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Full Length Article

Exploitation of Phenotypic Diversity in Male Accessions of Date Palm (*Phoenix dactylifera*) and its Use in Germplasm Conservation

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Abstract

Date palm (*Phoenix dactylifera* L. 2n=2x=36) is an evergreen, perennial, monocotyledonous and dioecious fruit plant. Pakistan is recognized for date palm cultivation due to its diverse agro-climatic conditions and stands at 6th position in the world. Owing to dioecious in nature, flowers of male and female trees do not mature at the same time. Limited information is available regarding the identification and description of male trees of date palm in Pakistan. This study was conducted to reveal the morphological diversity among181 male ecotypes of date palm. Thirty eight (24 quantitative and 14 qualitative) traits were noted and subjected to multivariate analysis. The results revealed significant distinction in morphological traits of male ecotypes of date palm. Wax cover of pinnae, color of pinnae, crown density, crown shape, trunk height, peduncle width at the base and top, total length of basal and median rachillae, prophyll length, total rachis length and mean number of acanthophylls were found morphologically diverse traits. The principal component analysis PCA plot exhibited high phenotypic variability and showed that measured variables can be helpful in diversity analysis for germplasm conservation of date palm male ecotypes to address the issue of rapid changing climate and germplasm erosion. Dendrogram constructed on the basis of quantitative as well as qualitative traits by using AHC (agglomeration hierarchical clustering) grouped the accessions in different classes and sub classes. The findings have implications in the identification, selection and conservation of diverse male date palm trees with superior traits and in future breeding programs. © 2020 Friends Science Publishers

Keywords: Date palm male trees; Morphological diversity; Conservation; Principal Component Analysis

Introduction

Date palm (*Phoenix dactylifera* L., 2n=2x=36) is an evergreen, perennial and monocotyledonous fruit tree of Arecaceae family with 183 genera and 2600 species (Dransfield *et al*. 2008). Date palm has a traditional history of cultivation and utilization in North Africa and the Middle East. Date palm is an extensively cultivated fruit plant in arid and semi-arid regions of the world (Kriaa *et al*. 2012). Starting from old to new world, date palm is nourishing millions of people especially in those regions where only limited plant species can be grown owing to harsh environmental conditions.

Pakistan ranks at 6th position in the world with total production of 524,041 tons from an area of 98,023 hectares (FAO 2017). It is the only tree which has significant role in livelihood of dry regions of Pakistan; and is one of the leading fruit tree having momentous contribution in regional economy. In fact, Pakistan is the leading exporter of dehydrated dates (Chohara) in the world. Dhakki (large size and more flesh) cultivar is one of the best varieties for dehydrated dates. On the other hand, Mozawati (semi-dry), Aseel (soft), Begum Jungi (soft), Gulistan (consumed at Khalal) and Hillawi (consumed at Khalal) are consumed as fresh or processed into pitting, powder and syrup.

Naturally, date palm is a dioecious plant in which male and female reproductive parts are present on different plants. Male flowers bear pollen while fruit is produced on female plants only. Date palm is naturally cross pollinated although manual pollination is prerequisite to obtain good quantity and superior quality fruit (Asif *et al*. 1986). It is considered as the primary plant pollinated by the human (Zohary and Spiegel-Roy 1975). Besides, the date palm exhibits an uncommon phenomena *i.e*. metaxenia which is influence of pollen on the maternal tissues of fruit (Janick 1979). In this phenomenon, male has direct impact on fruit size and nutrition. Date palm cultivars had rigorous yield when selected males were used for pollination rather than random (Djerbi 1991). Pollen grains from male trees of dissimilar genetic makeup may have significant diverse effect on fruit yield, quality and ripening time of date palm (Maryam *et al*. 2015a). Due to an unambiguous effect of pollen on fruit quality and quantity it is a prerequisite to select, identify and conserve the diverse date palm male

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trees of superior quality for use in catalogue development and breeding programs. Date palm due to different origin shows great variations in pollen quality (Nasr *et al*. 1986); even the male plants are uneven in growth habit and spathe attributes (Nixon 1935; El-Sabrout 1979). Male and female trees have asynchronized behavior of spathe emergence time. In most of dates growing countries, date palm male plants are propagated through seed, which leads to genetic variations. To get good yield and quality fruit, selected males are used for pollination rather random (Djerbi 1991). Previously, significant work has been done on Pakistani female date palm genetic resources characterization and conservation (Haider *et al*. 2015; Naqvi *et al*. 2015; Qadri *et al*. 2016). However, very limited attention has been given to indigenous male trees as a pollinizer (Maryam *et al*. 2015b; 2016). The male trees of date palm are being depleted due to urbanization, genetic erosion and unawareness in farming community about its significance.

There are several methods to assess diversity, but morphological characters are a useful tool for agronomic and taxonomic assessment (Jannatabadi *et al*. 2014). Assessment of morphological variants is uncomplicated and economical in contrast to molecular markers, which are expensive and require high proficiency. However, morphological characterization produces large phenotypic data sets (Rao 2004) which provide basis for an assessment of genetic diversity and association between molecular and morphological traits of date palm germplasm (Ahmed *et al*. 2011; Naqvi *et al*. 2015). Owing to these reasons, breeders prefer the morphological traits in selection of breeding parents (Geleta *et al*. 2006). Several studies have shown the significance of morphological traits in identifying Pakistani female date palm (Haider *et al*. 2015; Naqvi *et al*. 2015). However, characterization of highly potent indigenous male trees as pollinators is very important to enhance the yield and quality of date palm fruit. Therefore, a comprehensive morphological study was designed with the intent to assess and conserve the male genetic resources of date palm for varietal identification, registration and future breeding.

Materials and Methods

The study was carried out on 181 date palm male accessions collected from three regions with different ecological conditions *i.e*. Jhang (31°25° N, 72°33° E), Bahawalpur (29°38° N, 71°63° E) and Faisalabad (31°45° N, 73°13° E) (Table 1). A total of 38 traits were studied; out of which, 24 were quantitative and 14 were qualitative traits (Table 2). These traits have already been reported as a standard descriptor to characterize date palm (IPGRI 2005; Rizk and Sharabasy 2006; 2007). Fresh and mature leaves and spathe were used for data recording. Leaves from second whirl of the canopy were used for data scoring. Leaf and spathe attributes were evaluated in triplicate, while for trunk parameters, data of single tree was noted because most of the male trees were propagated naturally through seed dispersal and considered genetically diverse with single tree selection. All measurements were performed by using measuring tape. The quantitative and qualitative traits were evaluated by following the date palm descriptor (IPGRI 2005). Trunk perimeter was measured at a height of four feet from the ground surface. Number of leaves present in canopy was estimated. Distance from basal portion of leaf to the tip of apical pinnae was measured as rachis length total. Number of acanthophylls on right and left side of leaf was also counted. Distance from beginning to the end of spathe was measured as rachis (spathe) length. After removing the cover, number of rachillae was counted in each spathe. Distance from the starting point to the end of rachillae was measured as rachillae length total, while rachillae portion containing no flowers was measured as rachillae length sterile portion.

Statistical analysis

All 38 morphological traits representing in181 male date palm accessions were analyzed by using XLSTAT 2018 (version 2018.1) software and R program. The coefficient of variation (%) was calculated to determine variability among studied traits, find out useful phenotypic traits for effectual indirect selection and restrict powerless traits. In the correlation analyses, parametric Pearson correlations were used to evaluate the quantitative traits whereas non-parametric Spearman correlations were used to study the qualitative traits. Resemblance counting and the PCA plots of quantitative and qualitative traits were buildup. Dendrogram was created by using combine data of quantitative and qualitative traits. Genetic variation component was used to detect Euclidean distance and Ward's method was exercised for agglomerative hierarchical clustering (AHC).

