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Assessment of Phenotypic Diversity of Some Local Moroccan Date Palm Varieties and Clones (*Phoenix Dactylifera* L.) from the Zagora Region, Southern Morocco

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Abstract

The purpose of this research was a better understanding of the phenotypic diversity of date palms (*Phoenix dactylifera* L.) in southern Morocco. To determine the total degree of polymorphism and find their distinct phenotypic attributes, 17 date palm accessions from various date palm groves in the Drâa-Tafilalet zone (Zagora) were studied. Thirty vegetative and reproductive parameters were examined, and multidimensional statistical methods were used to assess the data. These findings indicated that the date palm germplasm exhibited a high level of genetic polymorphism. The principal component analysis (PCA) revealed that leaf length and width, spine length and width, and fruit sizes were responsible for a considerable amount of the observed variability. Strong correlations were found between the studied traits, especially between fruit dimensions (length and width) and fruit and pulp weights (0.776; 0.861; 0.868; 0.719), respectively. A positive correlation was also found between petiole width at the bottom and spines (0.706), between petiole width at the bottom and leaflets number (0.765) as well as between spadice length and spadice length at the ramified part (0.673). Five phenotypic groups were identified with levels of dissimilarity ranging from 0.37 to 0.92. The first cluster had four cultivars (Bourar, Mentouj tissgharine, Khalt lohmadi and Khalt abdelghani); the second group possessed six cultivars (Khalt bheir ngli, Khalt iaach, Bouezgagh, Black bousthammi, KHL and Elmensoum); the third cluster included four cultivars (Elahmer chetoui, Elasfer eljaid, Hak feddan laaneb and Khalt khel); the fourth group contained two cultivars (Khalt zoubair ibn laouam and Mentouj lhaj lehbib); and the fifth group contained only one cultivar, 'Khalt iaissi'. In each one of these groups, the similarities observed between cultivars were based on fruit characteristics (semi-dry, dry, and soft dates). This work highlighted the most important traits that can be used for assessing the diversity of date palm trees and fruit. Leaf length and width, spine length and width, and fruit sizes had the highest discrimination value.

Keywords: Morocco; diversity; date palm; *Phoenix dactylifera* L.; cultivars, Zagora palm grove.

1. Introduction

The date palm is the most valuable arid-region crop in Morocco, and it has commercial value in all of North Africa. There are about 5.4 million palm trees in Morocco (Sedra, 2015). The annual date production is more than 117 thousand tonnes (FAOSTAT, 2012). More than 456 cultivars are known in Morocco (INRA, 2011). Plantations of date palms contribute to the construction of oasis ecosystems because they have a diverse genetic stock and help to create a suitable environment for the growth of the underlying crops. In addition, they contribute to stabilizing human populations in arid regions where the resources are limited. Urbanization, drought, salt, desertification, insect infestations, poor soils, genetic erosion, age, and diseases such as Bayoud caused by *Fusarium oxysporum f. sp. albedinis* are all potentially damaging to Morocco's oases (Botes and Zaid, 2002; Awad, 2006; Ehsine *et al.,* 2014; Meddich *et al.,* 2015). All these constraints have resulted in an abandonment of orchards by farmers who preferred migration from rural areas to urban centers, leading to degradation of these areas. From an agronomic standpoint, the best strategy for combating Fusarium wilt as well as drought and salt issues is to plant resistant date palms with high quality fruit and good production (Saaidi *et al.,* 1992). Resistant date palms can be obtained by a transfer of genetic material between genetically different palm trees (natural interbreeding), thereby changing the composition of the gene pool that provides the new population with traits of resistance to drought and parasites. As a result, selecting local palm trees that are adapted to the soil and climatic conditions of Morocco is of high interest and relevance. Trees called 'khalts' or 'sairs' which result

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from natural seedlings (Munier, 1973) have an interesting degree of polymorphism because of the high heterozygosity of the parental varieties (Saaidi, 1992; Sedra *et al.,* 1998). Farmers' empirical selection has resulted in the existing cultivars in each oasis. The process of denominations is local and begins at the place where the crop is grown (Elhoumaizi *et al.,* 2002). Djerbi *et al.* (1986) observed that certain 'khalts' have excellent fruit quality and have a significant resistance to *Fusarium oxysporum* f. sp. *albedinis* in date palm plantations.

