity among seven varieties of mango in selected areas. It was statistically observed that all morphometric characters showed significant difference as observed in fruit width in Kala variety (21.6±0.16). The highest size of inflorescences was also observed in Moota variety (26.7±0.21). Similarly, other varieties of the mangoes species show the same results. Maximum canopy cover was measured in Langra variety (1997±0.02) and minimum in Sandoori (1388±0.54). Highest fruit length was observed in Gola variety (8.2±0.14) and lowest in Kala (6.1±0.08). The maximum leaf length was noted in Moota variety (22.7±0.21) and minimum in Kala (17.3±0.62). Largest size petiole length was noted in Kala variety (4.4±0.27) and lowest one in Langra (2.6±0.05) as shown in Table 3.

Cluster analysis for morphogenetic diversity of mangoes varieties: Cluster analyses of seven varieties of the genus Mangifera were documented. For this examination morphological features (petiole size, leaf length, leaf width, fruit length, fruit width, pulp thickness, seed length, seed width, inflorescence length, inflorescence width, stem length, stem diameter, canopy size) were used and documented on the basis of multistate variables. In all cases, the quantitative characters were recorded in multiple states. And all these multiple state characters were recorded as numbering from 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12 and 13. The numerical analysis for genetic diversity was performed by using the classical unweighted pair-group method with the computer package Statistical Product and Service Solutions (SPSS). Each of the variety was treated as outfitted genetic diversity unit. The multistate variables for the morphometric data of mango varieties for cluster analysis indicated in Table 4.

Genetic diversity for morphometric data of Mango varieties: The morphometric traits of mango varieties are classified in two main clusters on the basis of multivariate states. All the different clusters members for different varieties were described briefly in Fig. 2. Cluster I has two sub-clusters, sub-cluster Ia and Ib. Sub-cluster Ia contained 3 varieties Khakharia, Sandoori and Peela, sub-cluster Ib also contained three mango varieties Langra, Kala and Gola. Cluster II contain only one variety 'Moota'.

Table 4. **Parameters and multiple states used in cluster analysis for morphogenetic diversity of mangoes based on morphological data.**

S. No.	Parameters	Codes for numerical values
1.	A1	0-1= (0); 1.1-2=1; 2.1-3=(2); 3.1-4= (3); 4.1-5; (4); 5.1-6=(5); 6.1-7=(6)
2.	A2	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8)
3.	A3	0-1= (0); 1.1-2=(1); 2.1-3=(2); 3.1-4= (3); 4.1-5; (4); 5.1-6=(5); 6.1-7=(6)
4.	A4	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8)
5.	A5	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8)
6.	A6	0-1= (0); 1.1-2=(1); 2.1-3=(2); 3.1-4= (3); 4.1-5; (4); 5.1-6=(5); 6.1-7=(6)
7.	A7	0-1= (0); 1.1-2=(1); 2.1-3=(2); 3.1-4= (3); 4.1-5; (4); 5.1-6=(5); 6.1-7=(6); 7.1-8(7)
8.	A8	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8); 27.1-30(9); 30.1-33(10)
9.	A9	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8)
10.	A10	1-3=(0); 3.1-6=(1); 6.1-9=(2); 9.1-12=(3); 12.1-15=(4); 15.1-18=(5); 18.1-21=(6); 21.1-24=(7); 24.1-27=(8); 27.1-30=(9); 30.1-33=(10); 33.1-36=(11)
11.	A11	0-50=(0); 50.1-100=(1); 100.1-150=(2); 150.1-200=(3); 200.1-250=(4); 250.1-300=(5)
12.	A12	0-50=(0); 50.1-100=(1); 100.1-150=(2); 150.1-200=(3); 200.1-250=(4); 250.1-300=(5)
13.	A13	0-50=(0); 50.1-100=(1); 100.1-150=(2); 150.1-200=(3); 200.1-250=(4); 250.1-300=(5); 1201-1400=(6); 1401-1600=(7); 1601-1800=(8); 1801-2000=(9); 2001-2200=(10); 2201-2400=(11); 2401-2600=(12)

Key: A1 is Petiole size, A2 is leaf length, A3 is leaf width, A4 is fruit length, A5 is fruit width, A6 is pulp thickness A7 is seed length, A8 is seed width, A9 inflorescence length, A10 inflorescence width, A11 is stem length, A12 stem diameter and A13 is canopy size

Average linkage distance among selected areas of morphological data: The tree diagram based on three area of mango varieties are described in Fig. 2. The figure showed the two main clusters at the linkage value of distance of 5.8. The clusters are named as cluster I and cluster II. Cluster I is further classified into two sub-clusters Ia and Ib. Sub-clusters Ia consist of three mango varieties Khakharia, Sandoori, Peela and sub-clusters Ib also consist of three varieties Langra, Kala and Gola. While the cluster II consist of only one mango variety Moota and was an outlier and showed variation. In this group both species were at the same linkage distance (4.6) and showed similarity in response to morphological traits.