Results

Descriptive statistics of quantitative traits

Descriptive statistics of twenty-four quantitative traits regarding minima and maxima, means, standard deviations and coefficients of variation (CV) is presented in Table 3. The results indicated high range of morphological variability. Some traits like number of aerial suckers (213.13%), number of basal suckers (176.53%), height of basal root cone (113.04%), length of smallest acanthophyll (64.48%), length of sterile portion of upper rachillae (63.24%), tree height (60.67%) and total length of upper rachillae (60.53%) exhibited high values of coefficient of variation. The remaining traits showed relatively lower CV. Total rachis length had also the lowest CV (17.56%).

Number of leaves varied between 18–132 for accessions JG43 and JG50, respectively. Trunk perimeter ranged from 47 to 266.5 cm for BR90 and BR54 accessions, respectively. Mean number of acanthophylls on right side of leaf ranged from 3 cm (JG1) to 23 cm (BR7).

Table 1: List of male date palm accessions studied in various regions of Pakistan

No.	Accession Code	Collection site	Remarks	No.	Accession Code	Collection site	Remarks
1	BR$_{1}$	Bahawalpur	Spherical	78	BR$_{78}$	-do-	Hemi spherical
2	BR$_{2}$	-do-	Hemi spherical	79	BR$_{79}$	-do-	Hemi spherical
3	BR$_{3}$	-do-	Hemi spherical	80	BR$_{80}$	-do-	Hemi spherical
4	BR$_{4}$	-do-	Hemi spherical	81	BR$_{81}$	-do-	Hemi spherical
5	BR$_{5}$	-do-	Hemi spherical	82	BR$_{82}$	-do-	Hemi spherical
6	BR$_{6}$	-do-	Hemi spherical	83	BR$_{83}$	-do-	Erect
7	BR$_{7}$	-do-	Hemi spherical	84	BR$_{84}$	-do-	Erect
8	BR$_{8}$	-do-	Hemi spherical	85	BR$_{85}$	-do-	Erect
9	BR$_{9}$	-do-	Hemi spherical	86	BR$_{86}$	-do-	Hemi spherical
10	BR$_{10}$	-do-	Hemi spherical	87	BR$_{87}$	-do-	Erect
11	BR$_{11}$	-do-	Hemi spherical	88	BR$_{88}$	-do-	Erect
12	BR$_{12}$	-do-	Hemi spherical	89	BR$_{89}$	-do-	Hemi spherical
13	BR$_{13}$	-do-	Hemi spherical	90	BR$_{90}$	-do-	Hemi spherical
14	BR$_{14}$	-do-	Hemi spherical	91	BR$_{91}$	-do-	Hemi spherical
15	BR$_{15}$	-do-	Hemi spherical	92	BR$_{92}$	-do-	Hemi spherical
16	BR$_{16}$	-do-	Hemi spherical	93	BR$_{93}$	-do-	Erect
17	BR$_{17}$	-do-	Hemi spherical	94	BR$_{94}$	-do-	Hemi spherical
18	BR$_{18}$	-do-	Hemi spherical	95	BR$_{95}$	-do-	Hemi spherical
19	BR$_{19}$	-do-	Hemi spherical	96	BR$_{96}$	-do-	Erect
20	BR$_{20}$	-do-	Spherical	97	BR$_{97}$	-do-	Hemi spherical
21	BR$_{21}$	-do-	Hemi spherical	98	BR$_{98}$	-do-	Hemi spherical
22	BR$_{22}$	-do-	Hemi spherical	99	BR$_{99}$	-do-	Spherical
23	BR$_{23}$	-do-	Spherical	100	BR$_{100}$	-do-	Hemi spherical
24	BR$_{24}$	-do-	Spherical	101	BR$_{101}$	-do-	Hemi spherical
25	BR$_{25}$	-do-	Hemi spherical	102	BR$_{102}$	-do-	Erect
26	BR$_{26}$	-do-	Hemi spherical	103	BR$_{103}$	-do-	Erect
27	BR$_{27}$	-do-	Erect	104	BR$_{104}$	-do-	Hemi spherical
28	BR$_{28}$	-do-	Hemi spherical	105	BR$_{105}$	-do-	Hemi spherical
29	BR$_{29}$	-do-	Hemi spherical	106	BR$_{106}$	-do-	Hemi spherical
30	BR$_{30}$	-do-	Erect	107	BR$_{107}$	-do-	Hemi spherical
31	BR$_{31}$	-do-	Hemi spherical	108	BR$_{108}$	-do-	Hemi spherical
32	BR$_{32}$	-do-	Hemi spherical	109	BR$_{109}$	-do-	Hemi spherical
33	BR$_{33}$	-do-	Hemi spherical	110	BR$_{110}$	-do-	Hemi spherical
34	BR$_{34}$	-do-	Hemi spherical	111	BR$_{111}$	-do-	Hemi spherical
35	BR$_{35}$	-do-	Erect	112	BR$_{112}$	-do-	Hemi spherical
36	BR$_{36}$	-do-	Hemi spherical	113	BR$_{113}$	-do-	Hemi spherical
37	BR$_{37}$	-do-	Hemi spherical	114	BR$_{114}$	-do-	Hemi spherical
38	BR$_{38}$	-do-	Hemi spherical	115	BR$_{115}$	-do-	Hemi spherical
39	BR$_{39}$	-do-	Hemi spherical	116	BR$_{116}$	-do-	Erect
40	BR$_{40}$	-do-	Spherical	117	BR$_{117}$	-do-	Erect
41	BR$_{41}$	-do-	Erect	118	JG$_{1}$	Jhang	Hemi spherical
42	BR$_{42}$	-do-	Hemi spherical	119	JG$_{2}$	-do-	Hemi spherical
43	BR$_{43}$	-do-	Erect	120	JG$_{3}$	-do-	Hemi spherical
44	BR$_{44}$	-do-	Hemi spherical	121	JG$_{4}$	-do-	Hemi spherical
45	BR$_{45}$	-do-	Erect	122	JG$_{5}$	-do-	Hemi spherical
46	BR$_{46}$	-do-	Hemi spherical	123	JG$_{6}$	-do-	Hemi spherical
47	BR$_{47}$	-do-	Erect	124	JG$_{7}$	-do-	Hemi spherical
48	BR$_{48}$	-do-	Hemi spherical	125	JG$_{8}$	-do-	Hemi spherical
49	BR$_{49}$	-do-	Hemi spherical	126	JG$_{9}$	-do-	Hemi spherical
50	BR$_{50}$	-do-	Hemi spherical	127	JG$_{10}$	-do-	Hemi spherical
51	BR$_{51}$	-do-	Hemi spherical	128	JG$_{11}$	-do-	Hemi spherical
52	BR$_{52}$	-do-	Hemi spherical	129	JG$_{12}$	-do-	Hemi spherical
53	BR$_{53}$	-do-	Hemi spherical	130	JG$_{13}$	-do-	Hemi spherical
54	BR$_{54}$	-do-	Hemi spherical	131	JG$_{14}$	-do-	Hemi spherical
55	BR$_{55}$	-do-	Hemi spherical	132	JG$_{15}$	-do-	Spherical
56	BR$_{56}$	-do-	Hemi spherical	133	JG$_{16}$	-do-	Hemi spherical
57	BR$_{57}$	-do-	Erect	134	JG$_{17}$	-do-	Hemi spherical
58	BR$_{58}$	-do-	Hemi spherical	135	JG$_{18}$	-do-	Hemi spherical
59	BR$_{59}$	-do-	Hemi spherical	136	JG$_{19}$	-do-	Hemi spherical
60	BR$_{60}$	-do-	Hemi spherical	137	JG$_{20}$	-do-	Spherical
61	BR$_{61}$	-do-	Hemi spherical	138	JG$_{21}$	-do-	Hemi spherical
62	BR$_{62}$	-do-	Erect	139	JG$_{22}$	-do-	Hemi spherical
63	BR$_{63}$	-do-	Hemi spherical	140	JG$_{23}$	-do-	Hemi spherical
64	BR$_{64}$	-do-	Erect	141	JG$_{24}$	-do-	Spherical
65	BR$_{65}$	-do-	Erect	142	JG$_{25}$	-do-	Hemi spherical
66	BR$_{66}$	-do-	Hemi spherical	143	JG$_{26}$	-do-	Hemi spherical
67	BR$_{67}$	-do-	Hemi spherical	144	JG$_{27}$	-do-	Hemi spherical
68	BR$_{68}$	-do-	Hemi spherical	145	JG$_{28}$	-do-	Hemi spherical
69	BR$_{69}$	-do-	Spherical	146	JG$_{29}$	-do-	Hemi spherical
70	BR$_{70}$	-do-	Hemi spherical	147	JG$_{30}$	-do-	Hemi spherical
71	BR$_{71}$	-do-	Hemi spherical	148	JG$_{31}$	-do-	Hemi spherical
72	BR$_{72}$	-do-	Hemi spherical	149	JG$_{32}$	-do-	Hemi spherical
73	BR$_{73}$	-do-	Hemi spherical	150	JG$_{33}$	-do-	Erect
74	BR$_{74}$	-do-	Hemi spherical	151	JG$_{34}$	-do-	Hemi spherical
75	BR$_{75}$	-do-	Erect	152	JG$_{35}$	-do-	Hemi spherical
76	BR$_{76}$	-do-	Spherical	153	JG$_{36}$	-do-	Hemi spherical
77	BR$_{77}$	-do-	Spherical	154	JG$_{37}$	-do-	Hemi spherical

