MORPHOLOGICAL CHARACTERIZATION OF PAKISTANI MANGO (*Mangiferaindica*L.) VARIETIES USING PRINCIPAL COMPONENT ANALYSIS

H. Mukhtar, *M. Arifand F. Khan,

Botany Department, Lahore College for Women University, Jail Road, Lahore; *National Institute of Biotechnology and Genetic Engineering, Jhang Road, Faisalabad,Pakistan.
Corresponding author e-mail: drfarah_khann@yahoo.com

ABSTRACT: The morphological data of mango varieties was provided by Shujabad mango research center. The point of present study was to evaluate diversity and grouping pattern of the mango varieties and traits. A total of 36 morphological characters were considered.Twenty fourqualitative traits fromtree(4), leaves (5), inflorescences (4), fruits and seeds (11) were included. Twelve quantitative traitsfrom leaf(2),flower and seed(10) were selected.Principal component analysis (PCA) was done by XLSTAT.Fifteen fruit traits and four leaf traits were used to index mango morphology.The first three principal components clarified 34%of variation and identified fruit/stone traits especially the fruit length, fruit thickness and fruit width, fiber length, total soluble salts (TSS), leaf colour, twisting of leaf blade as important traits that could be used to categorize mango varieties.Fajri Kalan, Sindhri and Chaunsasufaidwere conspicuous due to highest fruit weight, stone thickness, fruit thickness and fruit length. The high morphological diversity within the mango varieties could prove to be helpful in their identification and categorization

Key words: Principal component analysis, twisting, Quantitative Traits and Qualitative Traits.

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INTRODUCTION

In Pakistan the area under Mango cultivation is 175 thousand hectares with a production of 1,784 thousand tonnes. Mango is the second major fruit crop of Pakistan which produces 8.5% of world's Mango(Govt. of Pakistan 2015). There is a dire need to characterize Pakistani mango varieties to compete in the global market. It is an important tool for improvement and breeding of mango in evolving new varieties. Morphological and bio-chemical description of mango is difficult and has never been addressed properly. (Rajwana*et.al.*,2011).

Numerousmeasures for the documentation and characterization of mango varieties have been establishedon the basis of fruit morphological traits. Morphological characteristics are used as landmark to improve mango varieties(Jaramillo and Baena, 2000). Mango is a perennial crop having a long juvenile period;it is always very difficult to identify a cultivar at the initial stage of plant growth. If problem of proper identification issolved then it will make the mango improvement much easier. Morphological characters on the other hand, have great role for the identification of different cultivars (Joshi*etal.*, 2012). Fruit shape is a very prominent morphological character which influences the choice of consumers (Seyif and Rashidi, 2007). Fruit size and weight areimportant economical parameters too (Sinnott, 1932). A universally accepted procedure has been developed for characterization of mango varieties by the International Plant Genetic Resources Institute (IPGRI). The IPGRI has a recognized and universal format of list of descriptors for mango that comprisesof the morphological traits of plant, flowers, leaves, seeds and fruits (Krishnapillai andWijeratnam, 2016).The morphological data of the mango varieties would be subjected to PCA in order to handle huge data properly. The target of present study was to provide a list of Morphological traits that could be used to identify mango varietiesat vegetative stage as well as to identify the mango fruit, depending upon the particular fruit characteristics.

MATERIALS AND METHODS

The morphological data of 46 Pakistani mango varieties was collected from the Shujabad Mango research center. Out of 36 morphological characters, 24 were qualitative while 12 were quantitative character. Qualitative characters included the Trees (tallness, vigour, branching and spreading), leaves (colour, shape, fragrance, tip shape and twisting of blade), inflorescence(length, branching, stalk colour and flower colour), fruits(beak, sinus, prescence of fiber, length of fiber, yield, peel colour and shape in cross section)traits.Quantitative characters were leaf (length and width), percent acidity, TSS, stone (length, thickness, width and average weight), fruit(length, width, thickness and average weight) traits,werecategorized and rated numerically(Table 1)

Table 1.Numerical Rating of the Qualitative Traits.

