Clustering of date palm (*Phoenix dactylifera* L.) cultivars using morphological and yield attributes as selection criteria

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Abstract

Thirty-two (32) date palm (*Phoenix dactylifera* L.) cultivars of diverse origin were characterized morphologically to assess the extent of inter-cultivar variability. These cultivars originated in parts of Pakistan, Iran, Iraq, and Saudi Arabia. A great magnitude of inter-cultivar variation was found in the set of date palm cultivars, not only in quantitative, but also in qualitative morphological characteristics. A multivariate (cluster) analysis of the date palm cultivars showed a lesser degree of similarity in qualitative morphological characters as compared to quantitative morphological characters. Based on qualitative morphological characters of the trunk and leaves, most of the cultivars from Punjab and two from Baluchistan were closely similar to each other, and a similar pattern of similarity was noted in their quantitative morphological characteristics. Characteristics like color of spines, number of leaflets per leaf, and size, shape, and color of fruits and seeds were found to be suitable morphological selection criteria for the exact identification of date palm cultivars. Date palm cultivars Dakki (from Khyber Pakhtunkhwa) and Chawara (from Baluchistan), and Hallawi-I (from Iraq) ranked better regarding fruit size, weight, and taste quality. Khudrawi (from Iraq) and Saib (from Punjab) were also likable, having large and tasty fruits.

Introduction

Genetic variability in date palm (*Phoenix dactylifera* L.) is extremely high, which may be due to wind pollination and hybridization potential (Ahmed et al., 2021; Othmani et al., 2024). As a result, many natural hybrids of date palm are available worldwide. It is estimated that over 5,000 identified cultivars of date palm are cultivated in different parts of the world (Flowers et al., 2019; Manikandan et al., 2025). Such genetic diversity is vital not only to improve the agronomic and commercial characteristics of date palms (Hawkesford and Griffiths, 2019; Kadri et al., 2025; Manikandan et al., 2025) but also for the adaptability potential to new environments (Hazzouri et al., 2020), in particular to abiotic stresses. However, intensive selections for the improvement of taste and fruit quality may

result in the depletion of genetic diversity of date palms in many countries (Bouguedoura et al., 2015; Younuskunju et al., 2024).

The main factors affecting the genetic variability in date palm have been identified as variable growth conditions (Guettouchi et al., 2022; Younuskunju et al., 2024), seed development from diverse parental crosses, pollination time, and variability in pollen from different male cultivars (Munir et al., 2020). All these have caused tremendous genetic diversity in date palm, particularly in its center of origin. Morphological characters such as leaf base width, leaf length, trunk thickness, pinna length and width, spathe length and weight, spine length and width, mean number of flowers on strands, and length of strands significantly differ among cultivars, and are considered the most important selection criteria for identification of date palm species and cultivars (Sharma et al., 2021). Percentage of spines on midrib part, maximal pinnae width at the top leaf, apical divergence angle, percentage of solitary spines, and spine length at the middle, and maximal spine angle can also be used for cultivar identification (Idris et al., 2023). Correct identification of palms is usually not possible until fruits are produced. Fruit weight, flesh thickness, flesh weight, and seed length and weight generally vary significantly between the cultivars (Hammami et al., 2024). The characterization of cultivars and evaluation of genetic diversity require a large set of phenotypic data that are often difficult to assess and sometimes variable due to environmental influences (El Kadri et al., 2019).

Pakistan is an important country, not only for the production of date palm on a commercial scale, but also for the huge genetic diversity of *Phoenix dactylifera* and other related species (*P. sylvestris* and *P. loureirii*) (Solangi et al., 2024). Identification and characterization of date palm have always been a challenge for taxonomists and horticulturists; therefore, the complete morphological-based characterization is the key to properly identify its cultivars, particularly at the vegetative stage (Manikandan et al., 2025). It was hypothesized that date palm cultivars should have differences in their qualitative and quantitative attributes because of exposure to microclimate and open pollination, which can be used as a selection criterion for identification. For this purpose, some identified cultivars were selected for the present study, which had been cultivated at the Date Palm Research Station, Jhang (Pakistan). All these cultivars belonged to diverse origins, i.e., all over Pakistan, Iraq, Iran, and other countries of the Middle East.

Materials and Methods

The Date Palm Research Station, Jhang, was surveyed to conduct qualitative and quantitative morphological characterization of date palm (*Phoenix dactylifera* L.) cultivars of diverse origins (**Table 1**), which were planted in 1956. The research station was visited during two seasons, first in April 2019 for recording vegetative characteristics, and second in June 2019 for reproductive characteristics and fruit collection (**Figure 1**).

