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Research Article

Characterization of palm date varieties (*Phoenix dactylifera* L.) growing in Saudi Arabia: Phenotypic diversity estimated by fruit and seed traits

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Abstract

In order to determine the variation and the degree of diversity among the most well-known Saudi date palm (*Phoenix dactylifera* L.), this study applied various widely detectible fruit and seed features. The properties of the fruit and seeds were described using ten phenotypic traits. Eighteen date palm varieties from six production sites were used in this study (Ḥa'il, Al-Madina, Al-Hassa, Al-Qassim, Kharaj, Najran). The data was analysed by Pearson r correlation. The principal components analysis (PCA) and UPGMA clustering were used to analyse the data set. According to PCA, the results showed significant variation among the analysed varieties. Our data shows that seed ratio varies among all varieties. The mean seed weight ratio varies between 4 and 13%. Varieties 'Raziz', 'Lubab' and 'Wasily' demonstrate higher seed ratio (over 10%). Whereas, Fankha depicts a 5 and 4% fresh and dry seed ratio. The statistical analysis indicates that the seed ratio in all 18 varieties is comparable in fresh and dry fruits. The result suggests variation among the numerous features due to dissimilarities and heterogeneity. However, the obtained results also propose the clustering and grouping of closely related features, e.g., weights of fresh and dry fruits. Eventually, it is suggested to conduct additional research on Saudi date palms utilizing more phenotypic traits in order to have a better understanding of the pack of morphological descriptors.

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Keywords: date palm (*Phoenix dactylifera* L.); Pearson r correlation (PRISM Graphpad, San Diego USA); PCA; phenotypic diversity Saudi palm date cultivars; UPGMA

Introduction

The palm date (PD) *Phoenix dactylifera* L, has remained an essential part of Arabian cuisine. In numerous countries, in North Africa, South-East Asia, the Middle East and arid and semiarid regions of America, the palm date contribute significantly to the sustenance of the agricultural industry (Al-Farsi and Lee, 2008; Sghaier-Hammami *et al*., 2009; Basu *et al*., 2014). Saudi Arabia is one of the leading dates producing nations (FAOSTAT, 2020). In fact, date fruits are an integral part of the Saudi diet.

Date palm's economic significance stems from its nutritional value which constitutes 72 to 88 percent sugar and nutrients (such as copper, magnesium, chlorine, iron, potassium, calcium phosphorus and sulphur), as well as vitamins and amino acids (Al-Shahib and Marshall, 2003).

PDs' primary and secondary metabolites are controlled by growing conditions such as temperature, rainfall, soil characteristic, etc. (Abdul *et al*., 2015). One of the often-used strategies to determine the degree of diversity and variation in PD is the use of morphological parameters (quantitative and qualitative traits). It has therefore been widely believed that characteristics linked to either the vegetative or the fruit parameters are helpful for date palm characterization (Shabana and Mawlod, 1983; Bouabidi *et al*., 1996; Elhoumaizi *et al*., 2002). Several teams have described the morphological characterizations (quantitative and qualitative) of the PD in Saudi Arabia (Jaradat and Zaid, 2004; Al-Khalifah *et al*., 2012, Khankahdani and Bagheri, 2019) and also molecular characterization using AFLP, ISSR, RAPD markers (Sabir *et al*., 2014; Abdulla and Gamal, 2010; Aljuhani, 2016). In addition, several Saudi cultivars were metabolically characterized to evaluate their nutritional value (Hamad *et al*., 2015). Sayqal *et al*. (2020) utilized crystal-based mid-infrared spectroscopy for fingerprinting study to distinguish between Saudi dates fruits for food adulteration. Likewise, nine KSA varieties were studied based on their phytochemical characteristics, physical properties, and biological activities (Abdul-Hamid *et al*., 2020). Morphological traits of Saudi Arabian date palm cultivars based on vegetative and reproductive attributes were investigated. Nowadays, for varieties identification, conservation, use, and advancement in fruit crops, the characterization of germplasm is crucial (Mehmood *et al*., 2013). Indeed, this characterization necessitates many phenotypic data, some of which can be difficult to quantify due to susceptibility to environmental influences (Rao, 2004), or change in the plant's progressing developmental phases. In addition, genetic degradation, the conversion of agricultural land, pests, and diseases are threats to this significant harvest (Alhudaib *et al*., 2022). This issue has been addressed in numerous research, which has classified different DP cultivars using either molecular markers (Sabir *et al*., 2014; Zehdi *et al*., 2012) or phenotypic information (Ahmed *et al*., 2011). When describing DP ecotypes, phenotypic diversity, and phylogenetic relationships, vegetative characteristics are useful.

Similar to this, different areas' growth conditions cause differences both inside and outside of the PD fruits. The observed alterations in the colour, size and chemical composition of date fruits are frequently used to categorize such changes.

It is important to have a better understanding of these cultivars, including morphological, chemical, biochemical, and particularly the degree of kinship, in order to preserve this heritage.

The main Saudi date varieties have been the subject of some studies with the aim of analysing the pomological, physicochemical, biochemical, and biological aspects of dates and classifying them according to particular standards. The examination of the variability of characteristics indicating the degree of kinship has, however, only been the subject of a very small number of research.