Table 1: continued

Table 1: continued

155	JG$_{38}$	Jhang	Hemi spherical	169	JG$_{52}$	-do-	Hemi spherical
156	JG$_{39}$	-do-	Hemi spherical	170	JG$_{53}$	-do-	Hemi spherical
157	JG$_{40}$	-do-	Spherical	171	JG$_{54}$	-do-	Spherical
158	JG$_{41}$	-do-	Hemi spherical	172	JG$_{55}$	-do-	Spherical
159	JG$_{42}$	-do-	Hemi spherical	173	JG$_{56}$	-do-	Hemi spherical
160	JG$_{43}$	-do-	Hemi spherical	174	JG$_{57}$	-do-	Hemi spherical
161	JG$_{44}$	-do-	Hemi spherical	175	JG$_{58}$	-do-	Hemi spherical
162	JG$_{45}$	-do-	Hemi spherical	176	JG$_{59}$	-do-	Hemi spherical
163	JG$_{46}$	-do-	Hemi spherical	177	JG$_{60}$	-do-	Spherical
164	JG$_{47}$	-do-	Hemi spherical	178	UAF$_{1}$	Faisalabad	Spherical
165	JG$_{48}$	-do-	Spherical	179	UAF$_{2}$	-do-	Spherical
166	JG$_{49}$	-do-	Hemi spherical	180	UAF$_{3}$	-do-	Spherical
167	JG$_{50}$	-do-	Hemi spherical	181	UAF$_{4}$	-do-	Hemi Spherical
168	JG$_{51}$	-do-	Hemi spherical				

Table 2: Quantitative and qualitative traits studied in date palm male accessions

Parameter	Code
Quantitative traits	
Height of basal root cone (cm)	HBRC
Trunk height (cm)	TH
Trunk perimeter (cm)	TP
Rachis length (total) (cm)	RLT
Length of smallest acanthophyll (cm)	LSA
Length of median acanthophylls (4 measures) (cm)	LMA
Length of longest acanthophyll (cm)	LLA
Prophyll length (cm)	Pro.L
Peduncle length (cm)	Ped.L
Peduncle width at the base (cm)	Ped.WB
Peduncle width at the top (cm)	Ped.WT
Rachis (Spathe) length (cm)	Rchs.L
Basal rachillae length total (cm)	BRL-T
Basal rachillae length Sterile (cm)	BRL-S
Median rachillae length total (cm)	MRL-T
Median rachillae length (sterile portion) (cm)	MRL-S
Upper rachillae length total (cm)	URL-T
Upper rachillae length sterile (cm)	URL-S
Number of basal suckers	NBS
Number of aerial suckers	NAS
Number of leaves (estimate)	NL
Mean number of acanthophylls (Right side of leaf)	MAR
Mean number of acanthophylls (Left side of leaf)	MAL
Rachillae number	Rchl. N
Qualitative traits	
Grown from (seed, offshoot)	GF
Crown shape (spherical, hemispherical, erect)	CS
Crown density (very dense, dense, open)	CD
Leaf lateral torsion (none, moderate, strong)	LLT
Leaf bases (persistent/ caducous)	LB
Fiber density (thin, medium, thick)	FD
Petiole color (green, yellowish green)	PtC
Grouping of acanthophylls (single, double, three, four)	GA
Transition spine/pinnae (sharp/progressive)	TS
Color of pinnae (light green, green, dark green)	CP
Aspect of pinnae (soft, rigid, spiny, stiff, bending)	AP
Wax cover of pinnae (none, thin, medium, thick)	WCP
Grouping pattern of pinnae of lower third of leaf rachis (Alternate, opposite)	GPL
Grouping pattern of pinnae of upper third of leaf rachis (Alternate, opposite)	GPU
Peduncle color (creamy, yellow, orange)	PdC
Rachillae shape (straight, light zigzag, strongly zig zag)	RS

Peduncle length ranged from 8.25 to 61 cm held by BR5 and BR49 accessions, respectively. Accession JG13 had the maximum rachillae number (424.5) followed by JG12 (381.5), BR17 (375) and JG25 (332) while minimum rachillae number (58.5) was recorded in the accession JG46. Maximum rachillae length (47.25 cm) at the basal portion of spathe was found in accession JG48. Maximum sterile portion (13 cm long) was observed in the rachillae of basal portion of accession BR107. Maximum number of basal suckers (35) was counted in accession JG38. Length of the longest acanthophyll on rachis ranged 8–33.25 cm for accessions BR6 and BR94, respectively.

Correlation estimation of quantitative traits

Strong positive correlation was detected in most of the studied quantitative variables (Table 4 and Fig. 1). The highest positive correlation (0.967) existed between number of acanthophyll on right side of leaf to the number of acanthophyll on left side of leaf. Furthermore, positive correlations were observed between peduncle width at the base and peduncle width at the top (0.907), length of median acanthophylls and length of longest acanthophyll (0.712), prophyll length and spathe length (0.668), height of basal root cone and trunk height (0.618), basal rachillae length total and basal rachillae length sterile portion (0.589), trunk perimeter and total rachis length (0.467), trunk height and number of leaves (0.434). In contrast, negative correlations were observed in certain quantitative traits. Trunk height showed maximum negative correlation (-0.351) with mean number of acanthophylls on right side of leaf. In addition, negative correlations were also noted in mean number of acanthophyll on left side of leaf to the length of smallest acanthophyll (-0.210), mean number of acanthophyll on right side of leaf to the length of smallest acanthophyll (-0.197). Upper rachillae length of sterile portion showed negative correlation (-0.183) with number of basal suckers.