				TREE MORPHOLOGY					
1				**TALLNESS**					
	Categories	Short		Medium		Tall			
	Rating	1		2		3			
2				**VIGOR**					
	Categories	Low		Moderate		Good		Well	
	Rating	1		2		3		4	
3				**BRANCHING**					
	Categories	Medium		Good		Well			
	Rating	1		2		3			
4				**SPREADING**					
	Categories	Semi		Spreading		Good		Well	
				LEAF MORPHOLOGY					
1				**COLOUR**					
	Categories	YG	LG		MG	DG			
	Rating	1	2		3	4			
2				**SHAPE**					
	Categories	Elliptical	Oblong						
	Rating	1	2						
3				**FRAGRANCE**					
	Categories	Absent	Present		Weak	Medium	Acute	Strong	
	Rating	1	2		3	4	5	6	
4				**TIP SHAPE**					
	Categories	Attenuate	Acuminate		Acute				
	Rating	1	2		3				
5				**TWISTING OF BLADE**					
	Categories	Absent	V.Weak		Weak	Slight	Medium	Present	
	Rating	1	2		3	4	5	6	
	Rating	1	2			3		4	

(YG= yellowish green, LG= Light green, MG=Medium Green, DG=Dark green, V.weak= Very weak.)

				INFLORESCENCE MORPHOLOGY						
1				**LENGTH**						
	Categories	Short	Medium	Long	V.Long					
	Rating	1	2	3	4					
2				**BRANCHING**						
	Categories	Less	Medium	Profuse						
	Rating	1	2	3						
3				**STALK COLOUR**						
	Categories	GW	GY	LG	LP	MP	P	BP	DP	PR
	Rating	1	2	3	4	5	6	7	8	9
4				**FLOWER COLOUR**						
	Categories	OW	GW	LG	G	LP	YP	P	MP	DP
	Rating	1	2	3	4	5	6	7	8	9

(V= very, GW= greenish white, GY= greenish yellow, LG= light green, LP= light pink, MP= medium pink, P=pink, BP= blush pink, DP= dark pink,PR=peachred,OW=offwhite,G=Green,YP=yellowishpink,DP=darkpink)

1	FRUIT MORPHOLOGY								FRUIT BEAK							
	Categories	**Absent**	**Almost absent**	**Weak to absent**	**Weak**	**Not prominent but pointed**	**Medium to weak**	**Short to medium**	**Short**	**Very short**	**Medium but obtuse**	**Medium**	**Rounded**	**Present**	**Broadly pointed**	**Prominent**
	Rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	**SINUS OF FRUIT**															
	Categories	Absent	Absent to weak	Very weak	Weak	Present	Slight	Slight to medium	Medium to strong	Medium	Strong					
	Rating	1	2	3	4	5	6	7	8	9	10					
3	**SKIN THICKNESS**															
	Categories	Thin	Medium	Thick												
	Rating	1	2	3												
4	**PRESCENCE OF FIBER**															
	Categories	Absent	Few	Rare	Very rare	Low	Medium	Medium to high	High	Abundant						
	Rating	1	2	3	4	5	6	7	8	9						
5	**LENGTH OF FIBER**															
	Categories	Absent	Very short	Short	Medium	Medium long	Long									
	Rating	1	2	3	4	5	6									
6	**FRUIT YEILD**															
	Categories	Low	Medium	Good	Very good											
	Rating	1	2	3	4											

7	**PEEL COLOUR**																	
	Categories	LY	PY	Y	LEY	MY	CY	CAY	GY	YG	PIY	YGP	YR	PYLPB	YGL	PYLPT	LEYPT	YRB	LYRB
	Rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
8	**FRUIT SHAPE IN CROSS SECTION**																	
	Categories	C.	OV	OV.round	OB.ovate	OV. oblong	OB	OBL. round	Oval OBL.	OBL. oval	OBL.oblong	OV.to OBL.	OB.to OBL. oval	BR.OBL. round					
	Rating	1	2	3	4	5	6	7	8	9	10	11	12	13					