The assessment of phenotypic diversity is an essential part of a breeding strategy (Brake *et al.,* 2021). There are variations in date palm genetic resources, according to several research reports. Most of them mainly focused on fruit morphology and the design of description cards (Mason, 1915; Nixon, 1950; Elhoumaizi *et al.,* 2006; Elshibli and Korpelainen, 2009; Rabei *et al.,* 2012; Zehdi-Azouzi *et al.,* 2015; Al-Khayri *et al.,* 2015). Some research, on the other hand, has emphasized the characteristics of fruit and leaves (Reynes *et al.,* 1994; Bouabidi *et al.,* 1996; Ahmen *et al.,* 2011; Elsafy *et al.,* 2015; Ennouri *et al.,* 2018).

The aim of the research reported here is to contribute to the assessment of phenotypic variability among seventeen date palm varieties and clones in Morocco's Zagora palm grove, to evaluate the degree of polymorphism among the varieties and clones investigated, and to find differences and similarities among cultivars that might be valuable in date palm classification. This will stimulate the selection of local palm trees that are productive and adaptable to the pedoclimatic conditions in Morocco in the future.

2. Material and methods

2.1. Plant materials

The 17 date palm accessions studied were obtained from different areas in the Drâa region (Zagora, Southern Morocco) (Table 1). The accessions were collected from different farmers' groves but were all growing in the Zagora oasis during the study period. These varieties and clones were available and abundant at the start of the study. During the harvest season in October 2018, the study was carried out in a field with the following GPS coordinates: 30°20' 59" N, longitude of 5°50'06" W, and elevation of 731 m, about 0.76 km from Zagora, Morocco. It was estimated that the field covered 39.04 hectares. The study region has a semi-arid environment with 61 mm of annual rainfall and a mean annual temperature of 22.9 °C. During the months of September and October 2018, sample parameters were measured. The physicochemical quality characteristics of the soil in the research area are shown in Table 2.

Table 1. Name, abbreviations and origin of date palm samples.

Accession	Label	Origin
Bourar	BRR	Tissgharine
Mentouj tissgharine	MTN	Tissgharine
Bouezgagh	BZG	Jenan lohmadi
Black bousthammi	BST	Jenan lohmadi
Khalt iaach	KHL	Jenan lohmadi
Khalt lohmadi	LHD	Jenan lohmadi
Elahmer chetoui	ECT	Aghlal elkhyat mehdia
Elasfer eljaid	EED	Aghlal elkhyat mehdia
Khalt zoubair ibn laouam	ZIE	Fedan laaneb tansita
Hak feddan laaneb	HFL	Fedan laaneb tansita
Khalt iaissi	IAS	Way hamama
Elmensoum	EMS	Way hamama
Khalt abdelghani	IAH	Bheir ingli
Iklane	IKL	Bheir ingli
Mentouj lhaj lehbib	MEL	Bheir ingli
Khalt bheir ngli	KBN	Bheir ingli
Khalt khel	KKL	Sefsafa

Table 2. Physico-chemical parameters of soils in the Zagora palm grove.

Site	**pH**	**EC ($mS.cm^{-1}$)**	**AP ($mg.kg^{-1}$)**	**TOC ($g.kg^{-1}$)**	**OM ($g.kg^{-1}$)**	**TN ($g.kg^{-1}$)**	**C/N**	**$CaCO_3$ ($g.kg^{-1}$)**	**Texture**
Zagora	7.58 ±0.01	0.46 ±0.02	10.40 ±0.14	1.35 ±0.34	2.32 ±0.58	0.14 ±0.04	10.32±0.06	104.04±1.43	Sandy-loamy

Ec: Electrical conductivity; AP: Available phosphorus; TOC: Total organic carbon; OM: Organic Matter; TN: Total Kjeldahl nitrogen; C/N: Carbon/Nitrogen ratio.

Thirty criteria were examined to describe the phenotypes. The reproductive and vegetative characteristics of the date palm that were evaluated (Table 3). The measurements were carried out on the 17 date palm accessions. These samples were collected as follows: The samples were collected and characterized starting from the first week of October, which was 8 to 12 weeks after full flowering. This period varied from one cultivar to another. In order to ensure the homogeneity of the samples and the representativeness of the results, a certain number of fully developed plant material was collected from different parts of each tree.

The weight of the fruit and seeds was determined using an analytical balance. Manual measuring tape was used to measure the length and width of various reproductive and vegetative parts of the date palm (Table 3), while a digital caliper was used to assess the fruit and seed diameter.

For morphometric analysis, three individuals from each accession were selected. These characters are reported as part of standard descriptors for the date palm (IPGRI, 2005). All attributes related to fruit were measured at harvest stage.