The current research's objective was to study the morphological variation of the fruits of 18 Saudi Arabian DP cultivars from the eastern, western, and central parts of the Kingdom based on fruit and seed attributes, at the stage called 'Tamar'. Therefore, 10 quantitative parameters, which are easily recognized, regarding the pulp and seed of the fruit were the focus of this investigation. The data was analysed by Pearson r correlation. The principal components analysis (PCA) and UPGMA clustering were used to analyse the data set.

Materials and Methods

Material sampling

Palm date fruits were purchased from the local markets in Hail, Al-Madina and Al-Hassa KSA (September 2021) (Figure 1). The collected fruit was botanically identified, and voucher specimens were deposited at the department of biology, College of Sciences with different accession numbers. The cultivars studied are presented in Tables 1 and 2

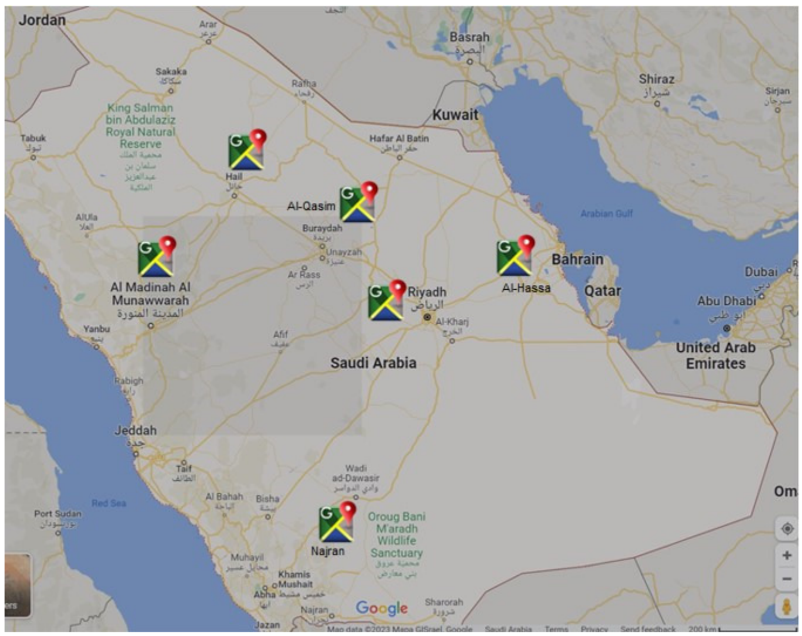

Figure 1. Saudi Arabian region's topographic map with the locations of the sample origins
1: Ḥail, 2: Al-Madina, 3: Al-Hassa, 4: Al-Qassim, 5: Kharaj, 6: Najran

Fruit materials

The eighteen Saudi palm date selected cultivars: 'Sukkari' (SUK), 'Fankha' (FAN), 'Ajwa' (AJW), 'Segae' (SEG), 'Sultana' (SUL), 'Barhi' (BAR), 'Miskani' (MIS), 'Shaqra' (SHA), 'Majdwal' (MAJ), 'Anbara' (ANB), 'Raziz' (RAZ), 'Luban' (LUB), 'Shishy' (SHI), 'Shalabi' (SHL), 'Khalas' (KHA), 'Wasilay' (WAS), 'Zamili' (ZAM), 'Mabrum' (MAB) (Table 1) have been cultivated in the six regions (Hai, Medina, Kharj, Najran, Al-Qassim, Al-Hassa) in the three location (eastern, western and central part of the Kingdom) of Saudi Arabia (Figure 1). All varieties were attained at the Tamar stage and identical treatment was given.

Fruit, pulp and seed weights

A composite sample made up of 10 fruits from each region underwent morphometric analysis. In fact, an analytical balance (Denver mark. Germany) was used to determine the weight of the entire date, including the pulp and seed.

Fruits dimensions

Using a manual calliper, the length and width of the fruits and seeds were measured in centimeters. Twenty fruits were used for each measurement.

Table 1. Detailed information of the studied verities: cultivars name, code, fruit class, sampling location coordinates (E, N), elevation and location

No	Cultivars	Abbreviation	Fruit class	E	N	Elevation	Sampling Location
1	'Sukkari'	SUK	Semi Soft	26.2852700	43.6257025	650	Al-Qassim
2	'Fankha'	FAN	Semi Soft	27.426875	41.609860	1001	Ḥa'il
3	'Ajwa'	AJW	Soft	24.4464900	39.6383654	636	Al-Madina
4	'Segae'	SEG	Dry	24.255793	47.192523	1360	Kharj
5	'Sultana'	SUL	Dry	27.426875	39.6383654	1001	Ḥa'il
6	'Barhi'	BAR	Soft	27.426875	39.6383654	1001	Ḥa'il
7	'Miskani'	MIS	Semi Soft	27.426875	39.6383654	1001	Ḥa'il
8	'Shaqra'	SHA	Dry	27.426875	39.6383654	1001	Ḥa'il
9	'Majdwal'	MAJ	Semi Soft	24.4464900	39.6383654	636	Al-Madina
10	'Anbara'	ANB	Dry	24.4464900	39.6383654	636	Al-Madina
11	'Raziz'	RAZ	Semi Soft	25.409879	49.651288	150	Al-Hassa
12	'Liban'	LUB	Semi Soft	17.563156	44.328094	1210	Najran
13	'Shaishee'	SHI	Semi Soft	25.409879	49.651288	150	Al-Hassa
14	'Shalabi'	SHL	Semi Soft	25.409879	49.651288	150	Al-Hassa
15	'Khalas'	KHA	Soft	25.409879	49.651288	150	Al-Hassa
16	'Wasilay'	WAS	Dry	25.409879	49.651288	150	Al-Hassa
17	'Zamili'	ZAB	Dry	25.409879	49.651288	150	Al-Hassa
18	'Mabrum'	MAB	Semi Soft	24.4464900	39.6383654	636	Al-Madina