(LY= light yellow, PY=pale yellow, Y= yellow, LEY= lemon yellow, MY= maize yellow, CY= cadmium yellow, CAY= canal yellow, GY= greenish yellow, YG= yellowish green, PIY= pinkish yellow, YGP= yellowish green with pinkish blush, YR= yellow with red, PYLPB = pale yellow with light pink blush, YGL= yellowish green with light blush, PYLPT= pale yellow with light pink tinge, LEYPT= lemon yellow with pink tinge, YRB= yellow with red blush, LYRB= light yellow with red blush, C= circular, OV= ovate ,OB= oblong ,OBL= oblique , BR.OBL= broad oblique)

	FRUIT MORPHOLOGY																	
7	**PEEL COLOR**																	
	Categories	LEYRB	YGCP	LG	SG	BG	LGYRB	LGRB	MGRBB	GYLPB	GYPB	OYRPB	OYRB	BLGT	BYGG	PR		
	Rating	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
8	**Fruit Shape In Cross Section**																	
	Categories	OV to IRR. Oval	OBL. flattened	OV. Elliptic	OBL. elliptical	N. elliptic	BR. elliptic	OV. and N. elliptic										
	Rating	14	15	16	17	18	19	20										

(LEYRB = lemon yellow with red blush, YGCP= yellowish green with crimson patches, LG= light green, SG= sea green, BG= bluish green, LGYRB= light green yellowish with red blush, LGRB= light green with red blush, MGRBB= medium green with reddish brown blush, GYLPB= greenish yellow with light pink blush, GYPB= greenish yellow with pink blush, OYRPB= Orange yellow with red and purple blush, OYRB= orange yellow with reddish blush , BLGT=brownish with light greenish tinge, BYGG= brownish yellow with golden glow, PR= purple red, IRR= irregular, N= narrow).

Twelve quantitative characters were recorded includingleaf width, leaf length, fruit width, fruit length, fruit thickness, percent acidity, total soluble salt (TSS), average fruit weight, stone length, stone width, stone thickness and average stone weight. The length and width of leaf, fruit and stone was measured in centimeters. The weight of stone and fruit were measured by electric balance in grams.Total soluble salt was determined by using digital bench refractometer.Titrable acidity was determined according to the protocol as described by Hortwitz(1960). Crude extract (10 ml) was taken in a beaker and titrated with 0.1 N NaOH by two to three drops of phenolphthaleinwere added as an indicator. The percentage of citric acid was calculated as per following formula.

$$\text{Titrable Acidity} = \frac{\text{volume of 1.2N NaOH x factor (0.0064) x 100}}{\text{Volume of sample used}}$$

The qualitative ratings and quantitative readings were used to prepare the Excel input file of XLSTAT (2012) to execute the principal component analysis(PCA). The PCA based on correlation matrix, was performed to evaluate diversity and grouping pattern of the germplasm and other traits evaluated. The data file was selected and the option of analysing data was selected through which principal component analysis was done. For observation / variable table the data input file was selected except the column of varieties. Pearson (n) PCA type was selected for observation labels the column of varieties was selected. The detailed PCA was generated including the summary statistics, Pearson correlation matrix, eigen value, eigen vectors, scree plot, factor loading, PCA biplot, percent contribution of observations and variables. The criterion of the significance of the eigenvalues, was used to select the statistically significant principal

components Kaiser (1960). Only those principal components (PCs)which haveeigenvalues greater than one were consideredas significant PCs.