Genetic diversity for morphometric data of Mango varieties from Watala: The morphometric traits of mango varieties are classified in two main clusters on the basis of multivariate states. All the different clusters members for different varieties were described briefly in Fig. 3. Cluster I contain only one member Peela. Cluster II has two sub-clusters, sub-cluster IIa and sub-cluster IIb. Sub-cluster IIa contain 3 varieties Langra, Kala and Gola, sub-cluster IIb also contain three mango varieties Khakharia, Sandoori and Moota.

Average linkage distance among Watala area of morphological data: The tree diagram based on three area of mango varieties are described in Fig. 3. The figure showed the two main clusters at the linkage value of distance of (5.2). The clusters are named as cluster I and cluster II. The cluster I consists of only one mango variety Peela and was an outlier and showed variation while Cluster II is further classified into two sub-clusters IIa and IIb. Sub-clusters IIa consist of three mango varieties Langra, Kala and Goola and sub-clusters IIb also consist of three varieties Khakharia, Sandoori, Moota. In this group both species were at the same linkage distance (5.0) and showed similarity in response to morphological traits.

Genetic diversity for morphometric data of Mango varieties from Bara area: The morphometric traits of mango varieties are classified in two main clusters on the basis of multivariate states. All the different clusters members for different varieties were described briefly in Fig. 4. Cluster I has two sub-clusters, sub-cluster Ia and sub-cluster Ib. Sub-cluster Ia contain 2 varieties Langara and Sandhoori and sub-cluster Ib contain four mango varieties Khakharia, Kala, Peela and Gola. Cluster II contain only one member Moota.

Average linkage distance among selected areas of morphological data: The tree diagram based on three area of mango varieties are described in Fig. 4. The figure showed the two main clusters at the linkage value of distance of (5.7). The clusters are named as cluster I and cluster II. Cluster I is further classified into two sub-clusters Ia and Ib. Sub-clusters Ia consist of two mango varieties Langra and Sandoori and sub-clusters Ib also consist of three varieties Khakharia, Kala, Peela 99999 Gola. While the cluster II consist of only one mango variety Moota and was an outlier and showed variation. In this group both species were at the same linkage distance (4.3) and showed similarity in response to morphological traits.

Genetic diversity for morphometric data of Mango varieties from Kadhala: The morphometric traits of mango varieties are classified in two main clusters on the basis of multivariate states. All the different clusters members for different varieties were described briefly in Fig 5. Cluster I have two sub-clusters, sub-cluster Ia and sub-cluster Ib. Sub-cluster Ia contain 1 variety Gola and sub-cluster Ib also contain only one variety Sandhoori. Cluster II also have two sub-clusters, sub-cluster IIa and sub-cluster IIb. Sub-cluster IIa contain 2 varieties Kala and Mota and sub-cluster IIb consist of 3 varieties Khakharia, Langra and peela.

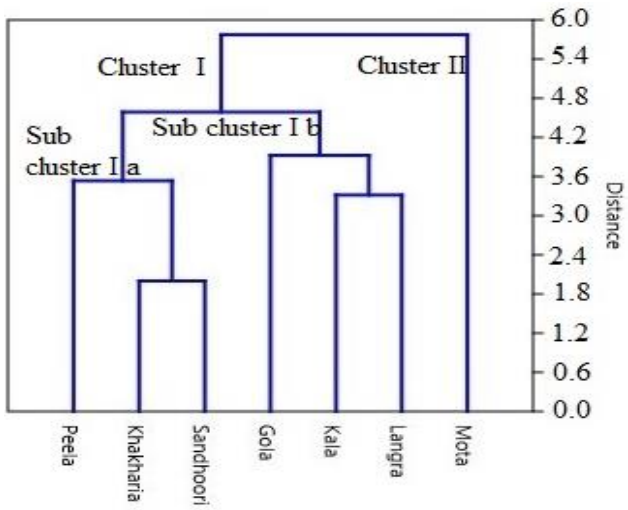

Fig. 2. Dendrogram based on average linkage distance of different varieties from selected areas of Barnala on the basis of morphometric data.