Table 3. Measured vegetative and reproductive characters.

Character	Unit	code
Leaf		
Spinted part length	cm	P1
Petiole width at the bottom	cm	P2
Leaf length	cm	P3
Leaf width	cm	P4
Rachis thickness between the last spine and the first leaflet	cm	P5
Leafleted part length	cm	P6
Spines		
Spines number		P7
Spine width at the middle	mm	P8
Spine lengh at the middle	cm	P9
Leaflets		
Terminal leaflet length	cm	P10
Leaflets number		P11
Spacing index		P12
Terminal leaflet width	mm	P13
Leaflet width at the middle	mm	P14
Leaflet length at the middle	mm	P15
Fruit		
Fruit length	mm	P16
Fruit width	mm	P17
Fruit weight	gr	P18
Pulp weight	gr	P19
Seed length	mm	P20
Seed width	mm	P21
Seed weight	gr	P22
Seed/fruit length ratio		P23
Seed/fruit width ratio		P24
Spadice		
Spadice length	cm	P25
Spadice width at the middle	mm	P26
Spadice thickness at the middle	mm	P27
Spadice length at the ramified part	cm	P28
Spathe		
Spathe length	cm	P29
Spathe width	cm	P30

2.2. Data analysis

The data was analyzed using principal component analysis (PCA) and cluster analysis (CA) (XLSTAT, 2014). To obtain a new set of variables identified as principal components, PCA starts with a linear model and minimizes the structure of a data table (Mainley, 1994). The genetic relationship between accessions was investigated using cluster analysis with Euclidean distances as similarity metrics and the Unweighted Pair-Group Method Arithmetic Average (UPGMA).

3. Results

Mean values of the reproductive and vegetative traits studied are shown in Table 4. The data show a large variability between cultivars.

Table 4. Date palm accessions' average values for measured characteristics.

Code	P 1	P 2	P 3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23	P 24	P 25	P 26	P 27	P 28	P 29	P 30
BRR	88.7	10.5	324	118.6	2.6	231	30	6	14.8	21	163	0.48	11	18	54.7	44.30	20.83	13.25	12.36	17.37	5.00	0.82	0.39	0.06	118	42	22	28.0	94	5.7
BST	122.3	12.2	404	123.3	3	272	25	3.8	14.2	24.3	195	0.72	16	19	70.7	28.43	16.70	8.35	7.24	16.00	6.10	0.95	0.56	0.11	119	42	5	26.3	73	7.3
BZG	110	10.2	401	103	3.2	280	20	8	15.3	25	187	0.51	20	34	56.9	38.40	18.00	10.04	8.80	19.20	6.33	1.19	0.50	0.12	73	51	20	24.7	45	8.5
ECT	156	11.8	431	129	2	272.3	42	4.5	15.2	30	182	0.60	17	22	65.1	40.43	20.73	15.97	14.34	24.17	6.13	1.53	0.60	0.10	158	75	20	65.0	73	9.7
EED	157	14.7	465	148	3.3	293.3	43	7.6	16.3	13.5	199	0.60	9	30	72.4	40.20	21.43	14.27	12.45	24.77	7.47	1.70	0.62	0.12	116	64	14	52.3	84	6.3
EMN	92	3.8	355	92.3	2.5	257.3	23	6	13.7	21.7	155	0.72	19	24	61.4	22.97	14.77	4.90	3.83	14.90	6.17	1.02	0.65	0.20	87	44	5	33.0	43	8.9
HFL	144.7	9.8	403	120.6	2.3	238.3	31	4.5	13.3	16.3	162	0.67	18	33	57.5	42.57	23.03	17.36	16.01	21.37	6.40	1.28	0.50	0.07	122	52	19	60.0	64	8.2
IAH	66.7	3.2	313	87	1.6	240	14	2.6	7.8	17.6	127	0.53	12	12	45.5	28.23	18.20	7.94	6.58	17.50	6.40	1.34	0.62	0.17	126	47	13	38.7	53	7.4
IAS	186.7	7.2	369	77	2.8	177.3	26	4	13.6	20.7	142	0.66	20	25	46.9	36.77	17.47	9.79	8.68	20.67	5.37	1.06	0.56	0.11	107	53	14	33.3	43	4.1
IKL	75.7	3.2	284	54	0.6	201.2	13	4.5	7.5	17.7	113	0.55	19	24	33.1	37.07	20.20	10.49	9.25	18.80	6.00	1.16	0.51	0.11	75	53	11	30.3	58	5.2
KBN	137	6.5	423	64	2.7	276.7	20	4	8.8	20.7	170	0.54	21	15	34.3	34.70	17.40	8.90	7.54	21.37	7.03	1.33	0.62	0.15	87	51	5	33.7	64	9.2
KHL	106	9.7	433	142.6	10.2	321.3	44	5	14.8	19.2	207	0.65	16	28	80.7	27.20	21.03	11.18	9.39	17.37	7.73	1.53	0.64	0.14	88	50	15	37.7	47	10.8
KKL	106.7	5.3	302	95	1.8	190	15	3.5	6.4	16.8	117	0.53	20	16	49.7	22.50	15.27	3.96	3.08	14.90	5.60	0.88	0.66	0.22	114	43	15	39.3	53	7.0
LHD	90	9.5	360	92	2.2	269.7	24	4.8	16.7	20.2	163	0.69	13	17	45.8	33.60	17.93	8.79	6.68	22.73	7.97	2.01	0.68	0.23	119	61	15	44.7	80	8.2
MEL	80	5.8	292	71.6	1.7	211.7	25	4	5.9	21.7	157	0.55	21	24	40.6	45.23	23.97	18.48	17.09	23.07	7.30	1.70	0.51	0.09	117	56	15	34.0	44	5.5
MTN	80.3	9.5	367	119	1.6	277	20	4	11	17.3	125	0.64	18	16	45.1	32.70	19.43	11.94	10.69	17.47	6.90	1.10	0.53	0.09	115	41	16	42.0	47	8.2
ZIE	115.3	12.7	360	98.6	1.8	235	28	4	10.2	19.8	224	0.61	15	21	56.6	33.23	18.00	9.93	8.18	18.77	7.57	1.66	0.57	0.17	118	45	15	50.7	74	7.2

