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Morphological variability of Mauritanian date-palm (*Phoenix dactylifera* L.) cultivars as revealed by vegetative traits

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The aim of this study was to use morphological markers to characterize twelve Mauritanian date-palm ecotypes currently grown by farmers. Eighteen phenotypic traits describing the vegetative systems were measured in the field in Atar Oasis. The data set was analyzed by principal components analysis (PCA) and UPGMA clustering. PCA revealed a great variability among the cultivars. Fourteen out of the 18 characters studied showed a high discriminating power suggesting their possible uses in the establishment of a Mauritanian date-palm catalogue. UPGMA Clustering revealed association between cultivars with similar fruit characteristics indicating that these ecotypes are morphologically related. Results also showed that individuals belonging to the Ahmar cultivar were morphologically distinct, suggesting it is likely a polyclonal variety.

Key words: *Phoenix dactylifera*, cultivar, morphology, variation

Introduction

The date palm (*Phoenix dactylifera* L., 2n = 36) constitutes the most important cultivated crop in the arid and semi-arid areas of North African countries. In Mauritania, there are approximately 1.9 million palm trees supporting the living of 500,000 oasis dwellers.

The date-palm is a perennial dioecious monocotyledon. Well adapted ecotypes empirically selected by farmers for their attractive fruit qualities are cultivated. These are maintained and clonally propagated throughout offshoots produced by the female trees. As a consequence, the local germplasm is composed of a variable scale of selected ecotypes of locally called cultivars and exhibits a great diversity. For instance, more than 220 and 800 cultivars have been reported in Morocco and in Algeria respectively (TOUTAIN et al. 1971, BENKHALIFA 1997) and 250 were identified in Tunisia (RHOUMA 2005). In Mauritania, little is known about local date-palm germplasm since only MUNIER (1973) has estimated the

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number of ecotypes, at 300. Nevertheless, taking into account the morphological parameters, the precise number of cultivars is still unknown since ecotypes exhibit homogenous traits and differ mainly by the fruit parameters. Therefore, several cultivars are morphologically nearly similar and are of similar denomination. Despite its great diversity, the Mauritanian date-palm is currently menaced by genetic erosion mainly due to abiotic stresses (high seasonal temperature, drought and rainfall irregularities). Since problems of synonymy and homonymy often occur, the establishment of research strategies aiming at the evaluation of the genetic diversity of this local date-palm germplasm has become imperative.

For this purpose, a large number of increasingly efficient methods has been reported and their suitability in the exploration of the genetic diversity in higher plants described (CHARCOSSET and MOREAU 2004, HENDERSON 2006). Among these methods, those based on morphological traits are of some benefit in date-palm genetic resources evaluation (MOHAMED et al. 1983, REYNES et al. 1994, BOUABIDI et al. 1996, BELGUEDJ 2002, ELHOUMAIZI et al. 2002, RHOUMA 2005). Therefore it has been assumed that criteria related either to the vegetative or the fruit parameters are useful for cultivar characterization, phenotypic diversity analysis and phylogenic relationship exploration among date-palm ecotypes. Moreover, phenotypic diversity evaluation constitutes an available basic step for the elaboration of a program to improve germplasm management and utilization of any crop (CHANG 1992). Taking into account these advantages, we designed the use of morphometric traits to survey the variability in the cultivars originating from Atar Oasis. The aim of this work was to develop vegetative traits suitable in the cultivars' identification and to establish a catalogue of the most important date-palm cultivars in our country.

In this paper we report the phenotypic variability and relationships among a set of Mauritanian date-palm ecotypes as revealed by vegetative parameters.

Materials and methods

The study was carried out on 12 date-palm ecotypes (Tab. 1) consisting of 11 cultivars (female trees) and one pollinator collected from Atar Oasis (Adrar region, North Mauritania, 20°32' N, 13°03' W, 300 m altitude). Atar Oasis is characterized by an mean annual temperature of 28.5 °C and mean annual rainfall of 110 mm. Five adult trees were randomly sampled for each cultivar and three leaves per tree were used to estimate the designed parameters. For this purpose, eighteen parameters were used (Tab. 2, Fig. 1). The main traits are reported as standard descriptors in the date-palm (IPGRI 2005).

Mean values of the measured criteria were subjected to principal components analysis (PCA) in order to identify the parameters that contributed significantly into the variability among cultivars (SNEATH and SOKAL 1973).

Cluster analysis, a method for displaying differences or similarities among cultivars, was employed for grouping together genotypes that showed dissimilarity in several traits (LEGENDRE and LEGENDRE 1998). Clustering was carried out using the unweighted pair-group method arithmetic average (UPGMA) method (LEGRADE 1983). All statistical analyses were performed using Statistical Analysis System software V6.07 (SAS 1990).