RESULTS AND DISCUSSION

Thecorrelations of the first three significant principal componentsi.ePC1, PC2 and PC3 with the variableswere observed in mango varieties. Only these first three principal components that exhibited the eigenvalues greater than one were considered as significant in accordance to (table 1). In a study Hair *et.al.*,(1998) suggested that eigen value greater than one was significant The first PC accounted for 15.25% cumulativevariability, second 9.69% and third 9.12%**.** According to Guei*et.al.*,(2005),theseprincipal components were the most imperative in reflecting the variation patterns among the differentvarieties and the related characters were most important in differentiation. Hence, the first three components were extracted to explain the variability which existed among the 46 mango varieties

Principal component analysis, as a data reduction tool played an important role in identifying the traits, responsible for differentiation among mango varieties as has been reported byMarboh*et al*.,(2015).The first principal component (PC1) was highlyassociated with ten of the original variablesPC1 was highly subjective to characteristics of the fruit morphology.PC1 increased with increase in leaf fragrance (LF,0.298), peel colour (PEC,0.276), fiber length (FBRLN,0.451),yield (Y,0.214) leaf width (LFW,0.291), total soluble salts (TSS,0.331), average weight of stone(AVWT,0.377), fruit width (FRWD,0.376), fruit thickness(FRTH,0.555) and average weight of fruit(AVGWT,0.640). Furthermore, PC1 was highly correlated with AVGWT (0.640). The second principal component (PC2) increased with the increase in five of the original variables including twisting of blade (TW,0.223), color of inflorescence stalk (SKCLR,0.383), color of flowers (FLCLR,0.419), stone length(STL,0.298), stone width (STW,0.262),and fruitlength (FRLG,0.324). PC2 was highly correlated withFLCLR(0.419). Third principal component (PC3) wascorrelated with three of the original variables.andincreased with the increase in leaf color (LC,0.163), leaf shape (LSH,0.256) and presence of fiber (FBR,0.233) while it was highly correlated with FBR (0.233).The conclusion of present study are in accordance with those of Malik *et.al.*,(2012) and Shrestha *et.al.*,(2012) who narrated that fruit weight, fruit length, fruit diameter, fruit rind thickness, TSS, leaf length and leaf width as important variables with the highest provenance to the variation contributed by the principal components.

The variables and observations were projected on a bipolt on the basis of first two PCs(figure 1 and 2). The net variation of the biplot is illustrated by PC1 and PC2. PC1 (15.26%) represented FRWD, FRTHK, AVGWT, PEC. According to Jintanawong*et.al.,(*1992)fruit color was the highlyattractivecharacter for commercial recognition of a variety. While PC2 (9.70) represented FRLG, STW, STL, STTHK. In first quadrant of biplot, the positive value of PC1 andPC2 indicated that, the varietiesi.eFajrikalan,Shindri and Chaunsasufaid showed diversityin the qualitative character of fruitsthe highest values of FRWD, FRTHK, AVGWT and FRLG, STW, STL, STTHK) were seen in second quadrant,the positive values for PC2 showed that LSH had highest values linked with the local varietiesi.eGhulam Muhammad wala, Zardaluand Golden ball.The varieties in second quadrant showed diversity in leaf shape and inflorescence color. In a studyToilli*et.al*.,(2013) reported thatthe color of fresh leaf, tree tallness, type of leaf margins, circumference of stem, strength of fragrance and length of leaf blade had strong correlation.In third quadrant,the negative values for PC1 and PC2 showed the lowest values of FRSK, LC, TSS, TW in local varietiesi.eBadia manna seyed, Intikhab, Almas, Rohaan, Aalishan, HaiderShah wala,Neelum and Burma surkha. These varieties showed diversity in leaf and tree characters.In fourth quadrant,the negative value of PC2 showed lowest values for SKCAV, linked with Badiamunaseyed. The positive value of PC1 indicated highest values of LF, IFL, IF W, AVWT, FBRLN, FBRrelated with Yakta and ChaunsasummarBahisht. The varieties in the first and fourth quadrant were famous commercial varieties.Commercially renowned mangos must have low fiber content, higher values for fruit length, width, thickness and weight as has been reported by (Human and Rheeder, 2004).Fruit traits were best for studying mango diversity(Gálvez-López*etal*.,2010).In future, mango varieties with superior fruit traits must be used in breeding efforts to produce improved hybrids and new cultivars.