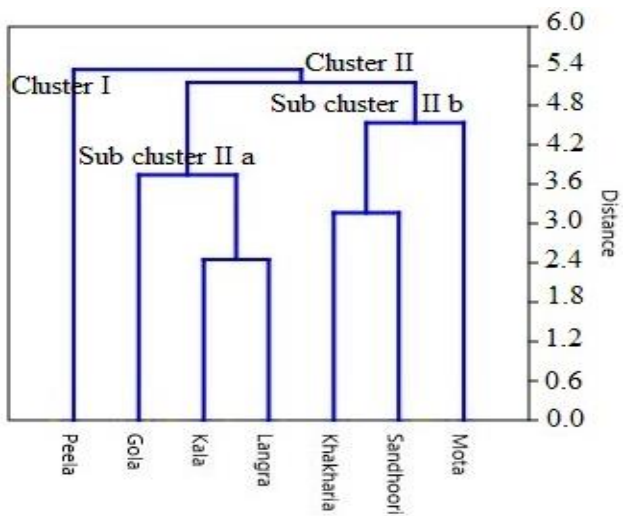

Fig. 3. Dendrogram based on average linkage distance of different varieties from Watala area of sub-division Barnala on the basis of morphometric data.

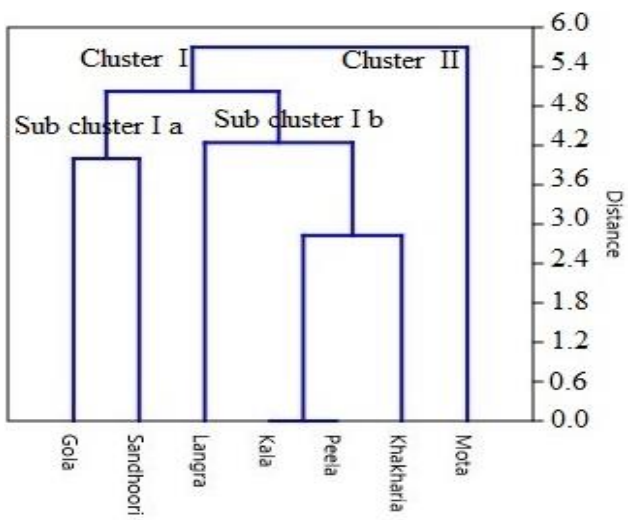

Fig. 4. Dendrogram based on average linkage distance of different varieties from Bara area on the basis of morphometric data.

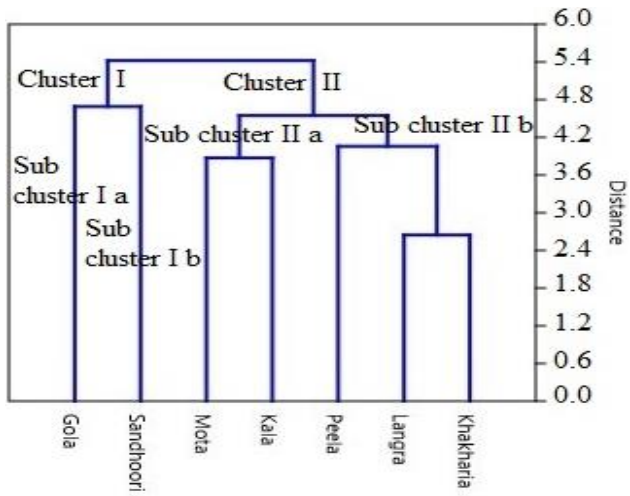

Fig. 5. Dendrogram based on average linkage distance of different varieties from Kadhala area on the basis of morphometric data.

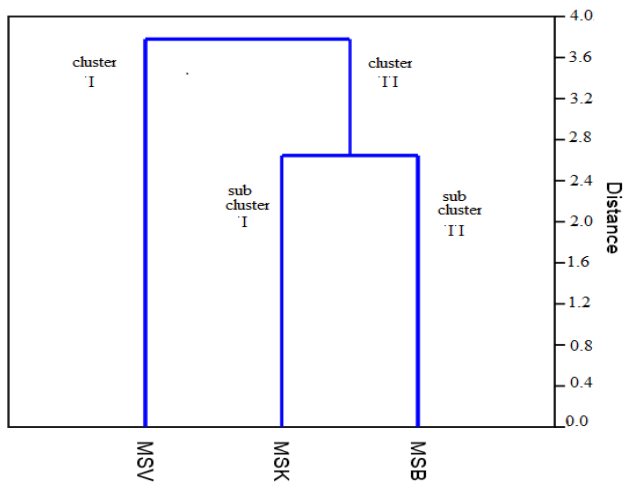

Fig. 6. Comparative assessment dendrogram based on average linkage distance of different varieties in three selected areas of sub-divisions Barnala.

Average linkage distance among selected areas of morphological data: The tree diagram based on three areas of mangoes varieties are described in Fig. 5. The figure showed the two main clusters at the linkage value of distance of (5.4). The clusters are named as cluster I and cluster II. Cluster I is further classified into two sub-clusters Ia and Ib which contain two varieties Sandhoori and Gola. Cluster II also consist two sub-clusters IIa and IIb which contain five mango varieties Langra, Kala, Mota, Khakharia, and Peela.