BRR : Bourar ; **MTN** : Mentouj tissgharine ; **BZG** : Bouezgagh ; **BST** : Black bousthammi; **KHL**: Khalt iaach; **LHD**: Khalt Lohmadi ; **ECT** : Elahmer chetoui ; **EED** : Elasfer eljaid ; **ZIE** : Khalt zoubir ibn laouam ; **HFL** : Hak feddan laaneb ; **IAS** : Khalt iaissi ; **EMS** : Elmensoum ; **IAH** : Khalt abdelghani ; **IKL** : Iklane ; **MEL** : Mentouj lhaj lehbib ; **KBN** : Khalt bheir ngli ; **KKL** : Khalt khel.

3.1. Principal component analysis

The differences in vegetative and reproductive parameters between genotypes were studied using PCA. The first component accounted 31.25 %, whereas the second and third components explained 50.28 % and 61.06 %, respectively (Table 5).

Table 5. Eigen values and levels of the variance associated with the three principal components.

Axe	1	2	3
Eigenvalues variance	9.37	5.71	3.23
Variance proportion			
Individual (%)	31.25	19.04	10.78
Cumulative (%)	31.25	50.28	61.06
Eigenvalues vectors[1]	P2 (0.269)	P6 (-0.242)	P8 (-0.265)
	P3 (0.245)	P16 (0.334)	P20 (0.279)
	P4 (0.242)	P17 (0.261)	P21 (0.316)
	P7 (0.295)	P18 (0.271)	P22 (0.402)
		P19 (0.286)	P23 (0.322)
		P24 (-0.271)	P26 (0.280)
		P30 (-0.265)	P28 (0.301)

[1] Only variable showing high weight was taken into account.

P2: Petiole width at the bottom; **P3**: Leaf length; **P4**: Leaf width; **P6**: Leafleted part length; **P7**: Spines number; **P8**: Spine width at the middle; **P16**: Fruit length; **P17**: Fruit width ; **P18**: Fruit weight ; **P19**: Pulp weight ; **P20**: Seed length; **P21**: Seed width; **P22**: Seed weight; **P23**: Seed/fruit length ratio; **P24**: Seed/fruit width ratio; **P26**: Spadice width at the middle; **P28**: Spadice length at the ramified part; **P30**: Spathe width.

Petiole width at the bottom, leaf length, leaf width, spines number and leaflets number had high positive weight in the first principal component. The attributes with high negative weight in the second component were leafleted part length, seed/fruit weight ratio, and spathe width. Positive weight was found in fruit length, fruit width, fruit weight, and pulp weight.