Table 1: Origin of 32 *Phoenix dactylifera* L. cultivars planted at Date Palm Research Station, Jhang, Pakistan

| Origin	Cultivar name	Abbreviations	Cultivar name	Abbreviations
Punjab (Pakistan)	Akhrot	Akh	Rachna	Rac
	Angoor	Ang	Saib	Sab
	Champa Kali	ChK	Shaddo	Shd
	Jaman	Jam	Wahan Wali	WhW
	Neelam	Nlm	Zardoo	Zar
	Peela Doraa	PDr	Zeerin	Zrn
	Peeli Sundar	PSn		
Sindh (Pakistan)	Aseel	Asl	Karbaline	Kar
	Be Rehmi	BRh		
South Punjab/Sindh (Pakistan)	Danda	Dnd		
Baluchistan (Pakistan)	Begum Jangi	BJg	Makran	Mak
	Chawara	Chw	Jansohaar	Jso
	Kohar Ba	KhB		
Khyber Pakhtunkhwa (Pakistan)	Kokna	Kok	Dakki	Dak
Iran	Koozan Abad	KzA	Shamran	Shm
Iraq	Hallawi-1	Hl1	Khudrawi	Khd
	Hallawi-2	Hl2	Zaidi	Zad
The Middle East	Qantaar	Qnt		
Algeria and Tunisia	Daglat Noor	DNr		
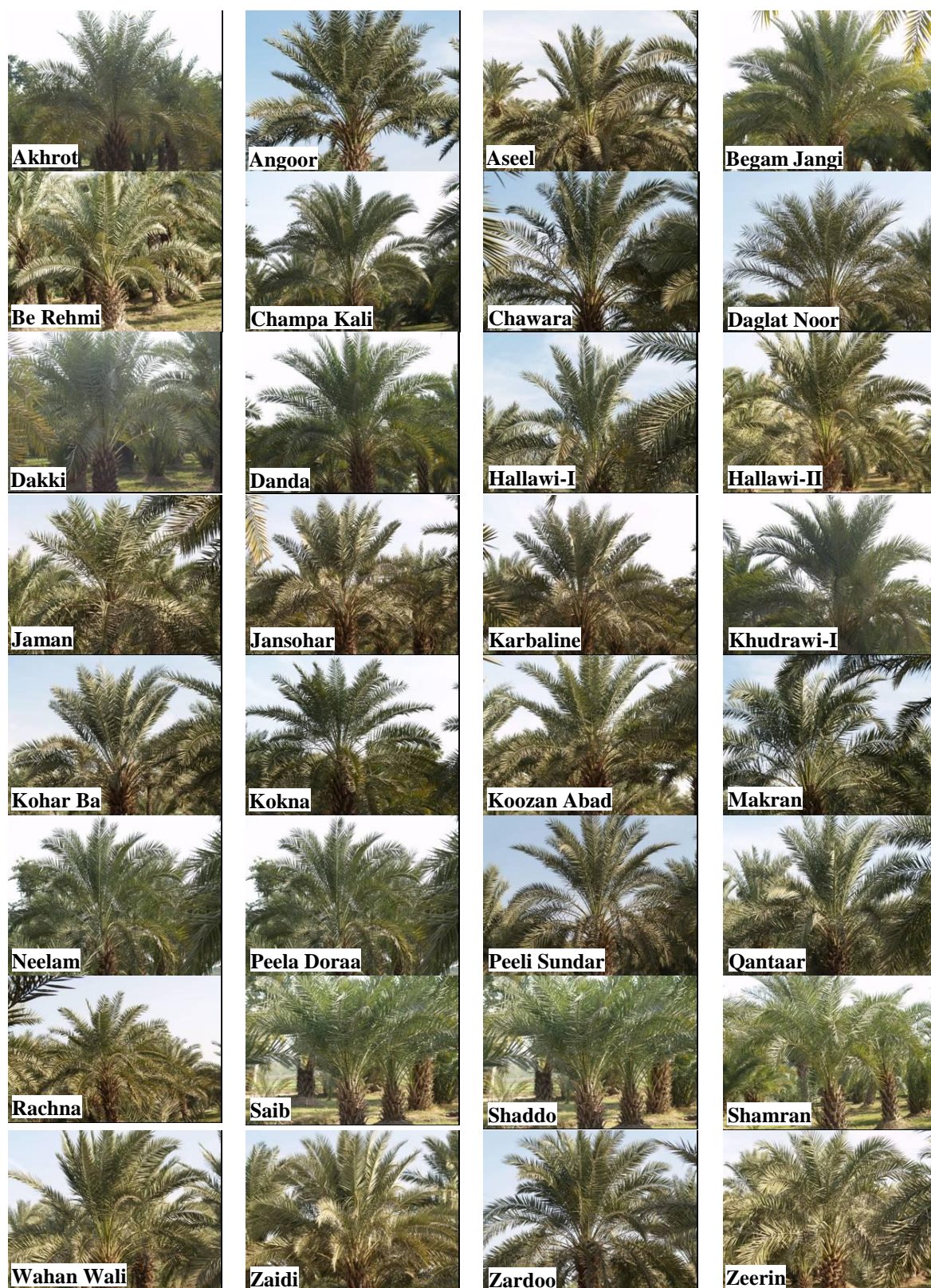
Figure 1: Photographs of the *Phoenix dactylifera* cultivars collected from diverse origins