Table 2. Analysed parameters and their codes

Character	Code
Fresh weight	FW
Dry weights	DW
Fresh seeds weight	FSW
Dry seeds weight	DSW
Fruits length	FL
Fruits width	FW1
Seeds length	SL
Seeds Width	SW

Statistical analysis

All experiments were conducted in triplicate, and all mean ± SD and standard errors were calculated using Microsoft Excel software. In order to distinguish the quantitative traits that significantly contribute to the variability among the studied cultivars, the mean values for 8 were submitted to principal components analysis (PCA) (Sneth and Sokal, 1973). Eight quantitative fruit traits were clustered separately using the Euclidean distance matrix and the unweighted pair-group method with arithmetic average (UPGMA) methods (Michener, 1958). Statistical analyses were done using linear regression (PRISM Graphpad, San Diego-USA). The data was analysed by Pearson r correlation. Heatmap were plotted using R-Studio (ver. 2022) to show the density of each variable against the species. Principle component analysis (PCA) to find the clusters of the sample based on their similarity was performed using R-Studio (ver. 2022). The phylogenetic lineages between the various species were analysed. Dissimilarity matrixes were used to construct dendrograms using the unweighted pair group method with arithmetic average (UPGMA) using R-Studio (ver. 2022).

Results and Discussion

We studied the phenotypic diversity among the topmost Saudi DP varieties; overall 10 quantitative traits were investigated and documented.

A wide range of variability in the measured parameters was observed by our investigations (Tables 3 and 4, Figure 2). Profound diversity was observed especially in length-width ratio, size, fruit texture and ripening, the shape of the fruit, softness, fruit-base. Previous studies on the characteristics of the DP have also shown similar conclusions (Salman Haider *et al*., 2015). In this study, in order to determine the phenotypic diversity in 16 Pakistani date palm varieties they investigated 42 characters. The researched parameters were crucial for identifying cultivars since, most of the traits are susceptible to environmental factors, quality assurance, resistance to diseases, and stress.

For statistical analysis, PCA was used for character identification and measurement while, a high positive and negative correlation between all analysed traits was seen via Pearson's r correlation. Similar results were reported by Salman *et al*. (2015).

Table 3. Ten quantitative phenotypic traits of Saudi date palm studied varieties' mean values

	FW	DW	FSW	DSW	FL	FW1	SL	SW	WFFW	WDFW
SUK	9.53±0.65	10.94 ±0.94	1.08±0.10	1.11±0.12	3.44	2.45	1.92	0.88	9%	10%
FAN	18.06±1.08	19.03±1.56	0.75±0.10	1.06±0.10	5.21	2.87	2.43	0.78	5%	4%
AJW	9.38±1.02	10.98±1.34	0.95±0.10	1.23±0.10	3.57	2.50	2.14	0.89	10%	9%
SEG	11.21±1.07	11.73±1.65	0.7±0.10	0.77±0.11	4.19	2.37	2.29	0.76	6%	6%
SUL	9.74±1.20	10.20±1.38	0.71±0.10	0.78±0.10	3.75	2.53	1.86	0.70	7%	7%
BAR	9.62±1.22	9.93±1.74	0.63±0.10	0.69±0.10	3.01	2.51	1.61	0.82	7%	6%
MIS	8.34±1.14	9.44±1.29	0.77±0.10	0.88±0.11	3.45	2.11	1.83	0.79	9%	9%
SHA	7.78±1.49	8.20±1.66	0.82±0.10	0.84±0.12	3.58	2.27	1.97	0.89	10%	10%
MAJ	12.29±1.24	12.73±1.65	0.89±0.11	0.92±0.14	4.46	2.44	2.37	0.78	7%	7%
ANB	11.61±1.34	12.12±1.76	0.96±0.13	1.06±0.14	5.57	2.59	2.67	0.73	8%	8%
RAZ	5.22±0.27	5.48±0.42	0.73±0.10	0.75±0.11	2.55	2	1.65	0.68	12%	12%
LUB	4.45±0.61	4.55±0.63	0.63±0.10	0.7±0.15	3.18	1.67	1.95	0.66	13%	13%
SHI	9.73±0.75	10.26±0.96	0.66±0.10	0.7±0.10	3.75	2.65	2.21	0.70	6%	6%
SHL	8.51±0.81	9.34±0.84	0.9±0.10	0.94±0.11	3.42	2.56	1.87	0.81	9%	10%
KHA	6.26±0.39	6.69±0.46	0.69±0.10	0.73±0.12	3.47	2.18	1.98	0.66	10%	10%
WAS	6.77±0.96	6.96±0.98	0.95±0.10	0.99±0.12	3.49	2.27	2.13	0.80	13%	13%
ZAM	8.97±0.59	9.34±1.08	0.83±0.11	0.85±0.13	3.49	2.48	1.93	0.71	8%	9%
MAB	8.91±1.12	9.10±1.21	0.75±0.10	0.84±0.10	4.13	2.05	2.43	0.63	8%	8%