The most important variables influencing the third principal component were spine width in the middle, which had high negative weight, and seed length, seed width, seed weight, seed/fruit length ratio, spadice width in the middle, and spadice length at the ramified part, which had strong positive weight.

The cultivars are shown on the plot axes (1-2) and (1-3) in Figures 1 and 2, respectively. In the plot of axis (1 and 2), the first axis presents a significant contrast between Elasfer eljaid (EED) and Khalt khel (KKL); (EED) has the largest petiole width at the bottom of the leaf. The second axis shows the contrast between Mentouj lhaj lehbib (MEL), characterised by a large size fruit, and Khalt iaach (KHL), distinguished by a large rachis thickness, leafleted part length, leaflet length and spathe width (Fig. 1). In the plot of axis (1 and 3), the third axis contrasts clone Khalt lohmadi (LHD), which has large size seed, to Bouzegagh (BZG) and Bourar (BRR), which are characterised by long leafleted part, terminal leaflet, spine, and leaflet width at the middle.

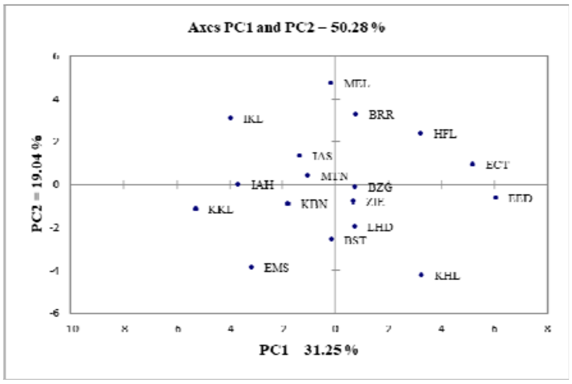

Figure 1. Representation of date palm accessions on the plan 1- 2 of PCA

BRR : Bourar ; **MTN** : Mentouj tissgharine ; **BZG** : Bouezgagh ; **BST** : Black bousthammi; **KHL**: Khalt iaach; **LHD**: Khalt Lohmadi ; **ECT** : Elahmer chetoui ; **EED** : Elasfer eljaid ; **ZIE** : Khalt zoubir ibn laouam ; **HFL** : Hak feddan laaneb ; **IAS** : Khalt iaissi ; **EMS** : Elmensoum ; **IAH** : Khalt abdelghani ; **IKL** : Iklane ; **MEL** : Mentouj lhaj lehbib ; **KBN** : Khalt bheir ngli ; **KKL** : Khalt khel.

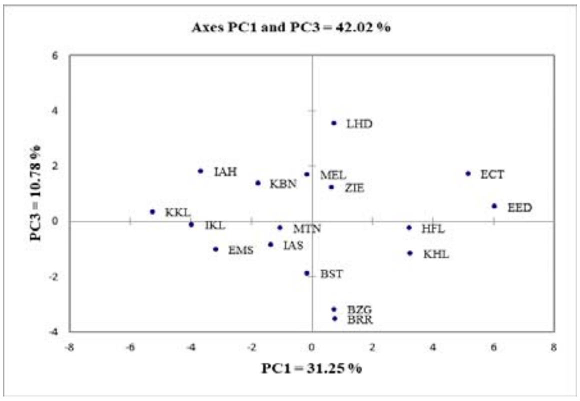

Figure 2. Representation of date palm accessions on the plan 1-3 of PCA.

BRR : Bourar ; **MTN** : Mentouj tissgharine ; **BZG** : Bouezgagh ; **BST** : Black bousthammi; **KHL**: Khalt iaach; **LHD**: Khalt Lohmadi ; **ECT** : Elahmer chetoui ; **EED** : Elasfer eljaid ; **ZIE** : Khalt zoubir ibn laouam ; **HFL** : Hak feddan laaneb ; **IAS** : Khalt iaissi ; **EMS** : Elmensoum ; **IAH** : Khalt abdelghani ; **IKL** : Iklane ; **MEL** : Mentouj lhaj lehbib ; **KBN** : Khalt bheir ngli ; **KKL** : Khalt khel.

3.2. Matrix correlation

Analysis of matrix interrelationships between the variables studied (Table 6) showed that leaf length (P3) was positively correlated to spined part length (P1) and petiole width at the bottom (P2). Leaf width (P4) was correlated to leaf length (P3) and petiole width at the bottom (P2). Leafleted part length (P6) was in correlation with leaf length (P3) and leaf width (P4).