According to PCA, peel colour, total soluble salt, average weight of stone average weight of fruit, fruit thickness, fruit length and fruit width were morphological traits used to differentiate between different mango varieties were found to bein line with the findings of. Marboh*et.al.*,(2015).

Table 1: Eigen values of the three significant Principal components

Values	PC1	PC2	PC3
Eigen values	5.493	3.491	3.284
Variability (%)	15.259	9.698	9.123
Cumulative %	15.259	24.957	34.080

Table 2: Correlation of the three Significant PCs with the original variables.

Variables	PC1	PC2	PC3
Leaf colour	0.018	0.071	**0.163**
Twisting of blade	0.044	**0.223**	0.152
Leaf fragrance	**0.298**	0.151	0.078
Leaf shape	0.240	0.046	**0.256**
Stalk colour	0.016	**0.383**	0.125
Flower colour	0.052	**0.419**	0.037
Peel colour	**0.276**	0.063	0.181
Prescence of Fiber	0.026	0.089	**0.233**
Fiber Length	**0.451**	0.044	0.165
Yeild	**0.214**	0.013	0.122
Leaf width	**0.291**	0.069	0.032
Total soluble salts	**0.331**	0.019	0.028
Avg. wt. per stone	**0.377**	0.025	0.224
Stone length	0.175	**0.298**	0.287
Stone width	0.082	**0.262**	0.019
Fruit length	0.033	**0.324**	0.288
Fruit width	**0.376**	0.037	0.062
Fruit thickness	**0.555**	0.040	0.070
Avg. wt. per fruit	**0.640**	0.024	0.133

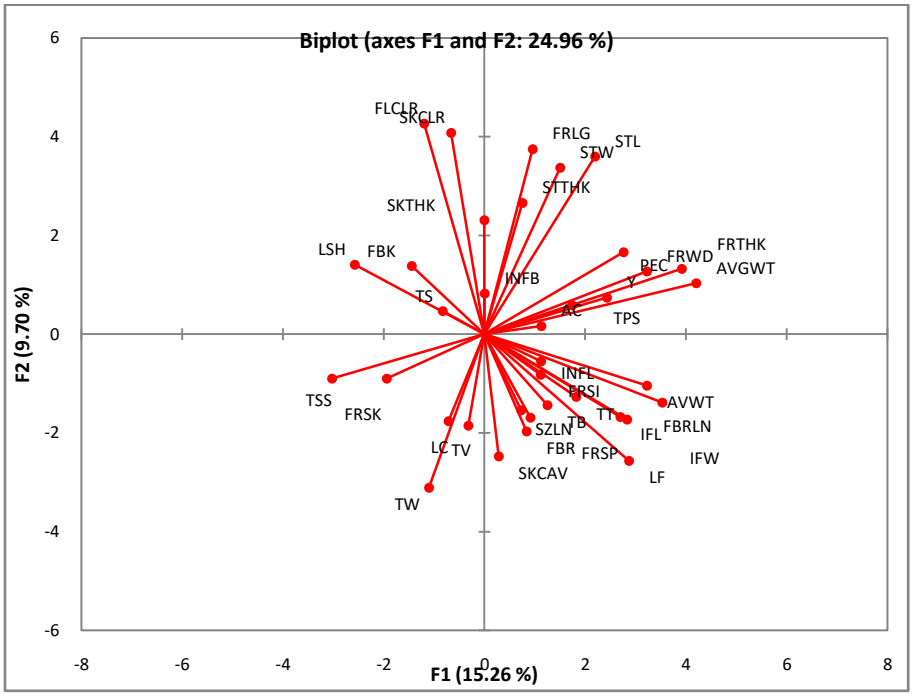

Figure 1: Projection of variables on bi plot depending upon first two Principal Components.