The qualitative morphological characteristics observed during the investigation were trunk color (dark, pale, grey or ash), crown shape (dense, moderate, loose flat or loose open), leaf color (light green, green and dark green), spine color (yellowish green, brown green, light green, dark green or green with yellow tips), spathe color (brown, creamy brown or creamy), fruit shape (cylindrical, elliptical, obovate-elongate, obovate, ovate or sub-spherical), fruit color at maturity (red, dark red, yellow, brown yellow or orange yellow), and fruit taste (delicious, delicious-sweet or palatable). The quantitative characteristics were trunk radius, petiole length, leaf area, leaflet area, number of leaflets per leaf, spine length, spathe length, fruit area, fruit weight, seed area, and seed weight.

Statistical analysis

The morphological data were subjected to a multivariate analysis to assess the similarities and relationships among qualitative and quantitative morphological and yield characteristics using the Minitab Statistical Software (ver. 11.1). The clustering was performed using WARD minimum variance, and dendrograms were constructed based on similarities in observed qualitative and quantitative attributes. The quantitative attributes were directly fed to the software, while the qualitative attributes were treated as nominal variables. A dummy numeric value was then assigned to each nominal class of every qualitative attribute and used for cluster analysis.

Results

Qualitative morphological characteristics

Table 1 lists all cultivars examined in the present study along with their origins. Ashy color or dark appearance of the trunk were more common features in the date palm cultivars (**Table 2**), where the dark-color trunks were generally recorded in the cultivars from the Baluchistan province and ashy color in the cultivars from the Punjab province of Pakistan. Regarding the crown shape, loose and open from the middle was the most dominant feature, but it seemed not to be related to the origin of the cultivars (**Table 2**). Dense crown shape was recorded in four cultivars from Punjab (cvs. Akhrot, Angoor, Jaman, and Wahan Wali) and one (cv. Qantaar) from the Middle East.

Table 2: Qualitative morphological characteristics of trunk and leaf of *Phoenix dactylifera* L. cultivars planted at the Date Palm Research Station, Jhang, Pakistan

Characteristics	Variation
Trunk color	Dark color
	Pale color
	Grey
	Ashy color
Crown shape	Dense
	Moderately dense
	Loose and flat above
	Loose and open from the middle
Leaf color	Light green
	Green
	Dark green
Spine color	Yellowish green
	Brownish green
	Light green
	Dark green
	Green with yellow tips
Spathe color	Brown
	Creamy Brown
	Creamy

P–Punjab, PS–South Punjab/Sindh, S–Sindh, B–Baluchistan, KPK–Khyber Pakhtunkhwa, In–Iran, Iq–Iraq, ME–Middle East, AT–Algeria and Tunisia

Table 3: Qualitative morphological characteristics of fruit of *Phoenix dactylifera* L. cultivars planted at the Date Palm Research Station, Jhang, Pakistan

Characteristics	Variation
Fruit shape	Cylindrical
	Elliptical
	Obovate-elongate
	Obovate
	Ovate
	Sub-spherical
Fruit color at maturity	Red
	Dark red
	Yellow
	Brown yellow
	Orange yellow
Fruit taste	Delicious
	Delicious-sweet
	Palatable

P–Punjab, PS–South Punjab/Sindh, S–Sindh, B–Baluchistan, KPK–Khyber Pakhtunkhwa, In–Iran, Iq–Iraq, ME–Middle East, AT–Algeria and Tunisia

Many of the cultivars exhibited light green or green leaf color (**Table 2**), whereas cultivars from Punjab and Iraq generally displayed green leaves. Dark green leaves were recorded in only five cultivars: Peela Doraa (from Punjab), Karbaline (Sindh), Begum Jangi and Kohar Ba (Baluchistan), and Qantaar (the Middle East). Yellowish-green spines were the most common feature in the date palm cultivars (**Table 2**). However, green spines with yellow tips were recorded in Hallawi-2 (Iraq), dark green in Kohar Ba (Baluchistan), and Hallawi-1 (Iraq), and brownish green in Chawara (Baluchistan). The spathe color was brown in the cultivars from Punjab and Iraq, and creamy in those from Sindh and Baluchistan (**Table 2**). The creamy brown spathes were recorded in three cultivars (Akhrot, Champa Kali, and Jaman) from Punjab and one (Kokna) from Khyber Pakhtunkhwa.