Principal component analysis (PCA) of quantitative traits

A 2D PCA plot based on quantitative traits was constructed. The accessions having similar phenotypic resemblance were grouped in the similar plot (Fig. 2). For example, accessions BR$_{5,}$ BR$_{7,}$ BR$_{15,}$ BR$_{69,}$ BR$_{81,}$ BR$_{105,}$ BR$_{111,}$ JG$_{11}$ and JG$_{33}$ with maximum number of acanthophylls on right side of pinnae were placed on lower right plane while the accessions BR$_{26,}$ BR$_{37,}$ BR$_{87}$, JG$_{1,}$ JG$_{49,}$ UAF$_{1}$ and UAF$_{3}$ with minimum

Table 3: Descriptive statistics for quantitative traits in date palm male accessions

Traits	Minimum	Maximum	Mean	Std. Deviation	CV%
Height of basal root cone (cm).	0	360	44.12	49.88	113.04
Trunk height (cm).	20	1182	347.18	210.66	60.67
Trunk perimeter (cm).	47	266.5	156.39	40.04	25.60
Number of basal suckers	0	35	2.55	4.51	176.53
Number of aerial suckers	0	5	0.59	1.26	213.13
Number of leaves	18	132	52.67	23.98	45.53
Rachis length (total) (cm).	169.5	483.5	314.96	55.33	17.56
Mean number of acanthophylls (Right side of leaf)	3	23	11.10	3.49	31.43
Mean number of acanthophylls (Let side of leaf)	3.5	23	11.34	3.46	30.53
Length of smallest acanthophyll (cm).	0.4	12.4	3.16	2.04	64.48
Length of median acanthophylls (cm)	3.88	17.5	8.58	2.63	30.68
Length of longest acanthophyll (cm).	8	33.25	16.41	4.44	27.07
Prophyll length (cm).	32.75	136.5	63.56	14.01	22.05
Peduncle length (cm).	8.25	61	22.73	8.94	39.34
Peduncle width at the base (cm).	1.8	6.2	3.52	0.80	22.87
Peduncle width at the top (cm).	1.9	6	3.82	0.82	21.60
Rachis (Spathe) length (cm).	9.5	66.5	30.80	7.95	25.82
Rachillae number	58.5	424.5	175.80	53.66	30.52
Basal rachillae length total (cm).	9.45	47.25	19.61	6.01	30.65
Basal rachillae length Sterile (cm).	0.1	13	3.43	2.05	59.87
Median rachillae length total (cm).	7	28.5	13.43	3.99	29.70
Median rachillae length (sterile portion) (cm).	0.25	8.75	2.31	1.32	57.43
Upper rachillae length total (cm).	3.05	68.3	9.49	5.74	60.53
Upper rachillae length sterile (cm).	0	5.35	1.53	0.97	63.24

Table 4: Correlation coefficients of quantitative traits among 181 date palm male accessions

Traits	HBRC	TH	TP	NBS	NAS	NL	RLT	MAR	MAL	LSA	LMA	LLA	Pro. L	Ped. L	Ped. WB	Ped. WT	Rchs. L	Rchl. N	BRL-T	BRL-S	MRL-T	MRL-S	URL-T
TH	0.618**																						
TP	-0.136	-0.127																					
NBS	-0.187	-0.280	0.263																				
NAS	-0.044	-0.175	0.107	0.479																			
NL	0.305	0.434**	0.106	0.077	0.110																		
RLT	-0.165	-0.172	0.467**	0.081	-0.019	0.047																	
MAR	-0.188	-0.351*	0.230	0.030	-0.017	-0.150	0.345																
MAL	-0.185	-0.343	0.256	0.033	-0.017	-0.146	0.316	0.967**															
LSA	0.002	0.097	-0.110	0.160	0.023	0.039	-0.043	-0.197*	-0.210*														
LMA	0.124	0.137	-0.025	-0.025	-0.046	-0.031	0.026	0.040	0.027	0.561													
LLA	0.194	0.154	-0.020	-0.124	-0.050	-0.047	0.020	0.000	-0.001	0.419	0.712**												
Pro. L	0.107	0.207	0.300	-0.013	-0.060	0.055	0.221	-0.027	-0.005	0.021	0.113	0.057											
Ped. L	0.039	0.121	0.202	0.067	0.024	0.075	0.027	-0.022	0.000	-0.035	0.040	0.027	0.664										
Ped. WB	0.178	0.231	0.112	-0.090	-0.054	0.158	0.076	-0.076	-0.045	0.032	0.087	0.128	0.361	0.058									
Ped. WT	0.150	0.174	0.117	-0.055	-0.003	0.143	0.087	-0.063	-0.040	0.040	0.068	0.072	0.292	-0.019	0.907**								
Rchs. L	0.130	0.213	0.156	-0.034	-0.140	0.092	0.188	0.010	-0.010	0.034	0.137	0.036	0.668**	0.283	0.373	0.360							
Rchl. N	0.214	0.312	0.019	0.011	-0.088	0.154	0.018	0.065	0.087	0.074	0.196	0.165	0.212	0.027	0.499	0.451	0.338						
BRL-T	0.099	0.104	0.275	-0.062	-0.096	0.147	0.291	0.061	0.044	0.007	-0.025	-0.004	0.402	0.110	0.358	0.379	0.410	0.135					
BRL-S	0.109	0.052	0.091	-0.089	-0.139	0.065	0.128	0.038	-0.019	-0.108	-0.083	-0.028	0.218	-0.019	0.296	0.290	0.331	0.031	0.589**				
MRL-T	0.219	0.218	0.257	-0.162	-0.101	0.092	0.209	-0.013	-0.028	0.013	0.094	0.036	0.472	0.213	0.515	0.502	0.383	0.213	0.504	0.397			
MRL-S	0.186	0.268	0.096	-0.145	-0.086	0.090	0.090	-0.084	-0.105	-0.029	0.084	0.051	0.333	0.138	0.355	0.312	0.303	0.234	0.293	0.311	0.603		
URL-T	0.073	0.044	0.073	-0.033	-0.035	-0.008	0.077	0.075	0.101	0.019	0.075	0.060	0.167	0.017	0.280	0.292	0.085	0.041	0.212	0.075	0.422	0.189	
URL-S	0.234	0.339	-0.055	-0.183*	-0.012	0.047	-0.038	-0.099	-0.124	0.134	0.102	0.079	0.164	0.021	0.152	0.181	0.051	-0.031	0.068	0.143	0.318	0.374	0.297

Significant at ** $P<0.01$ and * $P<0.05$

Abbreviations: Height of basal root cone (HBRC), Trunk height (TH), Trunk perimeter (TP), Number of basal suckers (NBS), Number of aerial suckers (NAS), Number of leaves (NL), Rachis length total (RLT), Mean number of acanthophylls on right side of leaf (MAR), Mean number of acanthophylls on left side of leaf (MAL), Length of smallest acanthophyll (LSA), Length of median acanthophylls (LMA), Length of longest acanthophyll (LLA), Prophyll length (Pro.L), Peduncle length (Ped.L), Peduncle width at the base (Ped.WB), Peduncle width at the top (Ped.WT), Rachis (Spathe) length (Rchs.L), Rachillae number (Rchl. N), Basal rachillae length total (BRL-T), Basal rachillae length Sterile portion (BRL-S), Median rachillae length total (MRL-T), Median rachillae length sterile portion (MRL-S), Upper rachillae length total (URL-T), Upper rachillae length sterile (URL-S)

number of acanthophylls on right side of pinnae were positioned in upper left plane. The accessions with green color grouped in the center of plot showed minimum diversity while the accessions with red and blue color were away from the center and showed maximum diversity. Accessions UAF_1, UAF_2 and UAF_4 were grouped in the upper left plane which depicted maximum diversity because prophyll length, peduncle width at the base and top and rachillae number owed maximum values. JG_{19}, JG_{54} and JG_{57} accessions set away from the center in the upper right plane due to their moderate trunk height, trunk perimeter, smallest acanthophyll length, median acanthophyll length and basal rachillae length.