Tab. 1. Denomination, label and fruit consistency of tested ecotypes. * – Ahmar 1 and 2 both have red colored date; ** - seedling date palm with good fruit quality; *** -male palm

cultivar	Label	Fruit consistency
Ahmar1*	AH1	Soft
Lemdina gouchatia	LMG	Soft
Tijeb	TJB	Half-soft
Tiguidert	TGD	Dry
Lemdina ghaïlania	LGH	Soft
Ahmar2*	AH2	Soft
Adaghd	ADG	Half-soft
Sekani	SKN	Half-soft
Amsakhsi	AMS	Dry
Tamchkrert	TAM	Half-soft
Alfa**	ALF	Soft
Emassine***	T01	

Tab. 2. Measured traits

Parameters	Labels
Leaf length (cm)	LL
Leaf width (cm)	LW
Leaf angle (degree)	LA
Spineted part length (cm)	SL
Length of leafleted part (cm)	LP
Petiole width (cm)	PW
Rachis thickness between the last spine and the first leaflet (cm)	RT
Leaflets number	LN
Terminal leaflet length (cm)	TL
Terminal leaflet width (cm)	TW
Ventral angle of middle leaflet (degree)	VA
Middle leaflet width (cm)	WM
Middle leaflet length (cm)	LM
Leaflets spacing index at the middle	LI
Angle of leaflets on both sides of the terminal one (degree)	AT
Spine number	SN
Middle spine width (cm)	WS
Middle spine length (cm)	LS

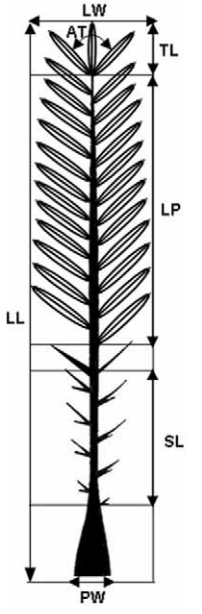

Fig. 1. Diagrammatic representation of some measured traits on leaf of date-palm. LL: Leaf length; SL: Spineted part length; PW: Petiole width; LP: Length of leafleted part; TL: Terminal leaflet length; LW: Leaf width; AT: Angle of leaflets on both sides of the terminal one

Results

The means of quantitative traits show a great variability in the date-palms studied (Tab. 3). This is strongly supported by results of the principal components analysis (PCA), which exhibited a typically continuous variation. In fact, results of PCA showed that the first three axes accounted 68.2% of the total variability among accessions (Tab. 4). The first component (38.8%) is mainly and positively correlated with the following parameters: the leaf width (LW), the length of leafleted part (LP), the petiole width (PW), the rachis thickness (RT) and the leaflets number (LN). The second axis (16.1% of the total variability) is positively influenced by the leaf length (LL), the spineted part length (SL) and the middle leaflet length (LM) traits. The middle leaflet ventral angle (VA) and the width (WM) parameters are negatively correlated with this principal component. In the third axis (13.2%), the angle of leaflets on both sides of the terminal leaflet (AT), the terminal leaflet length (TL) and the width (TW) showed high positive influences whereas the middle spine length (LM) is negatively correlated with this component. In addition, the correlation matrix between the characters studied exhibited strong correlations mainly between the leaf length, the length of leafleted part, the leaflets number and the middle leaflet length (Tab. 5). Significant correlations have been also registered between the leaf width, the petiole width and the middle leaflet length; the petiole width, the length of leafleted part and the leaflets number; the petiole width,

Tab. 3. Mean values of measured characters of date-palm cultivars. (see table 1 and table 2 for cultivars and parameter labels respectively)