Ten cultivars did not produce fruit during the experimental season, so it was not possible to collect their fruit data. Cylindrical or elliptical fruit shapes were more common in the cultivars listed in **Table 3**. Sub-spherical fruit was recorded in only one cultivar (Saib from Punjab), whereas cvs. Zardoo (Punjab) and Dakki (Khyber Pakhtunkhwa) showed obovate to elongate fruit shapes. Red and yellow fruits dominated among the cultivars (**Table 3**), where red was generally in cultivars from Sindh and yellow in those from Iraq. Brown-yellow fruit was only recorded in Peeli Sundar (from Punjab), orange-yellow in Rachna (Punjab), and dark red in Neelam (Punjab), Koozan Abad (Iran), and Zaidi (Iraq). The majority of the cultivars planted at the Date Palm Research Institute Jhang, had delicious fruits, whereas Chawara (Baluchistan) had delicious, sweet fruits (**Table 3**).

Quantitative morphological characteristics

The thickest stem was recorded in cultivar Zeerin (Punjab), followed by Hallawi-1 (Iraq) and Neelam (Punjab), which were about half of that recorded in cv. Zeerin (**Table 4**). Thin stems were recorded in cvs. Rachna and Wahan Wali (Punjab), Aseel (Sindh), Makran (Baluchistan), Dakki (Khyber Pakhtunkhwa), Zaidi (Iraq), and Daglat Noor (Algeria and Tunisia). The petiole length was over 100 cm in ten cultivars, where the thickest was recorded in Zardoo (Punjab), being much longer than that in cv. Chawara (Baluchistan). Three cultivars of Punjab (Champa Kali, Jaman, and Rachna) and one each of Khyber Pakhtunkhwa (Dakki) and Iran (Koozan Abad) had short petioles (**Table 4**). Large leaves were recorded in two cultivars of Punjab (Rachna and Saib) and one each of Baluchistan (Chawara), Iraq (Zaidi), the Middle East (Qantaar), and Algeria and Tunisia (Daglat Noor). Small leaves were recorded in Peela Doraa, Zardoo, and Zeerin (Punjab), Jansohar and Makran (Baluchistan), and Shamran (Iran).

Cultivars from Punjab (Shaddo) showed the maximum leaflet area (**Table 4**), which was approximately three-fold greater than that of the second next one cv. Makran (Baluchistan). The other cultivars showing leaflet area over 150 cm^2 were Neelam, Rachna, and Wahan Wali (Punjab), Danda (South Punjab/Sindh), Begum Jangi, Chawara, Jansohaar, and Kohar Ba (Baluchistan), Dakki (Khyber Pakhtunkhwa), Khudrawi and Zaidi (Iraq), and Daglat Noor (Algeria and Tunisia). Small leaflets were recorded in two cultivars from Punjab (Akhrot and Zeerin) and one each from Khyber Pakhtunkhwa (Kokna), Iran (Koozan Abad), and Iraq (Hallawi-1). The number of leaflets was the maximum in Zaidi (Iraq), which was closely followed by cvs. Rachna and Shaddo (Punjab), Danda (South Punjab/Sindh), Chawara (Baluchistan), and Aseel (Sindh).

Cultivar Peeli Sundar (Punjab) had the longest spines, being considerably higher than the second-best Kokna (Khyber Pakhtunkhwa). Cultivars Makran (Baluchistan) and Shamran (Iran) also showed long spines (**Table 4**). Two cultivars from Punjab (Akhrot and Zeerin) and one from Sindh (Be Rehmi) had much-reduced spines. Spathe length was the maximum in Karbaline (Sindh), which was followed by Champa Kali, Neelam, and Wahan Wali (Punjab), Kohar Ba (Baluchistan), and Koozan Abad (Iran).

Fruit area was the maximum in Dakki (Khyber Pakhtunkhwa), which was closely followed by Chawara (Baluchistan) and Khudrawi (Iraq). The maximum fruit weight was again recorded in Dakki (Khyber Pakhtunkhwa), and it was followed by that recorded in Chawara (Baluchistan), Khudrawi (Iraq), and Saib (Punjab). Seed area (**Table 4**), in contrast, was the maximum in Hallawi-1 (Iraq), which was followed by that in Chawara (Baluchistan), Saib (Punjab), and Khudrawi (Iraq). Seed weight, on the other hand, was the maximum in Peeli Sundar (Punjab), which was closely followed by Zeerin, Saib, and Wahan Wali (Punjab), Chawara (Baluchistan), and Dakki (Khyber Pakhtunkhwa).