PCA put 24 quantitative traits in five dimensions which showed 55.78% of total variation (Table 5). The first dimension illustrated 20.23% of total variation and contained median rachillae length total, peduncle width at the base, peduncle width at the top, prophyll length and median rachillae length of sterile portion. The second dimension accounted for 12.53% of total variation and included mean number of acanthophylls on right side of rachis, mean number of acanthophylls on left side of rachis, trunk height, rachis length total, trunk perimeter and height of basal root cone. Third dimension exhibited

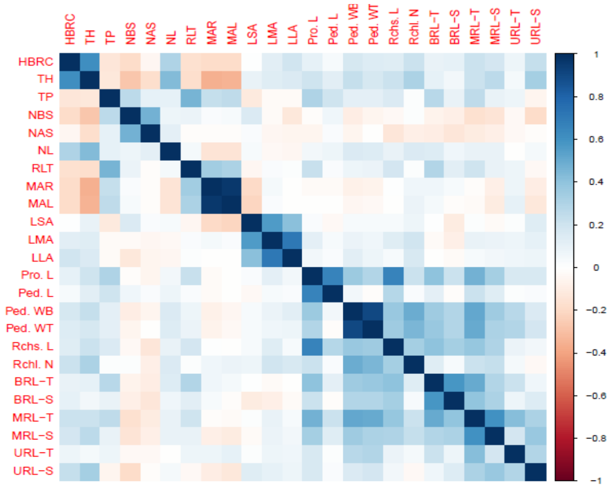

Fig. 1: Correlation matrix among quantitative traits in 181 date palm male accession

Abbreviations: Height of basal root cone (HBRC), Trunk height (TH), Trunk perimeter (TP), Number of basal suckers (NBS), Number of aerial suckers (NAS), Number of leaves (NL), Rachis length total (RLT), Mean number of acanthophylls on right side of leaf (MAR), Mean number of acanthophylls on left side of leaf (MAL), Length of smallest acanthophyll (LSA), Length of median acanthophylls (LMA), Length of longest acanthophyll (LLA), Prophyll length (Pro.L), Peduncle length (Ped.L), Peduncle width at the base (Ped.WB), Peduncle width at the top (Ped.WT), Rachis (Spathe) length (Rchs.L), Rachillae number (Rchl. N), Basal rachillae length total (BRL-T), Basal rachillae length Sterile portion (BRL-S), Median rachillae length total (MRL-T), Median rachillae length sterile portion (MRL-S), Upper rachillae length total (URL-T), Upper rachillae length sterile (URL-S)

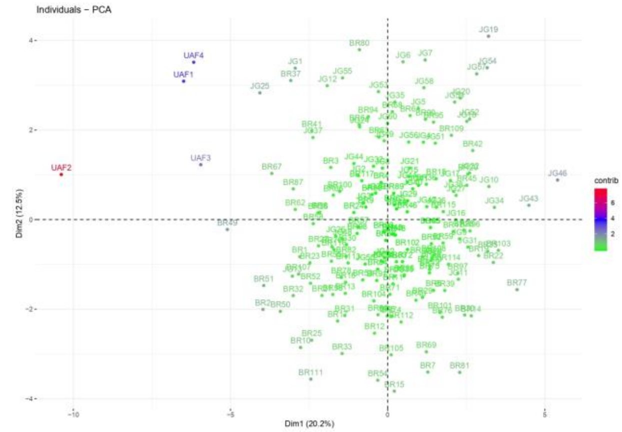

Fig. 2: PCA plot based on the first two dimensions for quantitative traits of 181 date palm male accessions

Table 5: First five dimensions from the PCA analysis for quantitative traits in date palm male accessions

Traits	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Height of basal root cone	2.99	7.43	0.09	0.45	0.18
Trunk height	4.60	11.84	0.33	0.005	1.31
Trunk perimeter	1.13	10.78	0.11	6.57	0.01
Number of basal suckers	0.67	2.02	0.59	24.21	9.36
Number of aerial suckers	0.55	0.23	0.03	15.89	10.95
Number of leaves	1.43	1.42	1.18	4.75	2.24
Rachis length (total)	0.87	11.53	0.98	0.20	0.17
Mean number of acanthophylls (Right side of leaf)	0.17	18.36	4.43	7.05	0.09
Mean number of acanthophylls (Let side of leaf)	0.17	18.31	4.50	6.41	0.02
Length of smallest acanthophyll	0.16	4.00	18.23	2.75	0.37
Length of median acanthophylls	0.91	1.74	33.49	0.004	0.56
Length of longest acanthophyll	0.76	2.21	27.71	0.31	0.46
Prophyll length	9.26	1.39	0.004	7.70	11.54
Peduncle length	1.79	0.51	0.0009	13.74	19.61
Peduncle width at the base	11.47	0.006	0.001	0.39	13.37
Peduncle width at the top	10.33	0.05	0.009	0.48	18.04
Rachis (Spathe) length	8.65	0.79	0.007	1.86	2.84
Rachillae number	4.65	0.08	2.41	0.10	6.35
Basal rachillae length total	7.97	2.87	1.05	0.001	0.001
Basal rachillae length (Sterile portion)	4.92	1.11	3.52	1.75	0.0003
Median rachillae length total	12.64	0.57	0.38	0.36	0.047
Median rachillae length (sterile portion)	8.10	0.05	0.66	0.49	0.48
Upper rachillae length total	2.86	0.39	0.18	2.44	1.15
Upper rachillae length (sterile portion)	2.82	2.20	0.02	1.99	0.74
Variability %	20.23	12.53	8.90	7.54	6.55

8.90% of total variation for length of median acanthophylls, length of longest acanthophyll, length of smallest acanthophyll, mean number of acanthophylls on right and left sides of leaf and basal rachillae length of sterile portion. Fourth dimension described 7.54% of total variation which incorporated number of basal suckers, number of aerial suckers, peduncle length and prophyll length. Fifth dimension showed 6.55% of total variation and comprised peduncle length, peduncle width at the top, peduncle length, peduncle width at the base, prophyll length and number of aerial suckers. Prophyll length showed high positive role in first, fourth and fifth dimension while second and third dimension showed minimum role of prophyll length in diversity. Peduncle width at the base had high positive loadings (11.47, 13.37) in first and fifth dimensions, respectively. However, rest of dimensions showed least role in phenotypic diversity. High positive role (13.74, 19.61) was noted in peduncle length in fourth and fifth dimensions respectively. In

Table 6: Descriptive statistics for qualitative traits in date palm male accessions

Traits	Minimum	Maximum	Mean	Std. Deviation	CV%
Grown from	1	2	1.62	0.48	29.70
Crown shape	1	3	2.02	0.49	24.42
Crown density	1	3	2.60	0.54	20.83
Leaf lateral torsion	1	3	2.07	0.28	13.85
Leaf bases	1	2	1.09	0.30	27.29
Fiber density	1	3	2.17	0.88	40.56
Petiole color	1	2	1.86	0.34	18.58
Grouping of acanthophylls	1	2	1.87	0.33	17.83
Transition spine/pinnae	1	2	1.96	0.19	9.85
Color of pinnae	1	3	1.51	0.53	35.09
Aspect of pinnae	1	4	2.55	1.46	57.14
Wax cover of pinnae	1	4	2.21	0.58	26.18
Peduncle color	1	2	1.09	0.30	27.29
Rachillae shape	1	3	2.149	0.50	23.25

dimension 2, mean number of acanthophylls on right and left side of leaf had high positive role (18.36, 18.31, respectively) in diversity.