Comparative cluster analysis of Mango varieties from three selected areas of sub-division Barnala on basis of morphogenetic diversity: The morphometric traits of mango Varieties are classified in two main clusters on the basis of multivariate states. Different clusters members for different varieties were described in Fig. 5. Cluster I contains only mango varieties collected from area MSV (Mango Sample of Vatala) while cluster II included of two areas MSB (Mango Sample of Bara) and MSK (Mango Sample of Kadhala).

Average linkage distance among three different areas of morphological data: The tree diagram based on three area of mango varieties is displayed in Fig. 6. The figure indicated two main clusters at linkage distance 3.8. The clusters are named as cluster I and cluster II. Cluster I consist of only one study area for mango varieties and was an outlier and showed variation. While the cluster II is further classified into two sub-clusters I and II. Sub-cluster I consist of MSB, whereas sub-cluster II is consist of MSK. In this group both species were at the same linkage distance (2.7) and showed similarity in response to morphological traits.

Discussion

This study elaborated the morphometric characteristics of endemic Mango varieties grown in three different areas of Tehsil Bernala, District Bhimber, Azad Jammu and Kashmir (AJK). This morphometric analysis among different varieties of Mango were performed by measuring 13 growth parameters which included petiole size, leaf length, leaf width, fruit length, fruit width, pulp thickness, seed length, seed width, inflorescence length, inflorescence width, stem length, stem diameter and canopy size. Morphometric characterizations of mango varieties were also assessed by Ribeiro *et al*., (2013). This study was further helped for analysis of genetic diversity of seven Mango varieties named as; goala, sandoori, kala, khakria, moota, peela and langra in different regions of Tehsil Bernala, AJK, Pakistan.

The morphometric data was subjected to statistical analysis, as the morphometric characters of different varieties showed significant difference in fruit width of Moota varieties. The maximum size of inflorescences was appeared against Gola and Kala varieties. Highest canopy cover was found in Langara variety and minimum in Sandhoori. Highest fruit length was observed in Gola variety and lowest in Kala. The maximum leaf length was noted in Moota variety and minimum in Goola. Largest petiole length was noted in Kala variety and lowest one in Langara. These findings also depicted that the suitable environmental factors like hot and dry aero-temperature supported to these varieties for high growth and better indications in morphological parameters (Rymbai *et al*., 2014). Some varieties did not adjust on these conditions. Therefore, they may be express adverse readings or minimum improvement in morpho-characterization. These results were found to be much similar with the studies of Das and Nath, (2016); Majumder *et al*., (2013).

Cluster analysis showed that Moota variety of selected areas is best suited in the study area due to better genetic makeup. Peela variety is also best suited in Vatala area as indicated in cluster analysis. Similarly, cluster analysis was also elaborated that Mota variety is best fit in Bara area. Sandhoori and Goola varieties have good characters in Kadhala area. These findings showed that it may be due to better climatic conditions present in those areas or good soil texture which boost up mango growth and their adoptability. These results were supported by Jiskani *et al*., (2007). It was observed that the texture of soil of Vatala is Sandy loam, soil of Bara is clay loam and soil of Kadhala is loam which may support to grow better different Mango varieties. These findings were positively correlated with Islam *et al*., (2019).

Minerals rich soil also promoted growth characteristics and better fruits production of mango varieties (Arshad *et al*., 2021). It was observed in many previous studies that phosphorus, nitrogen and potassium are best for the growth of Mango varieties. These findings were suppo9rted by Malik & Mitra, (2001). Area vise observation indicated that Vatala area have its maximum concentration as compared to the other areas that is why it is declared as best for mango cultivation. These findings were correlated and justified by Maqsood *et al*., (2020); Zafar & Sidhu (2017). Morphometric characteristics of Mango varieties were also measured in Sri Lanka (Krishnapillai & Wijeratnam, 2016) which strongly supported our findings.

It was observed that the entire tree diagram based on three areas of mango varieties is displayed in Fig. 5 which indicated two main clusters at very close linkage distance. The same linkage distance showed similarity in response to morphological traits. These findings were strongly supported by Malik & Mitra, (2001); Dhake *et al*., (2011); Koursar & Batti, (2021). Overall, it was observed that all mango varieties have closely similar morphometric characteristics.

Conclusion

It was concluded from the present study as; Moota variety of mango was considered best and suitable for cultivation and propagation in the areas of Barnala while Bara and Peela mango varieties were best suited in Vatala area. The Sandhoori and Gola varieties were exhibited better growth and production in Kadhala area due to suitable climatic and soil conditions. Overall, it is declared that Mango in Vatala area was grown best for their cultivation. Morphometric characterization assessment explored knowledge of different indigenous Mango varieties for manipulation and awareness among peoples living in surrounding vicinity. The cluster analysis was explored the history of mango varieties.

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