Table 4. The mean (n = 10) weight, length, and Width of the fresh (F) vs dry (D) seeds (gms)

No	Varieties	Fruits weight		Seeds weight		DF/ DS	DS/ DF %	SL/ FL	SW/ FW
		FF	DF	FS	DS				
1	SUK	10.94 ±0.94	9.53±0.65	1.11±0.12	1.08±0.10	8.82	11.3	60.3	60.5
2	FAN	19.03±1.56	18.06±1.08	1.06±0.10	0.75±0.10	25.09	4.1	0.27	70.4
3	AJW	10.98±1.34	9.38±1.02	1.23±0.10	0.95±0.10	9.87	10.1	60.3	0.60
4	SEG	11.73±1.65	11.21±1.07	0.77±0.11	0.7±0.10	16.01	6.2	0.32	50.5
5	SUL	10.20±1.38	9.74±1.20	0.78±0.10	0.71±0.10	13.71	7.2	80.2	0.50
6	BAR	9.93±1.74	9.62±1.22	0.69±0.10	0.63±0.10	15.26	6.5	30.3	0.53
7	MIS	9.44±1.29	8.34±1.14	0.88±0.11	0.77±0.10	10.83	9.2	0.37	0.53
8	SHA	8.20±1.66	7.78±1.49	0.84±0.12	0.82±0.10	9.48	10.5	0.40	0.55
9	MAJ	12.73±1.65	12.29±1.24	0.92±0.14	0.89±0.11	13.80	7.2	20.3	0.53
10	ANB	12.12±1.76	11.61±1.34	1.06±0.14	0.96±0.13	12.09	8.2	0.28	80.4
11	RAZ	5.48±0.42	5.22±0.27	0.75±0.11	0.73±0.10	7.15	13.9	0.34	50.6
12	LUB	4.55±0.63	4.45±0.61	0.7±0.15	0.63±0.10	7.06	14.15	0.40	0.61
13	SHI	10.26±0.96	9.73±0.75	0.7±0.10	0.66±0.10	14.74	6.7	60.2	90.5
14	SHL	9.34±0.84	8.51±0.81	0.94±0.11	0.9±0.10	9.45	10.57	20.3	50.5
15	KHA	6.69±0.46	6.26±0.39	0.73±0.12	0.69±0.10	9.07	11.02	0.30	70.5
16	WAS	6.96±0.98	6.77±0.96	0.99±0.12	0.95±0.10	7.12	14.03	0.35	0.61
17	ZAB	9.34±1.08	8.97±0.59	0.85±0.13	0.83±0.11	10.80	9.25	90.2	0.55
18	MAB	9.10±1.21	8.91±1.12	0.84±0.10	0.75±0.10	11.88	8.41	10.3	90.5

Figure 2. The fruit, seeds and seed powder of *Phoenix dactylifera* cultivars (1: 'Ajwa' 2: 'Wasilay' 3: 'Ruzeiz' 4: 'Mabroom' 5: 'Anbara' 6: 'Shalabi' 7: 'Fankha' 8: 'Shaqra' 9: 'Majdwal' 10: 'Zamili' 11: 'Segae' 12: 'Miskani' 13: 'Khalas' 14: 'Sukkari' 15: 'Sultana' 16: 'Barhi' 17: 'Shaishee' 18: 'Luban').

Fresh and dry fruit weights with and without seed comparison

The fresh weight was measured at the harvest and dry fruits weight was measured after 3 months of storage. The mean weight of the fresh vs dry fruits without seeds (Figure 3 A and B) are revealed in Table 4. Graphic presentation of fresh and dry fruits weights of date fruits without (A) and with seed (whole fruit) (B). Figure 3 demonstrates the data gathered from 18 different date varieties collected throughout KSA. In both graphs, the fresh fruit data is plotted against dry fruit data. Each black dot shows the mean value (n = 10) for each variety. The data were analysed using linear regression (PRISM Graphpad, San Diego-USA). The black line in both graphs indicates the diagonal isoeffective line. The data is statistically significant (P< 0.0001) for both A and B graphs. The goodness of Fit (0.9779) and (0.9763) for A and B, respectively.

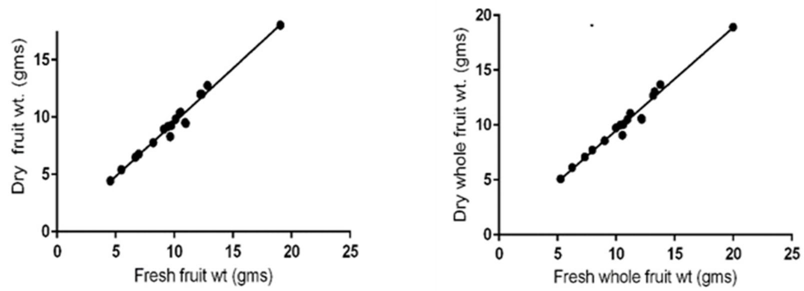

Figure 3. Graphic presentation of fresh and dry fruits weights of date fruits without (A) and with seed (whole fruit) (B)

Fresh vs dry seeds weihgts

The data represents the seed weights (n = 10) (Figure 4). The fresh weight was measured at the harvest and dry fruits weight was measured after 3 months of storage. The varieties and the mean weight of the fresh vs dry fruits seed are shown in table 5. Graph 4 presents fresh and dry seeds weights of date fruits. The graphs demonstrate the data gathered from 18 different date varieties collected throughout KSA. The fresh seed weight is plotted against dry seed. Each black dot shows the mean value (n = 10) for each variety. The data were analysed using linear regression (PRISM Graphpad, San Diego-USA). The black line in both graphs indicates the diagonal isoeffective line. The data is statistically significant (P< 0.0001). Goodness of Fit (0.9078).