Table 4: Quantitative morphological characteristics of *Phoenix dactylifera* L. cultivars planted at the Date Palm Research Station, Jhang, Pakistan

Cultivars	TRd (cm)	PtL (cm)	LfA (cm²)	LLA (cm²)	LLN	SpL (cm)	StL (cm)	FrA (cm²)	FrW (g)	SdA (cm²)	SdW (g)
Akhrot	15.91	100.71	13872.08	95.09	159.35	0.63	70.63	8.05	11.72	2.16	1.28
Angoor*	13.76	117.43	13391.20	145.83	120.37	1.52	74.48	–	–	–	–
Champa Kali*	14.24	61.20	12591.60	111.76	170.84	2.56	81.09	–	–	–	–
Jaman*	13.19	50.76	10320.72	137.52	144.67	2.12	54.06	–	–	–	–
Neelam	19.40	93.29	11550.53	150.37	161.64	4.76	88.16	9.68	11.12	2.32	1.46
Peela Doraa*	13.84	84.10	9359.92	120.35	150.87	2.98	77.38	–	–	–	–
Peeli Sundar	15.11	83.48	12950.12	130.01	178.21	7.01	55.72	8.88	7.83	1.89	1.65
Rachna	10.82	69.93	21360.11	156.09	209.49	3.91	53.30	8.32	9.40	1.83	0.78
Saib	14.32	78.32	20774.41	111.76	187.53	1.94	63.26	9.75	17.17	2.67	1.56
Shaddo*	14.94	88.62	16299.75	533.82	200.67	1.99	66.89	–	–	–	–
Wahan Wali	11.92	108.51	11775.27	166.14	181.23	1.85	92.24	5.95	7.93	2.13	1.51
Zardoo	14.55	186.29	9240.19	100.18	87.38	1.77	52.49	5.89	5.60	1.68	1.34
Zeerin	42.43	74.73	8753.15	91.74	156.12	0.64	31.29	8.14	10.11	2.41	1.58
Danda*	16.96	80.72	12250.13	175.01	214.77	2.83	59.06	–	–	–	–
Aseel	10.58	106.91	18095.21	128.65	190.21	1.40	59.22	8.82	11.47	1.68	1.17
Be Rehmi	14.79	92.36	10890.88	115.26	160.11	0.61	59.15	7.98	13.45	1.45	1.42
Karbaline	14.91	107.59	16500.76	111.25	182.24	2.13	104.17	7.80	13.03	1.52	1.12
Begum Jangi	16.96	94.51	15953.61	154.57	161.57	1.36	59.44	4.86	5.81	1.25	0.92
Chawara	15.89	125.56	23244.66	158.49	197.55	4.53	71.47	11.13	18.13	2.72	1.53
Jansohaar*	15.57	95.44	9600.29	175.12	168.91	2.09	65.91	–	–	–	–
Kohar Ba	13.80	91.41	17803.81	168.98	184.56	3.17	82.61	7.21	7.23	2.13	1.15
Makran	12.09	86.96	8400.21	288.10	172.48	5.14	56.39	5.67	8.22	1.47	1.12
Dakki	12.09	60.04	14940.21	160.11	169.03	2.57	35.91	12.15	18.17	2.34	1.53
Kokna*	15.67	74.06	12799.83	88.16	185.60	6.21	69.29	–	–	–	–
Koozan Abad	14.47	65.15	13200.12	80.06	186.28	4.09	84.03	4.18	7.24	1.18	0.87
Shamran*	16.94	93.29	8400.09	125.05	165.75	5.14	76.04	–	–	–	–
Hallawi-1	26.25	99.13	10880.05	67.20	167.36	2.38	55.29	6.84	7.83	4.25	1.05
Hallawi-2	16.35	85.19	12489.61	130.76	183.65	2.83	56.09	5.51	11.83	2.48	1.21
Khudrawi	16.62	103.32	15234.23	151.98	188.05	1.77	63.71	10.45	18.04	2.52	1.19
Zaidi	12.09	100.76	19240.02	180.99	227.07	2.09	59.19	7.82	9.78	1.54	1.13
Qantaar	14.67	97.32	19143.61	124.80	180.56	2.24	55.61	6.82	8.32	1.47	0.86
Daglat Noor*	12.72	120.34	23010.65	165.05	165.29	2.18	56.19	–	–	–	–

* Fruit data were not available because these species did not fruit at the study site

Abbreviations: TRd–Trunk radius; **PtL**–Petiole length; **SpL**–Spine length; **StL**–Spathe length; **FrA**–Fruit area; **FrW**–Fruit weight; **SdA**–Seed area; **SdW**–Seed weight; **LfA**–Leaf area; **LLA**–Leaflet area; **LLN**–Number of leaflets per leaf; **SdW**–Seed weight

Correlation studies

Pearson's correlation coefficients indicated a significant positive association of leaf area with leaflet number and fruit weight (**Table 5**). A negative correlation was recorded between petiole length and leaflet number. Seed weight showed a positive correlation with fruit area, fruit weight, and seed area. A significant positive correlation was observed among seed area, fruit weight, and fruit area.