High intercorrelations were observed between spines number (P7) and petiole width at the bottom (P2), leaf length (P3) and leaf width (P4). Spine width at the middle (P8), spines number (P7), leaf width (P4), leaf length (P3) and petiole width at the bottom (P2) were correlated with spine length at the middle (P9). High correlations were also noticed between leaflets number (P11) and petiole width at the bottom (P2), leaf length (P3) and spines number (P7). Leaflet width at the middle (P14) was correlated to spine width at the middle (P8). The correlation matrix also showed a significant intercorrelation between leaflet length at the middle (P15) and petiole width at the bottom (P2), leaf length (P3), leaf width (P4), rachis thickness between the last spine and the first leaflet (P5), spines number (P7), spine length at the middle (P9) and leaflets number (P11). Fruit width (P17) was correlated to fruit length (P16). A high correlation was observed between fruit weight (P18) and fruit sizes (P16, P17). Length, width and weight of fruit (P16, P17 and P18) were strongly correlated to pulp weight (P19). Seed length (P20) was correlated to fruit length (P16) and the weight of fruit and pulp (P18, P19). Seed weight (P22) was highly correlated to seed length and width (P20, P21).

Table 6 Coefficients of correlation between the studied characters in date palm accessions.

Variables	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
P1	**1**	0.4729	**0.6657**	0.2698	0.1441	0.0120	0.5191	0.1567	0.4169	0.1500	0.3705	0.2683	0.0889	0.4132	0.3230	0.2418	0.0219	0.2069	0.2020	0.4621	-0.1261	0.0358	0.1014	-0.2318	0.2211	0.4342	0.0356	0.3929	0.1507	-0.0441
P2		**1**	**0.6955**	**0.7626**	0.2590	0.5089	**0.7060**	0.4167	**0.6659**	0.1404	**0.7657**	0.2036	-0.4787	0.3311	**0.6330**	0.3391	0.2703	0.3975	0.3680	0.3712	0.2788	0.2909	-0.1409	-0.3180	0.3850	0.2564	0.3435	0.4091	**0.6040**	0.1675
P3			**1**	**0.6547**	0.5115	**0.7494**	**0.7075**	0.4202	**0.6810**	0.1552	**0.6841**	0.3655	-0.1825	0.4162	**0.6446**	0.0824	0.0966	0.2139	0.1798	0.3877	0.3339	0.2612	0.2366	-0.1680	0.0912	0.3837	-0.0366	0.3857	0.2333	0.5421
P4				**1**	0.5126	**0.6293**	**0.7630**	0.3834	**0.6583**	-0.0049	0.5411	0.2581	-0.5458	0.3103	**0.8729**	0.0239	0.2607	0.2873	0.2701	0.0551	0.1507	0.0744	0.0215	-0.2524	0.3906	0.1174	0.3608	0.4223	0.3647	0.4110
P5					**1**	0.5820	0.5912	0.2369	0.4055	-0.0024	0.5082	0.2251	-0.0910	0.3265	**0.6602**	-0.2260	0.1299	0.0091	-0.0161	-0.1108	0.3200	0.1379	0.2280	-0.0077	-0.2588	-0.0193	0.0075	-0.0823	-0.1339	0.5088
P6						**1**	0.5153	0.4138	0.5627	0.1388	0.5985	0.2593	-0.3180	0.1567	0.5822	-0.1106	0.0963	0.0955	0.0516	0.1330	0.5680	0.3502	0.2654	0.0067	-0.0489	0.1771	-0.0818	0.1612	0.1801	**0.7777**
P7							**1**	0.3752	**0.6367**	0.1433	**0.6936**	0.2752	-0.3653	0.4594	**0.7659**	0.3067	0.4876	0.5376	0.5047	0.4602	0.2929	0.3964	0.0517	-0.3217	0.3610	0.5067	0.3094	0.5292	0.3696	0.3121
P8								**1**	**0.6265**	0.0556	0.3983	-0.0897	-0.2389	**0.6615**	0.4078	0.2995	0.1213	0.1498	0.1432	0.2038	0.0484	0.0561	-0.2018	-0.1551	-0.3620	0.2157	0.2517	-0.0997	0.1886	0.0934
P9									**1**	0.2659	0.5396	0.4469	-0.4337	0.4250	**0.6590**	0.1481	0.0269	0.1305	0.1031	0.2316	0.0756	0.1476	0.0220	-0.1254	0.1121	0.3090	0.2280	0.1892	0.4036	0.3046
P10										**1**	0.2936	0.0360	0.3031	-0.0084	0.1460	0.1255	-0.1235	0.0795	0.0865	0.0869	-0.2134	-0.0386	-0.1074	-0.1469	0.1922	0.2908	0.0850	-0.0775	0.0019	0.2810
P11											**1**	0.2327	-0.2751	0.3906	**0.6850**	0.1403	0.1479	0.2330	0.1923	0.2603	0.4680	0.4289	0.0447	-0.0844	0.0859	0.2060	0.0383	0.2198	0.3812	0.3817
P12												**1**	0.0311	0.1531	0.3999	-0.3369	-0.1945	-0.1109	-0.1391	-0.0308	0.2767	0.1635	0.4119	0.1919	0.0973	0.0301	-0.4077	0.2222	-0.0798	0.2494
P13													**1**	0.1284	-0.3944	-0.0801	-0.1523	-0.0759	-0.0447	-0.1138	-0.1689	-0.2487	-0.0174	-0.0168	-0.3842	-0.0893	-0.2229	-0.2311	**-0.6984**	0.0645
P14														**1**	0.4321	0.3929	0.4103	0.4327	0.4290	0.3131	0.0737	0.1271	-0.2510	-0.3732	-0.2982	0.2949	0.3016	0.1419	-0.1373	0.0161
P15															**1**	-0.1727	0.0674	0.0884	0.0690	-0.0735	0.1341	0.0622	0.1735	-0.0753	0.1888	0.0967	0.1120	0.2511	0.2078	0.4294
P16																**1**	**0.7768**	**0.8617**	**0.8685**	**0.7192**	-0.0313	0.2538	**-0.6905**	**-0.7387**	0.2203	0.4684	0.5577	0.2114	0.3520	-0.3646
P17																	**1**	**0.9447**	**0.9372**	0.5938	0.2474	0.3989	-0.4895	**-0.6955**	0.2563	0.4133	0.5345	0.3620	0.1812	-0.1101
P18																		**1**	**0.9964**	**0.6909**	0.1807	0.3771	-0.5255	**-0.7663**	0.3867	0.4952	0.5423	0.4443	0.2176	-0.1018
P19																			**1**	**0.6514**	0.1091	0.3023	-0.5747	**-0.8024**	0.3759	0.4527	0.5460	0.4058	0.1968	-0.1354
P20																				**1**	0.4013	**0.7104**	-0.0056	-0.2789	0.3422	**0.8673**	0.2806	0.5368	0.3073	-0.0803
P21																					**1**	**0.8585**	0.4407	0.2952	-0.0203	0.2789	-0.1412	0.3149	0.0360	0.4146
P22																						**1**	0.3725	0.2165	0.2357	**0.6490**	0.1008	0.5012	0.2046	0.2185
P23																							**1**	**0.8154**	0.0509	0.2300	-0.4689	0.2545	-0.1673	0.4430
P24																								**1**	-0.1451	-0.0863	-0.4116	-0.0307	-0.1139	0.2556
P25																								-	**1**	0.3662	0.3688	**0.6737**	0.4458	-0.0092
P26																										**1**	0.2620	0.5775	0.2331	0.1043
P27																											**1**	0.3635	0.2031	-0.0603
P28																												**1**	0.3123	0.2836
P29																													**1**	-0.0768
P30																														**1**