Descriptive statistics of qualitative traits

Fourteen morphological qualitative traits evaluated in date palm male accessions were found polymorphic (Table 6). The traits exhibiting higher coefficient of variation were aspect of pinnae (57.14%), fiber density (40.56%) and color of pinnae (35.09%). Minimum CV% was noted for transition spine (9.85%). Majority of the accessions exhibited spherical and hemispherical crown shape but 24 accessions had erect crown shape (BR$_{27}$, BR$_{30}$, BR$_{35}$, BR$_{41}$, BR$_{43}$, BR$_{45}$, BR$_{47}$, BR$_{57}$, BR$_{62}$, BR$_{64}$, BR$_{65}$, BR$_{75}$, BR$_{83}$, BR$_{84}$, BR$_{85}$, BR$_{87}$, BR$_{88}$, BR$_{93}$, BR$_{96}$, BR$_{102}$, BR$_{103}$, BR$_{116}$, BR$_{117}$ and JG$_{33}$). Most of the accessions had persistent leaf bases except for 18 accessions (BR$_{41}$, BR$_{43}$, BR$_{116}$, JG$_{3}$, JG$_{7}$, JG$_{15}$, JG$_{19}$, JG$_{20}$, JG$_{35}$, JG$_{51}$, JG$_{52}$, JG$_{53}$, JG$_{54}$, JG$_{56}$, JG$_{57}$, JG$_{58}$, JG$_{59}$ and JG$_{60}$) which had caducous bases. Petiole color displayed variability from green to yellowish green color. Most of the accessions had petiole of green color but 25 accessions (BR$_{40}$, BR$_{61}$, BR$_{75}$, BR$_{80}$, BR$_{85}$, BR$_{86}$, BR$_{87}$, BR$_{89}$, BR$_{90}$, BR$_{91}$, BR$_{92}$, BR$_{93}$, BR$_{94}$, BR$_{95}$, BR$_{96}$, BR$_{97}$, BR$_{100}$, BR$_{101}$, BR$_{103}$, JG$_{1}$ JG$_{12}$, JG$_{13}$, JG$_{18}$, JG$_{26}$ and UAF$_{1}$) were with yellowish green color. Rachillae shape showed wide range of variability from straight to light zigzag and strong zigzag. The dominant rachillae shape in the studied accessions was light zigzag. Thirty seven accessions (BR$_{3}$, BR$_{6}$, BR$_{21}$, BR$_{25}$, BR$_{26}$, BR$_{27}$, BR$_{33}$, BR$_{34}$, BR$_{40}$, BR$_{46}$, BR$_{59}$, BR$_{66}$, BR$_{70}$, BR$_{73}$, BR$_{76}$, BR$_{82}$, BR$_{87}$, BR$_{90}$, BR$_{91}$, BR$_{94}$, BR$_{98}$, BR$_{100}$, BR$_{105}$, BR$_{107}$, BR$_{112}$, BR$_{115}$, , JG$_{4}$, JG$_{8}$, JG$_{11}$, JG$_{13}$, JG$_{17}$, JG$_{25}$, JG$_{29}$, JG$_{34}$, JG$_{42}$, JG$_{45}$ and UAF$_{2}$) had strong zigzag shape of rachillae. In addition, 10 accessions (BR$_{37}$, BR$_{51}$, BR$_{54}$, BR$_{60}$, BR$_{69}$, BR$_{75}$, BR$_{85}$, BR$_{93}$, JG$_{40}$ and JG$_{60}$) had straight rachillae shape.

Correlation estimation of qualitative traits

Positive correlations were observed in most of the qualitative traits (Table 7 and Fig. 3). Maximum positive correlation (0.264) was present in fiber density and color of pinnae. Positive correlations were also observed between color of pinnae and wax cover of pinnae (0.229), crown shape and crown density (0.219), leaf bases and petiole color (0.133), crown density and transition spine (0.119). In contrast, maximum negative correlation (-0.261.) existed between leaf bases and grouping of acanthophylls. Other negative correlations were noted between color of pinnae and aspect of pinnae (-0.153), leaf lateral torsion and wax cover of pinnae (-0.134), crown shape and leaf lateral torsion (-0.129).

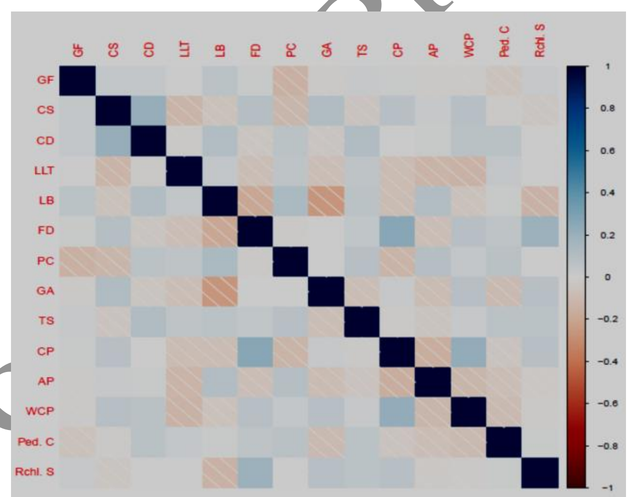

Fig. 3: Correlation matrix among qualitative traits in 181 date palm male accessions

Abbreviations: Grown from (GF), Crown shape (CS), Crown density (CD), Leaf lateral torsion (LLT), Leaf bases (LB), Fiber density (FD), Petiole color (PtC), Grouping of acanthophylls (GA),Transition spine (TS),Color of pinnae (CP), Aspect of pinnae (AP), Wax cover of pinnae (WCP),Grouping pattern of pinnae of lower third (GPL),Grouping pattern of pinnae of upper third (GPU),Peduncle color (PdC), Rachillae shape (RS)

PCA of qualitative traits

PCA plot was constructed on resemblance of qualitative traits (Fig. 4). Accessions closer to the centre of axis were considered less diverse. However, the accessions like BR$_{27}$,

Table 7: Correlation coefficients of quantitative traits among 181 date palm male accessions

Traits	GF	CS	CD	LLT	LB	FD	PC	GA	TS	CP	AP	WCP	Ped. C	Rchl. S
CS	0.0344													
CD	0.0363	0.219**												
LLT	0.0073	-0.129*	-0.018											
LB	0.0636	-0.052	0.104	0.0391										
FD	0.0110	0.093	-0.040	-0.0760	-0.193									
PC	-0.1411	-0.112	0.065	0.0521	0.133**	-0.011								
GA	-0.0177	0.118	-0.031	-0.0706	-0.261*	0.001	-0.009							
TS	0.0243	-0.049	0.119**	0.0540	0.067	0.040	0.086	-0.0765						
CP	0.0171	0.083	-0.002	-0.0822	-0.082	0.264**	-0.121	0.0295	-0.0196					
AP	-0.0127	0.029	0.011	-0.1295	0.101	-0.073	0.098	-0.0815	-0.0412	-0.153*				
WCP	-0.0111	0.080	0.076	-0.134*	-0.060	0.088	0.038	0.0847	0.0252	0.229**	-0.116			
Ped. C	-0.0511	-0.015	0.070	0.0391	0.013	0.059	0.080	-0.0949	0.0667	-0.047	-0.077	-0.092		
Rchl. S	0.0228	-0.036	-0.008	-0.0034	-0.136	0.192	-0.009	0.0809	0.0600	0.083	-0.023	-0.016	0.012	

**Correlation is significant at 0.01 level
*Correlation is significant at 0.05 level
Abbreviations: Grown from (GF), Crown shape (CS), Crown density (CD), Leaf lateral torsion (LLT), Leaf bases (LB), Fiber density (FD), Petiole color (PtC), Grouping of acanthophylls (GA),Transition spine (TS),Color of pinnae (CP), Aspect of pinnae (AP), Wax cover of pinnae (WCP), Peduncle color (PdC), Rachillae shape (RS)

Fig. 4: PCA plot based on the first two dimensions for qualitative traits in 181 date palm male accessions

BR_{40}, BR_{83}, BR_{95}, BR_{90}, JG_{7}, JG_{15} JG_{53}, JG_{60} and UAF_{1} were away from the center and had maximum level of diversity. Similarly, the accessions having phenotypic resemblance were grouped in same plot. For example, 15 accessions (BR_{41}, BR_{43}, JG_{3}, JG_{7}, JG_{19}, JG_{20}, JG_{35}, JG_{51}, JG_{52}, JG_{53}, JG_{54}, JG_{56}, JG_{57}, JG_{58} and JG_{59}) having caducous leaf bases were assembled together in upper left plane. Accessions *i.e.*, BR_{1}, BR_{2}, BR_{3}, BR_{11}, BR_{14}, BR_{15}, BR_{31}, BR_{32}, BR_{34}, BR_{39}, BR_{40}, BR_{42} etc. having persistent leaf bases were placed in lower left plane. Similarly accessions BR_{27}, BR_{38}, BR_{55}, BR_{81}, BR_{83} and BR_{95} were clustered based on thick wax cover of pinnae.