Table 5: Pearson's correlation coefficient (*r*) among morphological characteristics of date palm cultivars collected from the Date Palm Research Station, Jhang

Variables	TRd	PtL	LfA	LLA	LLN	SpL	StL	FrA	FrW	SdA
PtL	-0.080									
LfA	-0.343	0.103								
LLA	-0.212	-0.026	0.123							
LLN	-0.158	-0.416	0.508	0.283						
SpL	-0.171	-0.212	-0.065	0.013	0.228					
StL	-0.316	0.102	0.012	-0.017	0.085	0.168				
FrA	0.107	0.119	0.336	-0.206	0.192	-0.053	-0.181			
FrW	0.063	0.072	0.353	-0.194	0.234	-0.130	-0.132	0.948		
SdA	0.313	0.148	0.174	-0.269	0.112	-0.081	-0.177	0.862	0.814	
SdW	0.192	0.197	0.145	-0.227	0.052	-0.064	-0.149	0.931	0.870	0.865

TRd–Trunk radius; **PtL**–Petiole length; **LfA**–Leaf area; **LLA**–Leaflet area; **LLN**–Number of leaflet per leaf; **SpL**–Spine length; **StL**–Spathe length; **FrA**–Fruit area; **FrW**–Fruit weight; **SdA**–Seed area; **SdW**–Seed weight

Positively significant at *P* ≤ 0.05   Negatively significant at *P* ≤ 0.05

Cluster analysis

Qualitative morphological characteristics showed a diverse pattern of clustering; however, quite a few cultivars of Punjab, such as Akhrot and Angoor, Neelam and Saib, Jaman, Wahan Wali and Shaddo, and Zardoo and Zeerin showed close clusters (**Figure 2**). More or less similar patterns were observed in the case of quantitative morphological characteristics, where a close clustering of the Punjab cultivars, i.e., Jaman and Neelam, Akhrot, Angoor, and Champa Kali, Peela Doraa and Zardoo, and Rachna and Saib was observed (**Figure 3a**). On the other hand, no specific pattern of clustering was observed in the case of qualitative and quantitative characteristics of fruit, where almost all cultivars clustered independently, irrespective of their origin, indicating dissimilarity in features of fruits that can be used for identification (**Figure 3b**).

Redundancy analysis

A close association of plants' petiole length and trunk radius was observed with Akhrot and Be-Rehmi, and Halwai-1 and Zeerin. Fruit and seed weight and area were associated with Dakki and Khud Rawi, while leaf number and area showed association with Rachna and Zaidi. Cultivars Makran and Koozan Abad were linked with leaflet area, spike length, and spathe length. Shamran, Jaman, Jansohar, Peela Doraa, and Angoor showed a close relationship regarding the recorded quantitative attributes. Whereas Chawara, Saib, Qantaar, Kohar Ba, Wahan Wali, Peeli Sundar, Karbaline, and Aseel assembled in a separate group. Other cultivars were plotted sporadically in the RDA plot since they did not show any link with qualitative morphological attributes (**Figure 4**).
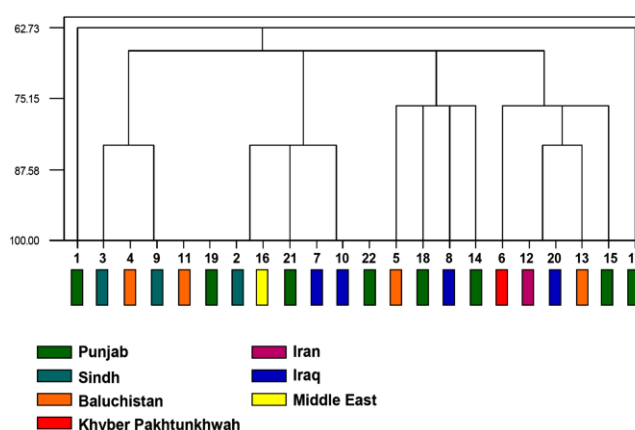

Fig. 2: Clustering of qualitative morphological characteristics of *Phoenix dactylifera* L. cultivars from diverse origins

1: Akhrot, 2: Angoor, 3: Aseel, 4: Be Rehmi, 5: Begum Jangi, 6: Chawara, 7: Champa Kali, 8: Danda, 9: Dakki, 10: Daglat Noor, 11: Hallawi-1, 12: Hallawi-2, 13: Jaman, 14: Jansohaar, 15: Karbaline, 16: Khudrawi, 17: Kohar Ba, 18: Kokna, 19: Koozan Abad, 20: Makran, 21: Neelam, 22: Peela Doraa, 23: Peeli Sundar, 24: Qantaar, 25: Rachna, 26: Saib, 27: Shaddo, 28: Shamran, 29: Wahan Wali, 30: Zaidi, 31: Zardoo, and 32: Zeerin