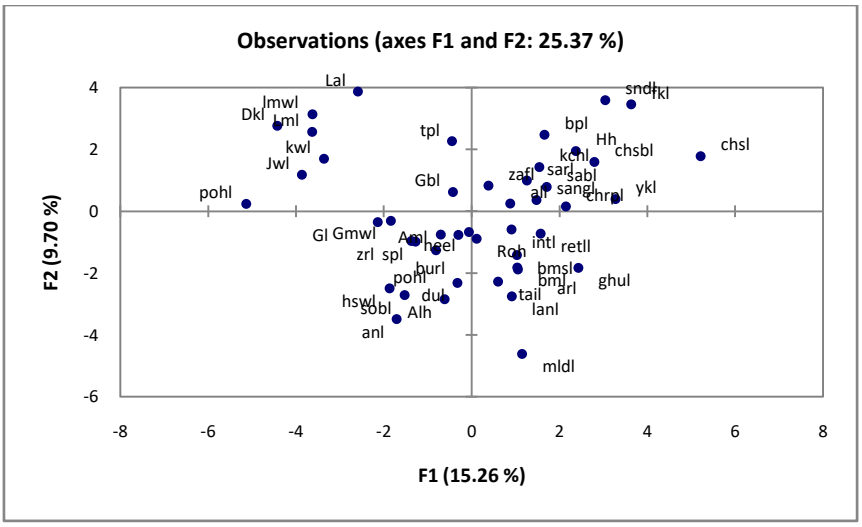

Figure 2: Projection of mango varieties (n=46) on biplot depending upon the first two Principal components.

Traits ABBREVATIONS	
TT	tree talness
TV	tree vigour
TB	tree branching
TS	tree spreading
LC	leaf colour
TW	twisting of blade
TPS	shape of tip
LF	leaf fragrance
LSH	leaf shape
INFL	inflorescene length
INFB	inflorscence branching
SKCLR	stalk colour
FL CLR	flower colour
FRSP	fruit shape in cross section
PEC	colour of peel
SZLN	size of lenticles
FRSK	fruit skin
SK CAV	Stalk cavity
F BK	fruit beak
FR SI	fruit sinus
SKTHK	skin thickness
FBR	prescence of fiber
FBR LN	fiber length
Y	Yield
LF L	leaf length
LFW	leaf width
AC	Acidity
TSS	total solid salt
AV WT	avgwtpr stone
ST L	stone lenth
ST W	stone width
ST THK	stone thickness
FR LG	fruit length
FR WD	fruit width
FR THK	fruit thickness
AVG WT	avgwtpr fruit

Varieties ABBREVATIONS	
SPL	Shah pasand
ZRL	Zardalu
HSWL	Haider shah wala
SARL	Saroli
BPL	Bagan pali
YKL	Yakta
CSBL	Chaunsa (SammarBahisht)
SNDL	Sindhri
MLDL	Malda late
KCHL	Kala chaunsa
CHSL	Chaunsasafaid
RETLL	Retaul late
SANGL	Sanglakhi
SOBL	Sobe de ting
POHL	Pohi lot
TAIL	Taimuria
CHRPL	Chaunsa (Rampuri)
SABL	Saleh bhai
NEEL	Neelum
ZAFL	Zafran
BURL	Burma surkha
BMSL	Badiamunasyed
ALL	Almas
INTL	Intikhab
LANL	Langra
ANL	Anmole
GHUL	Ghulab-e-khas
BML	Bara mashi
DUL	Dusehri
ARL	Anwar retaul
FKL	Fajrikalan
TPL	Totapari
LMWL	Langramayewala
PNL	Pan
LML	Lab-e- Mashooq
LAL	Lahotia

JWL	Joiyawala
KWL	Kachnaliwala
DKL	Dusehrikalan
GMWL	Ghulam Muhammad wala
GL	Golden
GBL	Golden ball
AML	Aminia
ALH	Aalishan
ROH	Rohan
HH	Hasaan

Conclusion: Principal Component Analysis reduced the dimensionality of the data. The first three significant Principal components were highly correlatedto the traits, such as fruit weight, fruit thickness, fruit width, Flower colour and prescence of fiber, twisting of leaf blade, leaf colour and leaf shape which considerably differentiated the 46 mango varietiesin the groups under study.

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