In PCA 14 qualitative traits were put in five dimensions (Table 8), which showed 48.30% of total variation. The first dimension accounted for 12.83% of total variation for color of pinnae, leaf bases, fiber density, wax cover of pinnae, grouping of acanthophylls and fiber density. The second dimension exhibited 9.61% of total variation and included crown density, crown shape, leaf bases, wax cover of pinnae, leaf lateral torsion and transition spine. The third dimension described 9.48% of total variation for transition spine, peduncle color, fiber density, aspect of pinnae, leaf lateral torsion and rachillae shape. Fourth dimension had 8.44% of total variation for grown from, petiole color, grouping of acanthophylls, aspect of pinnae, leaf lateral torsion and leaf basis. Fifth dimension demonstrated 7.92% of total variation for wax cover of pinnae, rachillae shape, aspect of pinnae, crown shape, peduncle color and petiole color. Leaf basis depicted highly positive (16.8, 10.96) role in first and second dimension while leaf bases in rest of the dimensions showed relatively less role in diversity. Similarly crown density had the highest positive loading (35.67) in second dimension. In contrast, rest of the dimensions showed least role in phenotypic diversity. High positive role (10.06, 29.03) was noted in wax cover of pinnae in first and fifth dimensions respectively. In dimension first and third, fiber density had high positive role (15.84, 11.03, respectively) in diversity.

Dendrogram construction by AHC

Euclidean distance was used to examine the genetic divergence in 181 accessions based on quantitative and qualitative traits. Ward's method was applied for agglomeration (Fig. 5 and Table 9). The dendrogram successfully created three distinct clusters (C1, C2, C3). Clusters C1 and C2 contained 103 and 64 accessions, respectively, while C3 included only 14 accessions. Accessions having greater rachillae number were located in cluster C3. Similarly, majority of the accessions included in cluster C1 had light zigzag rachillae shape, except few that included in cluster C2, had thin wax cover of pinnae. No specific clustering based on different growing areas was observed among 181 accessions of date palm male trees. Cluster C1 was further divided in two sub groups viz. C1A and C1B. Thirty two accessions were set in C1A while C1B was comprised 71 accessions. Cluster C2 having 64 accessions was further divided in two sub-clusters *i.e.* C2A and C2B. C2A was comprised of 23 accessions (BR_{4}, BR_{2}, BR_{57}, BR_{48}, JG_{44}, JG_{8}, JG_{14}, BR_{47}, BR_{49}, JG_{19}, JG_{2}, JG_{53}, BR_{63}, BR_{67}, BR_{62}, BR_{64}, BR_{45}, BR_{20}, BR_{61}, JG_{57}, JG_{60}, JG_{52} and JG_{59}) and remaining 41 accessions were assembled in C2B.

Table 8: First five dimensions from the PCA analysis of qualitative traits in date palm male accessions

Traits	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Grown from	0.11	1.39	0.47	34.64	5.72
Crown shape	6.05	21.15	4.68	0.009	7.48
Crown density	0.08	35.67	1.75	0.094	2.26
Leaf lateral torsion	4.51	7.86	8.27	5.65	1.15
Leaf bases	16.85	10.96	0.24	3.81	2.76
Fiber density	15.84	0.01	11.08	0.30	4.73
Petiole color	5.52	0.97	6.49	31.61	3.22
Grouping of acanthophylls	9.62	2.10	6.18	9.00	0.004
Transition spine	0.67	3.77	21.91	0.01	0.23
Color of pinnae	19.06	1.34	2.91	3.33	6.15
Aspect of pinnae	5.26	2.29	10.10	8.25	12.67
Wax cover of pinnae	10.06	8.89	0.20	1.09	29.03
Peduncle color	1.02	0.07	17.69	0.89	6.45
Rachillae shape	5.27	3.46	7.96	1.25	18.08
Variability %	12.83	9.61	9.48	8.44	7.92

Table 9: Dendrogram grouping based on quantitative and qualitative traits of 181 date palm male accessions

Cluster	Genotypes
C1	BR_{12},BR_{13},BR_{14},BR_{15},BR_{16},BR_{17},BR_{18},BR_{19},BR_{21},BR_{22},BR_{23},BR_{24},BR_{25},BR_{28},BR_{29},BR_{30},BR_{31},BR_{32},,BR_{33},BR_{34},BR_{35},BR_{36},BR_{39},BR_{40},BR_{42},BR_{43},BR_{51},BR_{53},BR_{54},BR_{55},BR_{56},BR60,BR_{68},BR_{69},BR_{70},BR_{71},BR_{72},BR_{73},BR_{74}, BR_{75},BR_{76},BR_{77}, BR_{78}, BR_{79},BR_{81},BR_{82},BR_{83},BR_{84}, BR_{85},BR_{86},BR_{87},BR_{88},BR_{89},BR_{90},BR_{91},BR_{92},BR_{93},BR_{94},BR_{95},BR_{96},BR_{97},BR_{99},BR_{101}, BR_{102},BR_{103},BR_{104}, BR_{105},BR_{106},BR_{107},BR_{108}
C2	BR_2,BR_4,BR_9,BR_{20},BR_{26},BR_{27},BR_{38},BR_{41},BR_{44},BR_{45},BR_{46},BR_{47},BR_{48},BR_{49},BR_{50},BR_{52},BR_{57},BR_{58},BR_{59},BR_{61},BR_{62},$BR_{63}$$BR_{64}$,$BR_{65}$,$BR_{66}$, BR_{67}, BR_{98},BR_{100},JG_1,JG_2,JG_4,JG_5,JG_8,JG_{11}, JG_{13},JG_{14},JG_{15},JG_{16},JG_{18},JG_{19},JG_{20},JG_{21},JG_{22},JG_{23},JG_{24}, JG_{26},JG_{29},JG_{33},JG_{35},JG_{38},JG_{39},JG_{41}, JG_{42},JG_{44},JG_{48},JG_{49},JG_{51},JG_{52},JG_{53} ,JG_{54},JG_{56},JG_{57},JG_{59},JG_{60}
C3	BR_{37},BR_{80},JG_6,JG_7,JG_{12},JG_{25},JG_{32},JG_{37},JG_{55},JG_{58},UAF_1,UAF_2,UAF_3,UAF_4

Similarly, cluster C3 was further divided in two sub clusters *i.e*. C3A and C3B. C3A was consisted of thirteen accessions including BR_{37}, BR_{80}, JG_6, JG_7, JG_{12}, JG_{25}, JG_{32}, JG_{37}, JG_{55}, JG_{58}, UAF_1, UAF_2 and UAF_3 and remaining one accession (UAF4) fell in group C3B. Cluster analysis showed that JG_{30} and JG_{26} accessions were indistinctly associated with other studied ecotypes. Cluster analysis of phenotypic traits depicted that male ecotypes of date palm were clustered separately on the basis of resemblance of studied characters. It was also noted that similarity degree was significantly high within each cluster. The results further confirmed that significant morphological diversity exists in male accessions of date palm.