Seed fruit/length ratio (P23) was negatively correlated to fruit length (P16) and correlated positively to seed/fruit weight (P24). A high negative intercorrelation was shown between seed/fruit weight ratio, fruit length and width (P16, P17) and fruit and pulp weight (P18, P19). Spadice width at the middle (P26) was correlated to spadice length at the ramified part (P28). Spathe length (P29) was positively correlated to the petiole width at the bottom (P2) and correlated negatively to the terminal leaflet width (P13). A high correlation was also found between spathe width (P30) and leafleted part length (P6).

3.3. Cluster analysis

UPGMA produced a dendogram with five phenotypic groups identified among the 17 date palm accessions (Figure 3). The level of dissimilarity ranged from 0.37 to 0.92. The BRR, MTN, LHD, and IAH cultivars were part of the first cluster. BRR and MTN originated from Tissgharine whereas LHD and IAH originated from Jenan lohmadi and Bheir ingli, respectively. The second group included six cultivars that can be divided into two subgroups: KBN and KHL from Bheir ingli; and BZG, BST and KHL from Jenan lohmadi and EMS from Way hamama. The third cluster included four cultivars: ECT and EED from Aghlal lekhyat mehdia, HFL from Fedan laaneb tansita, and KKL originating from Sefsafa. EED and KKL were closely related to the lowest registered dissimilarity level (d = 0.37). The fourth group included two cultivars: ZIE originating from Fedan laaneb tansita and MEL belonging to Bheir ingli. The single cultivar IAS from Way hamama represented the last cluster.