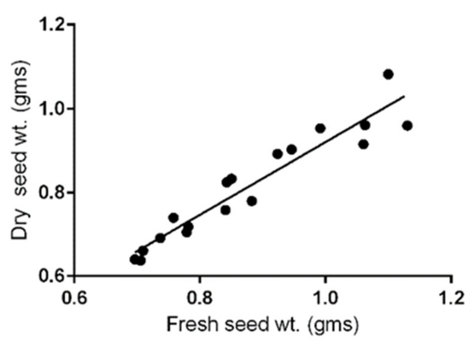

Figure 4. Graphic presentation of fresh and dry seeds weights of date fruits.
The graphs demonstrate the data gathered from 18 different date varieties collected throughout KSA. The fresh seed weight is plotted against the dry seed. Each black dot shows the mean value (n = 10) for each variety. The data were analyzed using linear regression (PRISM Graphpad, San Diego-USA). The black line in both graphs indicates the diagonal isoeffective line. The data is statistically significant (P< 0.0001). The goodness of Fit (0.9078).

Seed ratio (by weight) in whole fresh and dry fruits

We measured and compared the seed ratio by weight in whole fresh fruit (WFF) and whole dry fruit (WDF) across all the varieties included in our study. The data represents the mean (± SD) (n = 10). Our data shows that seed ratio varies among all varieties. The mean seed ratio varies between 4 and 13%. Varieties Raziz (RAZ), Lubab (LUB) and Wasily (WAS) demonstrated higher seed ratio (over 10%). In comparison Fankha (FAN) depicts 5 and 4% fresh and dry seed ratio (Figure 5). Furthermore, our data indicated that the seed ratio in all 18 varieties is comparable in fresh and dry fruits.

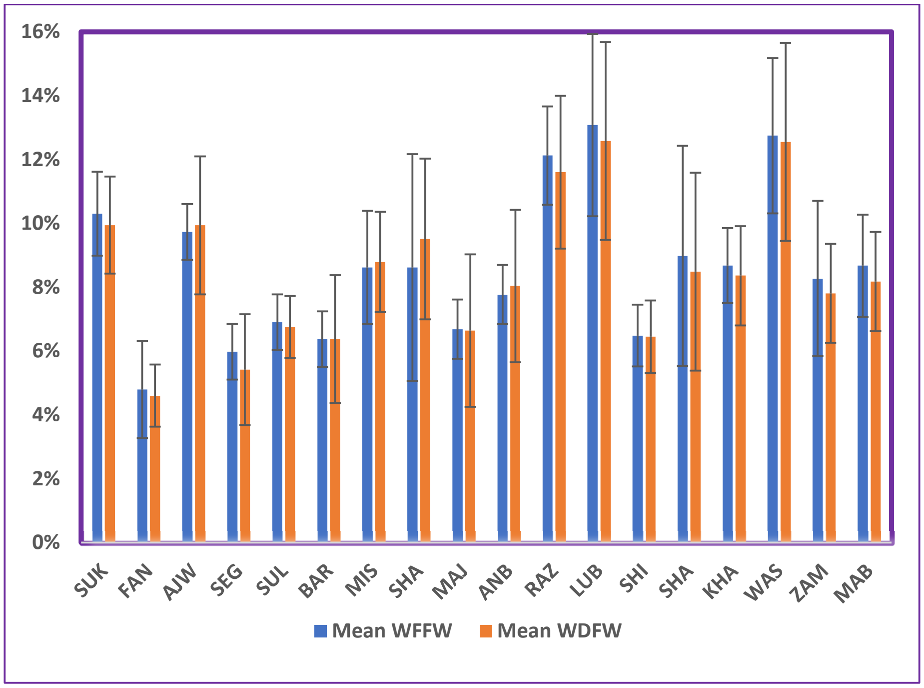

Figure 5. The mean (± SD) seed ratio by weight (gms) in whole fresh fruit (WFF) and whole dry fruit (WDF) across all 18 varieties are demonstrated by bar graphs

Correlation of 10 structural features among 18 varieties:

Altogether we characterized eight different structural features (Fresh Fruit weight (FFwt), dry fruit weight DFwt, whole fresh fruit weight (WFFwt), whole dry fruit weight (WDFwt), seed length (SL), seed width (SWd), fruit length (FL) and fruit width (FWd)) among 18 different dates varieties. The data was analyzed by Pearson r correlation. The data (Figure 5) suggests variation among the numerous features due to dissimilarities and heterogeneity e.g., FL, FWd, FFWt, SL, and SWd. However, the data also propose the clustering and grouping of closely related features e.g weights of fresh and dry fruits.