Discussion

Pollen source influence not only the fruit set and size but also govern the maturity time of date fruit (Swingle 1928; Maryam *et al*. 2015a). Pollen grains can cause a great variation in yield, size and quality of fruit. Farmers usually use readily available pollen of diverse genetic background, which results in variations in fruit quality, yield and maturity time from year to year (Osman *et al*. 1974). The current study was conducted to investigate the morphological diversity of 38 traits (qualitative and quantitative) in 181 male date palm accessions. Evaluation of morphological traits is uncomplicated and economical in contrast to molecular markers which are expensive and require high proficiency. Owing to these reasons, breeders choose morphological traits in selection of breeding parents (Geleta *et al*. 2006). Historically, global climate has been changing continuously. In recent time, unpredictable and quick climate change is being noticed in the world which is affecting agriculture industry adversely, particularly in developing countries like Pakistan. Rapidly changing global climate and increasing human population is resulting in depletion of genetic resources, reduction of fertile land and water scarcity. Genetic variations are of primary importance for conservation of germplasm. Genetic dissimilarity inside a species has a key role in its potential to adjust in changing climate (Ahuja 2017). Species occupying larger level of diversity have more ability to readjust and survive in climate change scenario. So, genetic diversity within species is very crucial for conservation planning.

Earlier studies have confirmed that several phenotypic traits like fronds, number and grouping of acanthophylls, number of pinnae and spathe (Salem *et al*. 2008; Eissa *et al.* 2009; Hammadi *et al*. 2009), length of spiny portion of leaf (Peyron and Gay 1988; Rhouma 1994; 2005; IPGRI 2005), spine length, frond length and length of spiny portion of leaf (Hammadi *et al*. 2009), number of wings and frequency of wings (Naqvi *et al*. 2015) are reliable for discrimination and description of date palm accessions. Likewise, Haider *et al.* (2015) evaluated date palm ecotypes on the basis of morphological traits and purposed that height of the plant, number and grouping of pinnae, length of rachis, number and grouping of acanthophylls are valuable characters that can be used to discriminate various date palm accessions. Our results revealed that trunk height, spathe length, peduncle width at the base, peduncle width at the top, total

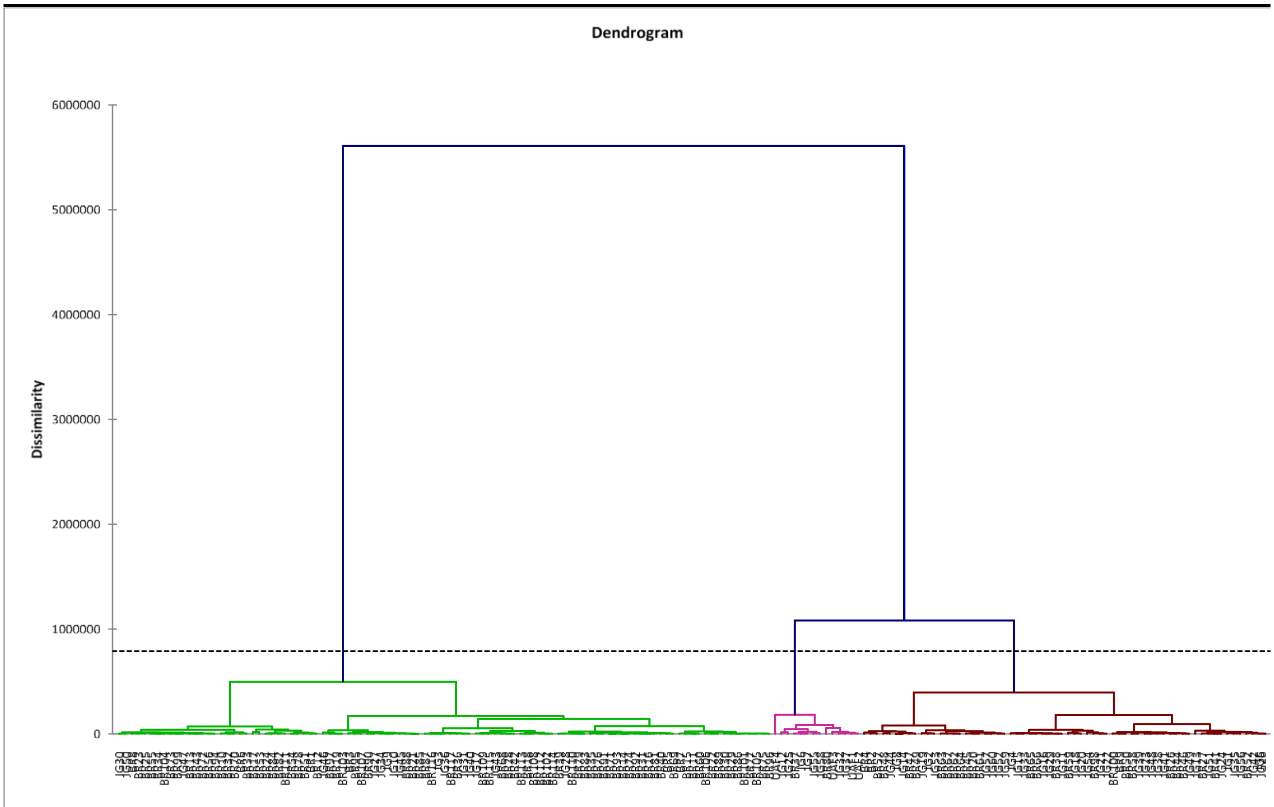

Fig. 5: Dendrogram of hierarchical clustering based on quantitative and qualitative traits of date palm male accessions

length of basal and median rachillae, prophyll length, total rachis length, mean number of acanthophylls, wax cover of pinnae, color of pinnae, leaf basis, crown density and crown shape are the distinctive traits which are involved in the diversity assessment of several accessions. On the whole, the analyses of phenotypic traits depicted the importance of morphological markers in the assessment of genetic diversity of Pakistani date palm male accessions. Djerouni *et al.* (2015) evaluated 08 males morphologically and confirmed that vegetative traits can be used as standard to determine the morphological variability in male date palm accessions. However, supplementary traits like trunk height, number of leaves, mean number of acanthophylls on right and left side of leaf, length of smallest, median and longest acanthophylls, length of sterile portion of basal, median and upper rachillae have been included in the current study.

Strong correlations in our studies indicated that structural design of date palm accessions is well arranged *i.e*. more the height of trunk, more will be the length of basal root cone. Similarly, more trunk perimeter is needed to support longer rachis and more number of leaves are outcomes of more trunk height. Longer prophyll will result in more spathe length and longer rachillae have more sterile portion. Our results are in accordance with Haider *et al.* (2015) who declared that positive and negative correlations exist among morphological traits of date palm.

In the current study, it was observed that independence exist between origin of collection and morphological attributes of date palm male accessions. One example is that the accessions collected from Bahawalpur and Jhang were dispersed in three different clusters according to phenotypic data which shows that there was exchange of plant material in the growing areas of country. However, few accessions were grouped according to their geographical location as accessions collected from Faisalabad were clustered together in the same group. Similar results in date palm have been described by Elhoumaizi *et al.* (2002), Salem *et al*. (2008), Taain (2013) and El-Kadria *et al.* (2019). Comparable findings have also been noticed in other species as in olive (Ouazzani *et al*. 1995), fig (Saddoud *et al*. 2008), ber (Razi *et al*. 2013) and pomegranate (Nafees *et al*. 2015).

Conclusion

Vegetative and reproductive traits like wax cover of pinnae, color of pinnae, crown density, crown shape, trunk height, spathe length, peduncle width at the base and top, total length of basal and median rachillae, spathe length, prophyll length, total rachis length, mean number of acanthophylls are helpful tool to assess morphological diversity in Pakistani male date palm. This study would be helpful for researchers and growers in identification, selection and conservation of diverse male having superior traits and in other breeding programs. Keeping in view the metaxenial effect, the yield and quality of Pakistani dates can be enhanced.

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