Discussion

Variations were observed in qualitative as well as quantitative morphological characteristics of the date palm cultivars examined in the present study, which were brought from diverse origins at the Date Palm Research Station, Jhang (Pakistan). This shows that date palm has great genetic diversity because of its cross-pollinating nature, as reported earlier (Naqvi et al., 2015; Kadri et al., 2024) in Egyptian date palm. Although date palm cultivars show a lot of diversity, vegetative morphological characters do not contribute significantly to cultivar identification (Bedjaoui and Benbouza, 2020). Vegetative characters could be important because they are fixed in the genotype evolutionary process and can play a decisive role in date palm selection and adaptation (Rivera et al., 2022).

In the present investigation, some morphological characteristics were common in most of the date palm cultivars, e.g., dark and ashy color of trunk, strongly bent leaves, and loose and open from the middle and moderately dense crown shape. However, considerable diversity was recorded in the cultivars to midrib and leaf colors. Leaf color is particularly associated with the intensity of leaf chlorophyll content (Bekheet and El-Sharabasy 2015; Huo et al., 2024). Therefore, cultivars Rachna and Shaddo (Punjab), Kokna (Khyber Pakhtunkhwa), and Karbaline (Sindh) may have better performance in terms of yield because of their dark green leaves.
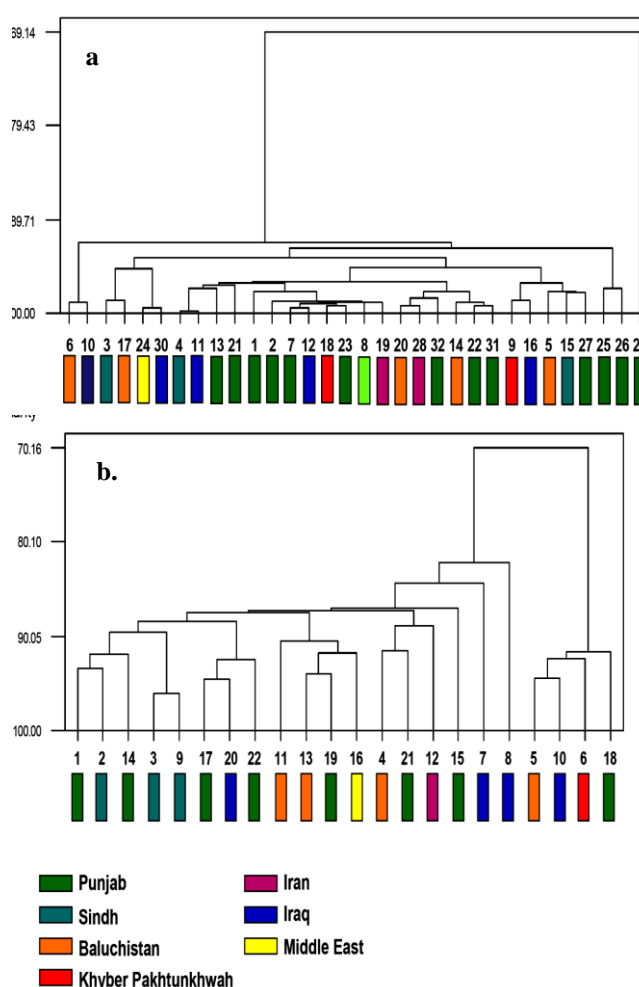

Figure 3: Clustering of quantitative morphological characteristics (a) and fruit yield attributes (b) of *Phoenix dactylifera* L. cultivars from diverse origins

1: Akhrot, 2: Angoor, 3: Aseel, 4: Be Rehmi, 5: Begum Jangi, 6: Chawara, 7: Champa Kali, 8: Danda, 9: Dakki, 10: Daglat Noor, 11: Hallawi-1, 12: Hallawi-2, 13: Jaman, 14: Jansohaar, 15: Karbaline, 16: Khudrawi, 17: Kohar Ba, 18: Kokna, 19: Koozan Abad, 20: Makran, 21: Neelam, 22: Peela Doraa, 23: Peeli Sundar, 24: Qantaar, 25: Rachna, 26: Saib, 27: Shaddo, 28: Shamran, 29: Wahan Wali, 30: Zaidi, 31: Zardoo, and 32: Zeerin