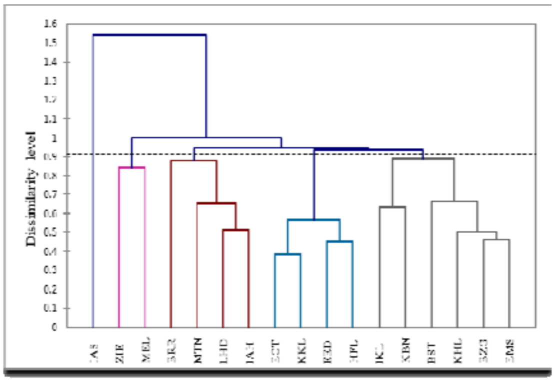

Figure 3 Cluster dendogram of Moroccan date palm accessions.

BRR : Bourar ; **MTN** : Mentouj tissgharine ; **BZG** : Bouezgagh ; **BST** : Black bousthammi; **KHL**: Khalt iaach; **LHD**: Khalt Lohmadi ; **ECT** : Elahmer chetoui ; **EED** : Elasfer eljaid ; **ZIE** : Khalt zoubir ibn laouam ; **HFL** : Hak feddan laaneb ; **IAS** : Khalt iaissi ; **EMS** : Elmensoum ; **IAH** : Khalt abdelghani ; **IKL** : Iklane ; **MEL** : Mentouj lhaj lehbib ; **KBN** : Khalt bheir ngli ; **KKL** : Khalt khel.

4. Discussion

The aim of this work was the investigation of the phenotypic diversity in reproductive and vegetative traits in 17 Moroccan date palm accessions growing in the Zagora palm grove. The date palm trees' quantitative markers have been used as morphological features to detect similarities and differences between date palm cultivars growing in different countries, e.g. Tunisia, Algeria, Morocco and Mauritania (Rhouma, 1994; Elhoumaizi *et al.,* 2002; Mohamed Ahmed *et al.,* 2011). In addition, traits related to the reproductive system were assessed. Our results are similar to Mohamed Ahmed *et al.* (2011), who studied 30 parameters associated with the plant's vegetative and reproductive systems to find a high degree of polymorphism in 23 Mauritanian date cultivars, and Elhoumaizi *et al.* (2002), who found a significant degree of polymorphism in twenty-six Moroccan date cultivars from the Figuig oasis, based on the date palm's vegetative system.

PCA showed that traits related to leaf (petiole width at the bottom, leaf length, leafleted part length), spines number, leaflets number, spathe width and fruit sizes and weight accounted for a high proportion of variability. A high correlation was observed between some characters (leaf length and leafleted part length and between leaf width and leaflet length at the middle) based on Pearson's coefficient correlation, showing that the tree is architecturally arranged, as reported by Mohamed Ahmed *et al.* (2011).

Cluster analysis revealed that the date palm germplasm studied is characterized by a continuous phenotypic diversity. This result is confirmed by the obtained topology of the dendogram and is due to the extensive transfer of plant material between different growing areas. As a consequence, geographical origin was not a determining criterion for the classification of cultivars. Similar findings were reported by Elhoumaizi *et al.* (2002).

Furthermore, the UPGMA dendogram revealed similarities between cultivars based on fruit characteristics such as half dry date in LHD and IAH, dry date in BZG and EMS, and soft date in EED and HFL. Similarities between cultivars based on fruit characteristics were noted in LHD and IAH characterised by semi-dry date, BZG and EMS with a dry date, EED and HFL exhibiting a soft date.

5. Conclusions

The present data showed that characters associated with the date palm's vegetative and reproductive organs were good discriminating traits to analyse the phenotypic diversity in date palms. The traits related to leaf length and width, spine, fruit sizes had the best differentiating value. Five clusters were obtained by a dendrogram classification and showed typical continuous phenotypic variations that differentiate the date palm varieties and clones. There was a significant phenotypic variability among date palm accessions in this research. Biochemical and molecular indicators should be investigated in order to accurately describe the phenotypic and genetic diversity of Moroccan date palm germplasm.

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Data Availability

The data used to support the findings of this study are included within the article.

Conflict of Interest

The authors declared no conflict of interest.

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