	LL	LW	LA	SL	LP	PW	RT	LN	TL	TW	VA	WM	LM	LI	AT	SN	WS	LS
AH1	312.33	73.52	60.12	48.50	221.12	8.12	2.33	137.33	31.05	2.40	64.45	3.85	44.35	0.34	40.12	27.33	1.63	14.33
LMG	290.21	71.43	33.14	61.20	195.33	7.33	1.92	144.12	19.70	1.60	49.63	3.64	40.66	0.29	20.32	28.35	1.12	11.43
TJB	332.50	80.30	25.31	64.12	256.25	9.36	2.43	149.25	22.25	2.33	80.52	3.35	44.25	0.47	32.52	39.44	1.25	18.25
TGD	368.17	87.50	41.11	57.15	255.40	10.15	3.03	165.15	43.80	3.20	97.32	3.95	48.52	0.31	50.32	33.22	2.24	6.36
LGH	270.12	79.15	31.16	54.23	177.36	8.25	1.76	119.36	24.22	1.70	48.12	3.72	47.25	0.37	40.65	27.75	0.83	13.64
AH2	398.00	83.50	60.23	56.33	281.20	10.66	2.33	169.45	25.80	2.20	66.42	3.33	47.53	0.45	27.35	29.85	1.05	13.92
ADG	350.33	89.00	25.54	57.41	223.05	9.15	1.95	131.50	36.33	2.05	63.25	2.92	59.33	0.60	50.45	33.65	1.15	11.15
SKN	338.05	103.50	30.12	47.05	241.17	11.52	3.25	182.41	20.11	1.80	113.32	4.21	54.45	0.29	30.28	39.43	2.43	14.28
AMS	448.10	103.30	45.30	95.51	284.83	10.45	2.53	168.25	42.33	1.81	50.62	3.23	67.22	0.38	30.34	36.50	1.16	9.26
TAM	280.42	73.21	40.10	52.21	232.20	9.28	2.20	125.83	26.26	2.44	82.21	3.63	34.54	0.41	35.84	43.55	0.95	9.98
ALF	310.00	43.00	22.05	101.26	175.24	6.66	1.23	123.55	15.12	1.52	60.02	2.12	33.05	0.43	29.62	35.39	0.63	10.89
T01	381.20	89.14	40.21	50.42	283.31	11.33	2.82	179.66	21.80	2.10	54.15	3.15	53.50	0.27	30.35	35.42	1.12	11.33

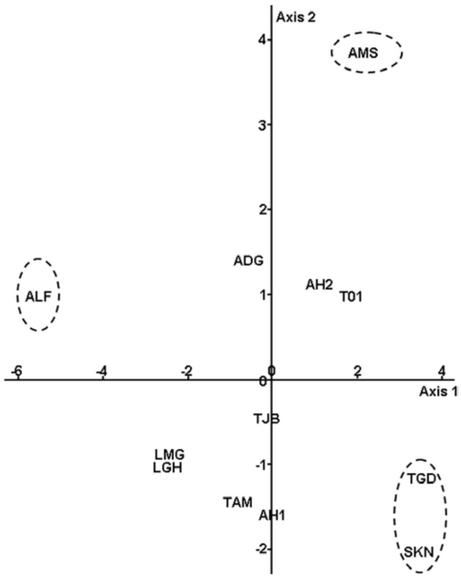

Fig. 2. Principal components analysis. Projection of date-palm cultivars on the plan generated by 1–2 axes. (§ table 1 for cultivars labels)

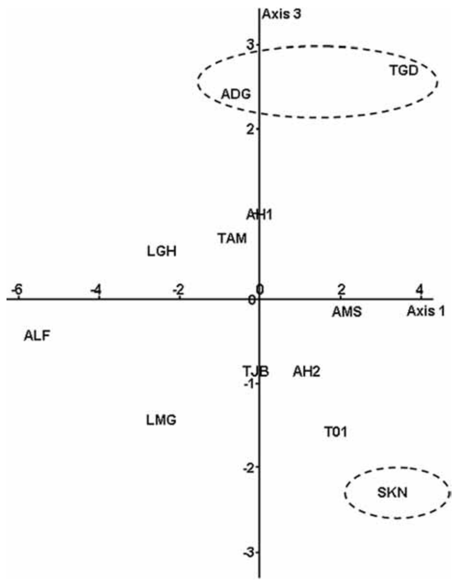

Fig. 3. Principal components analysis. Projection of date-palm cultivars on the plan generated by 1–3 axes. (§ table 1 for cultivars labels)

the rachis thickness and the leaflets number, the rachis thickness and the leaflets number and, the middle leaflet width and the ventral angle together with the middle spine width.

The projection of the cultivars studied on the plot was defined by the two first principal component axes 1–2 (Fig. 2). A significant opposition of Tiguidert and Sekani cultivars to the Alfa cultivar was registered according to the first axis, and taking into account the following traits: leaf width, the length of leafleted part, petiole width, rachis thickness and

Tab. 4. Eigenvalues, variance proportions and eigenvectors of the three first principal components for vegetative traits of date-palm cultivars (see table 2 for parameters' labels). $^{\dagger -}$only variables showing high loadings in different principal components were taken into account

Principal component	1	2	3
Eigenvalues	6.999	2.895	2.383
Variance proportion			
Individual (%)	38.88	16.08	13.24
Cumulative (%)	38.88	54.96	68.20
Eigenvectors†	LW(0.328)	LL(0.431)	TL(0.467)
	LP(0.306)	SL(0.409)	TW(0.368)
	PW(0.340)	LM(0.318	AT(0.577)
	RT(0.362)	VA(–0.319)	LS(–0.314)
	LN(0.314)	WM(–0.383)	