Data for 18 palm date investigated verities according to ten pomological traits are given in Table 4. The results indicated a high variation between samples. Although, the results showed the maximum length of date is for FAN (over 5.21 cm). The fruit of the FAN variety has an elongated shape, with size being the highest length. FAN dates seem to contain more flesh than other varieties. It is noted for dates of the RAZ variety for the minimum length (2.55 cm). The width is ranged from minimum a of 1.67 cm for LUB dates to a maximum of 2.87 cm for FAN dates. Between 12.73 g for MAJ dates and 4.55 g for LUB dates, on average, are recorded as the fresh weights. Likewise, the result is the same for the dry weight.

To differentiate between date palm varieties, many traits are considered, such as physical properties (the color, shape, size, and texture of the fruit) and their nutritional/organoleptic properties, such as flavor of the fruit (Baliga *et al*., 2011, Abdul-Hamid *et al*., 2020). Likewise, through the physical features, fruit and seed weight and the length and diameter of fruit were noticeably variable between varieties.

Climate (Table 5) and cultural practices that vary between the production sites, as well as the met axenic effects brought on by the usage of various pollinators, could be used to explain differences between the six origins.

The traits P1 (weight of the seed / weight of the fruit), P2 (length of the seed/ length of the fruit) and P3 (width of the seed / width of the fruit) (Table 4) show significant variability between different varieties. P1 varies from 14.15 for the cultivar LUB to 4.1 for the cultivar FAN. These variations could result from the traits of cultivars or the results of pollination. A fruit of inferior quality is indeed produced either by poor or absent pollination.

Table 5. Principal climate traits of the six date palm growth regions in the three provinces of KSA

	Hail	Al Medina	Al Kharj	Al Hasa	Najran	Al-Qassim
Soil type	Mountains, sandy and volcanic rocks	Clay- sandy	Mountainous and sandy	Sandy	Mountains	Rocky Mountains and sandy
Summer climate °C	40,5	43,8	*48*	44,2	*,829*	45
Winter climate °C	3,8	12	*5*	10,5	8,2	3
Precipitation (mm)	69	58	84	88	68,0	110
Humidity %	34	40	-	-	-	49

https://www.worlddata.info/asia/saudi-arabia/climate.php#google_vignette

The current study evaluated the width and length of the palm date fruit DPF as well as the seed to weight mass ratio as physical features of (PDF). Table 4 contains a summary of this data. Regarding the dimension parameters, there were notable variability across the dates, particularly for the FAN variety. The AJW had relatively medium sized fruits, albeit being one of the most expensive and marketable. It has dimensions of 2.5 cm in width and 3.57 cm in length. Among all the studied samples, the FAN dates were found to have the longest length (5.21 cm).

Between AJW, SHA, and ZAB, there were no significant variations in the seed-per-fruit mass ratio. With 14.15 g, the LUB cultivar showed the highest seed-to-weight mass ratio. The FAN cultivar, with a seed-per-fruit mass ratio of 4.1 g, had the lowest value.

Location and cultivar significantly affected fruit size (length, width) and weight as well as seed size (length, width) and weight, but not necessarily frond length, and width (Table 3 and 4)

In a recent study conducted in Al-Hassa (our studied six varieties were grown in this region: Raziz, Shishy, Shalabi, Khalas, Wasilay and Zamili) (Almadini *et al*., 2021), the author demonstrated that there is a remarkable difference in soil fertilization practices between the old and new oases. The average number of date palm trees per farm and the amount of agricultural land used were affected by these differences in farm locations between the old and new oases, favoring the new oasis over the older one (Almadini *et al*., 2021).

These findings are likely the result of the poor soil fertility and improper agricultural management practices employed by the farmers in the oasis, as suggested by other researchers and as well (Erskine *et al*., 2004; Almadini *et al*., 2021). Likewise, the findings of other researchers support the improvement of date palm output through soil fertilization practices (Kassem, 2012; Elamin *et al*., 2017).

Climate variations, cultural practices that differ across production sites, met axenic effects brought on by the employment of various pollinators, and other factors could all be used to explain differences between the seven origins.

Accurate estimations of genetic variation within and among gene pools in this center of origin and center of diversification, especially for fruit quality parameters, are crucial factors to take into account for a successful date palm industry.

Jaradat and Zaid (2004) studied 203 cultivars from Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates), and described that there is difference between the three different regions in KSA: eastern, western and central. Indeed, they show that in the western region, very big fruit size, in eastern region ovate/ovate-elongate fruit and in the central region, the main characteristic is late ripening fruit.

In a recent study published in September 2022, it was reported that the morphological traits of 14 varieties cultivated in Al-Madina regions using three main traits related to fruit, seed and trunk. They further demonstrated that fruits and seeds stood out, whereas the trunk was the least distinctive feature (Alaida and Aldhebiani, 2022).