Considerable variation was observed in the fruit characteristics of the date palm cultivars. Fruit characteristics like shape and color at maturity are believed to play an important role in the identification of date palm cultivars (Sirisena and Ajlouni,2015; Sejpal et al., 2025). Variation in fruit color in date palm has also been reported by different researchers (Hazbavi et al., 2015; Al-Karmadi and Okoh, 2024). Variation in fruit color may have been due to the differential cultivar origins with different agro-climatic conditions. Carotenoids, anthocyanins, flavones, lycopene, flavo-xanthins, and lutein are the pigments responsible for fruit color (Bodian et al., 2014; Nabi et al., 2023). Anthocyanins are particularly produced due to fruit exposure to sunlight, and the inferior fruit quality is due to the reduced production of these compounds (Reshef et al., 2018). Shiny-skinned fruits in date palm cultivars correlated well with delicious taste, as also reported variations in fruit taste in some date palm cultivars (Bekheet and El-Sharabasy, 2015).

Some seed characters, like seed shape, varied significantly in the date palm cultivars, but the diversity for seed weight was not significantly different in date palm (Simozrag et al., 2016). The variation in spathe color was relatively low as most of the cultivars showed yellowish green spathe color; however, Atghaei et al. (2020) reported that spathe length plays an important role in species identification.

Trunk radius was the most variable character in the date palm cultivars, which is analogous to what was reported elsewhere (Arinkin et al., 2014; Khan et al., 2020; Hakim et al., 2021). Leaf characteristics are also important for the identification of date palm cultivars (Haider et al., 2015). Parameters, like leaf area, can be effectively used for the characterization of date palm cultivars. Considerable variation in leaf characters was recorded among the cultivars, which indicates that leaf characters could be of value in species identification. A great amount of variation in the number of leaflets per leaf among different date palm cultivars has been reported earlier (Nasser et al., 2016; Alaida and Aldhebiani, 2022). In the present study, considerable variation was recorded in the cultivars based on the number of leaflets, which seems to be an important parameter for cultivar characterization. Regarding spine characters, spine length was the most reliable quantitative characteristic in the date palm cultivars under investigation, as has earlier been reported in other cultivars (Bouguedoura et al., 2015; Hamad et al., 2015; Yaish et al., 2015; Solangi et al., 2025). They investigated that spine characters are specific for each cultivar, and therefore, can be used for the characterization and identification of date palm cultivars.

The variation in fruit characters was reasonably high in the date palm cultivars studied in the present investigation. Fruit characters are important not only in the identification of date palm cultivars (Alam et al., 2021), but also for commercial grading, based on physical characters and general appearance of fruits (Ibourki et al., 2021). High genetic variability in fruit attributes like area and weight has been reported by many authors (Al-Najm et al., 2016; Hassanzadeh Khankahdani and Bagheri, 2019; Huda et al., 2019; Kadri et al., 2024). Seed characters (seed area and weight) also showed high variation. Variation in seed characters has already been reported in date palm cultivars (Gros-Balthazard et al., 2016; Salomon-Torres et al., 2017; Solangi et al., 2025).

Conclusion

Overall, a great magnitude of variation was present in the date palm cultivars of different origins. Such variation was based on both quantitative and qualitative morphological attributes. This variation is important for morphological characterization, differentiation, and identification of date palm cultivars, as they are expected to be fixed during the long evolutionary history. The most promising cultivar was Chawara (Baluchistan), characterized by long petioles, large leaf area, and fruit and seed area and weight. Fruits were sweet and delicious, yellow coloured and oval. The second best was Dakki (Khyber Pakhtunkhwa), which showed the largest and heaviest fruits. Vegetative traits generally showed no correlation with yield contributing traits; only leaf area positively correlated with fruit weight. All fruit and seed traits significantly correlated with each other. In general, qualitative characteristics varied greatly, and it was cultivar-specific.

Author(s), Editor(s) and Publisher's declarations

Contribution of authors
Conceptualization and designing of the research work: MN, MH, FA, MSAA. Statistical data analysis: MN, MSAA, SF, SB, ZP. Preparation of initial draft: MN, MH, FA, MSAA, SMRS, JS, AA, ZP. Proofreading and approval of the final version: All authors.

Permissions and ethical compliance
This study does not involve human/animal subjects, and thus no ethical approval is required.

Handling of bio-hazardous materials
The authors certify that all experimental materials were handled with great care during collection and experimental procedures. After completion of the study, all materials were properly discarded to minimize/eliminate any types of bio-contamination.

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No supplementary material is included with this manuscript.

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The authors declare no conflict of interest.

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Authors' consent
All authors have critically read this manuscript and agreed to publish in IJAaEB.

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It is declared that the authors did not use any AI tools or AI-assisted services in the preparation, analysis, or creation of this manuscript submitted for publication in the International Journal of Applied and Experimental Biology (IJAaEB).

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