The examined palm date cultivars may constitute a complex gene pool within which recent introductions, historical mobility of germplasm, and human selection are influencing the genetic structure, according to the overall partitioning of genetic diversity based on fruit and seed attributes (Jaradat and Zaid, 2004). The date palm, which is a cultivar without the advantages of a dynamic mutation-recombination system, is represented by discrete clones that were produced through clonal propagation (Wrigley, 1995). Few research groups study the genetic variability of palm date. In fact, Elmeer *et al*. (2011) study the assessing genetic diversity of Shishi date palm cultivars in Saudi Arabia and Qatar using microsatellite markers. In this study the authors showed that the sexual propagation by seeds is the main source of variation in the date palm. Sabir *et al*. (2014) characterized ten date palm (*Phoenix dactylifera* L.) cultivars from Saudi Arabia using AFLP and ISSR markers. They found that the used biomolecular technics enabled discrimination among 10 date palm cultivars of from Saudi Arabia cultivated in 4 regions in the Kingdom. Fruit shape is one of the traits most influenced by genetic diversity, according to a correlation between morphologic characters and genomic similarity using RAPD markers. More genetic similarity was seen in situations where cultivars had minor length-width ratios. The development of numerous elite date palm cultivars with extremely varying fruit size, shape, color, texture, sugar, and protein contents is the result of genetic changes at the molecular level (Al-Khalifah *et al*., 2012).

Group and study of correlations between cultivars: Principal Component Analysis:

The heatmap of the species against the variable density indicates that the density of FF and DF is higher in MIS and least in LUB (Figure 7). Similarly, density of FS is higher in SHA and least in SUL. Similarly, the density of DS is higher in SUK and least in SUL. Similarly, the density of FL is higher in ANB and least in FAN. Similarly, the density of FW is higher in MIS and least in LUB. Similarly, the density of SL is higher in ANB and least in SUL. Similarly, the density of SW is higher in MAB and least in RAZ. Principal component analysis (PCA) represents a clear separation of the cultivars into six different groups (Figure 8). PCA plot showed that the first two principal components (PC1 and PC2) represent 79% of the total variance within the data set. Further, it is also noticed that the first principal component PC1 explained 55.2%, whereas the second principal component PC2 explained 23.8% of the data variation. Cultivars are distributed in six different groups based on their location. The first group (Al-hasa) consisted of SHL, WAS, SHI, RAZ, KHA, LUB cultivars, the second group of Al Qassim consisted of SUK, the third group of Hail consisted of BAR, SUL, FAN, SEG, AJW, the fourth group of Al-Kharj consisted of ZAB, the fifth group of Al-Medina consisted of SHA, MIS, ANB, MAJ, and the sixth group of Najran consisted of MAB cultivars. PC1 showed loadings for two clusters (Al-Hassa and Al-Hail), whereas PC2 showed loadings for cluster Al-Qassim. It is also noticed that the cultivars in two clusters (Al-Hassa and Hail) which includes in PC1, shows the maximum variability. Principal component analysis performed on the fruits and seeds of 24 different cultivars from Southeastern Algeria showed large variability between cultivars. 10 of the 14 traits examined were found to be strong discriminating factors (Allam *et al*., 2021).

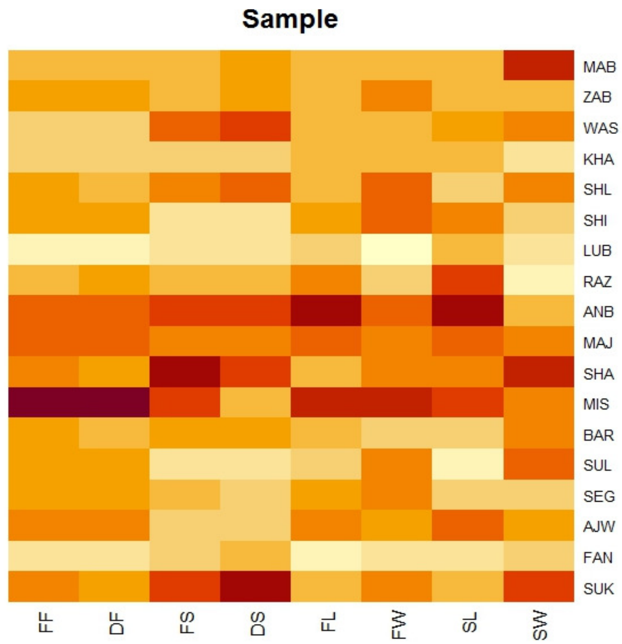

Figure 7. Heat maps of the 8 quantitative traits of 18 Saudi date cultivars

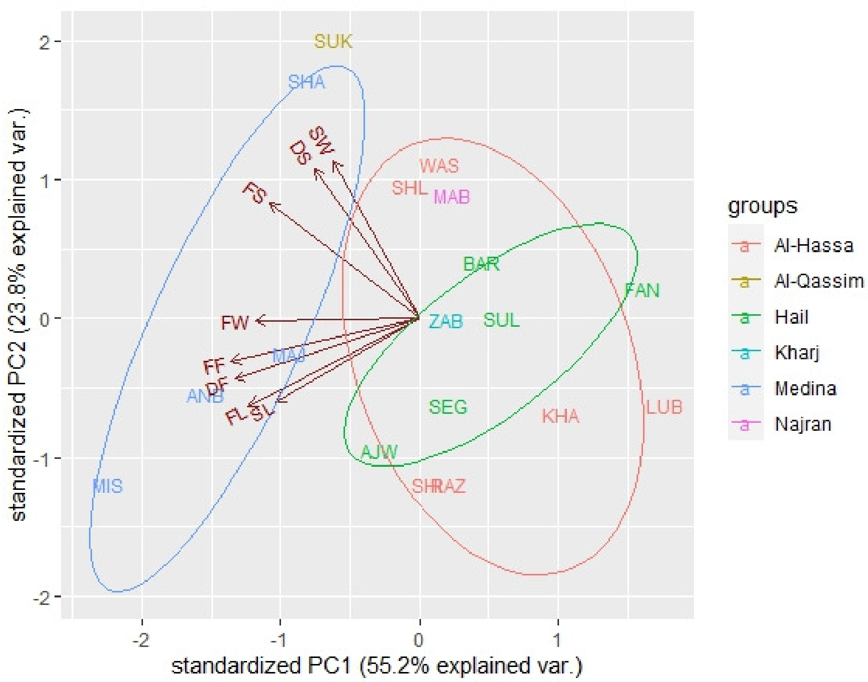

Figure 8. Principal component analysis of 18 Saudi varieties based on the 8 quantitative traits

Principal component analysis (PCA) represents a clear separation of the cultivars into six different groups (Figure 8). PCA plot showed that the first two principal components (PC1 and PC2) represent 79% of the total variance within the data set. Further, it is also noticed that the first principal component PC1 explained 55.2%, whereas the second principal component PC2 explained 23.8% of the data variation. Cultivars are distributed in six different groups based on their location. The first group (Al-hasa) consisted of

SHL, WAS, SHI, RAZ, KHA, LUB cultivars, the second group of Al Qassim consisted of SUK, the third group of Hail consisted of BAR, SUL, FAN, SEG, AJW, the fourth group of Al-Kharj consisted of ZAB, the fifth group of Al-Medina consisted of SHA, MIS, ANB, MAJ, and the sixth group of Najran consisted of MAB cultivars. PC1 showed loadings for two groups (Al-Hassa and Al-Hail), whereas PC2 showed loadings for group Al-Qassim. Moreover, based on the characteristic variability principal component analysis provides three distinguished clusters. Out of these three clusters two clusters includes in PC1 and one in PC2. It is also noticed that the cultivars of Al-Hasa and Hail groups distributed in two clusters which includes in PC1 as shown in Figure 8, shows the maximum variability among all the varieties of the dates.

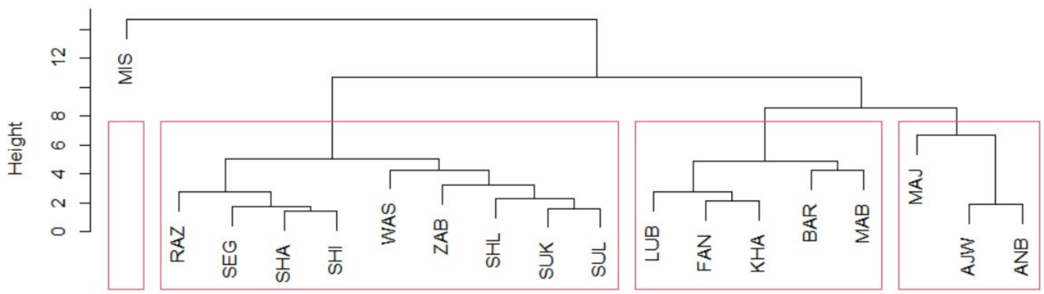

Figure. UPGMA clustering dendrogram based on eight quantitative attributes of 18 date palm cultivars

UPGMA clustering measured the variations in the different cultivars. Four main clusters were detected at distance matrix height 8, as observed in Figure 9. The first cluster consisted of MIS. The second cluster consisted of RAZ, SEG, SHA, SHI, WAS, ZAB, SHL, SUK and SUL. The third cluster consisted of LUB, FAN, KHA, BAR, MAB. The fourth cluster contained MAJ, AJW and ANB. UPGMA analysis indicates that characteristics of SHA (Al-Qassim) and SHI (Al-Hasa) are very similar to one another. Similarly, SUK (Al-Qassim) and SUL (Hail), FAN (Hail) and KHA (Al-Hasa), BAR (Hail) and MAB (Najran), AJW (Hail) and ANB (Madina) are very similar to each other among different clusters. It is also noticed that MIS (Madina) is a unique variety among all. Recently Alaida and Aldhebiani (2022) studied the distance of similarities and differences in morphological characters between different cultivars in Al-Madinah Al-Munawarah, Saudi Arabia using principal coordinates analysis and cluster analysis (UPGMA). They concluded that fruit and seed are the most distinguishing characteristics between cultivars.

Conclusions

Our data demonstrate robust phenotypic characterization of the eminent date palm cultivars grown in KSA. We showed that there is great variability among the studied cultivars. Clusters among the varieties were detected based on density of various types of fruits and seeds. It is also found that one of the variety MIS (Al-Madina), is unique for its fresh fruit size. The diversity in qualitative and quantitative traits could be explained by differences in climate and nature of the soil in the six studied regions in KSA. On other hand, genetic variability can be an interesting factor in giving such diversity. However, to round off the study we recommend the detailed and thorough subsequent investigations need to be carried out: bio chemical analysis of all the cultivars, Comparative bio chemical analysis on fresh and dry fruits and seeds would describe the contrasting yet economic sustainability of the important cultivars. Finely, the genotypic analysis would further explain the rationale behind the apparent diversity and variation. Furthermore, this cutting-edge analysis would also embark the scope and importance of the genetic diversity.

Authors' Contributions

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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