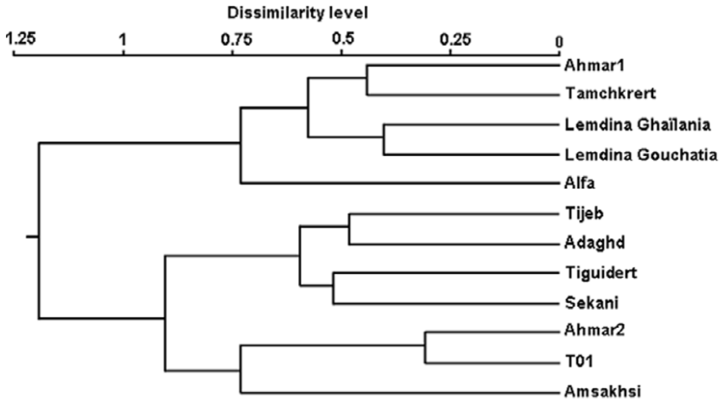

Fig. 4. Dendrogram of date-palm cultivars based on UPGMA clustering.

leaflets number. The second axis strongly characterized Amsakhsi by the leaf length, the spineted part length and the middle leaflet length. The third axis opposed cultivars Adaghd and Tiguidert to Sekani by the terminal leaflet length and width, the angle of leaflets on both sides of the terminal leaflet and the middle spine length parameters (Fig. 3).

The UPGMA dendrogram of cluster analysis showed that the dissimilarity levels are ranged from 0.29 to 1.18. This phenogram clustered the 12 date-palm cultivars into main phenotypically related groups (Fig. 4). The first cluster is composed of Ahmar 1, Tamchkrert, Lemdina Ghaïlania and Lemdina Gouchatia together with Alfa cultivars with a significant divergence of Alfa from the others. All the remaining cultivars are ranged in the second cluster, which exhibited two sub-clusters. The cultivars Tijeb, Adaghd, Tiguidert and Sekani are ranged in the first sub-cluster while the Ahmar 2, T01 and Amsakhsi cultivars composed the second sub-cluster.

Discussion

This present study portrayed the use of morphological parameters to examine the phenotypic variability in a set of Mauritanian date-palm cultivars. As a result we assume that the studied cultivars are characterized by a high level of genetic diversity. This is strongly supported by projection of the cultivars in PCA plots as well as in UPGMA cluster analysis. In addition, taking into account the parameters studied, a significant discrimination among cultivars has been observed. Therefore, consideration of the following traits: leaf length and width, the length of leafleted and the spineted part, the leaflets number, the terminal leaflet length and width, the angle of leaflets on both sides of the terminal one, the middle leaflet length, the width and the ventral angle, the petiole width, the rachis thickness and the middle spine length has permitted the characterization of several cultivars.

Our data generally agree with those reported for Moroccan date-palm cultivars (ELHOUMAIZI et al. 2002). However, additional characters such as the petiole width, the rachis thickness, the terminal leaflet width, the angle of leaflets on both sides of the terminal leaflet, the middle leaflet length and the ventral angle have been revealed in the present study. On the other hand, the strong correlation between the parameters used suggested that the tree

Tab. 5. Correlation matrix between the different vegetative traits of date-palm cultivars. (§ table 2 for parameters' labels).

	LL	LW	LA	SL	LP	PW	RT	LN	TL	WT	VA	WM	LM	LI	AT	SN	WS
LW	0.597																
LA	0.370	0.211															
SL	0.294	–.339	–.269														
LP	**0.831**	0.678	0.483	–.118													
PW	0.660	**0.841**	0.289	–.355	**0.853**												
RT	0.480	0.788	0.307	–.468	0.728	**0.861**											
LN	**0.729**	0.695	0.315	–.160	**0.803**	**0.843**	**0.839**										
TL	0.537	0.513	0.359	0.035	0.420	0.298	0.348	0.164									
TW	0.168	0.197	0.390	–.407	0.443	0.336	0.519	0.196	0.575								
VA	–.012	0.301	–.088	–.357	0.222	0.455	0.640	0.367	0.067	0.498							
WM	–.143	0.539	0.341	**–.713**	0.163	0.379	0.660	0.314	0.222	0.397	0.499						
LM	**0.741**	**0.858**	0.124	0.015	0.561	0.629	0.490	0.552	0.591	–.028	–.050	0.136					
LI	0.042	–.147	–.240	0.221	–.078	–.195	–.468	–.452	0.150	–.030	–.125	–.521	0.055				
AT	–.040	0.154	–.045	–.260	–.066	0.039	0.100	–.268	0.639	0.589	0.237	0.136	0.208	0.350			
SN	0.101	0.169	–.361	0.129	0.318	0.381	0.295	0.167	–.070	0.128	0.526	–.083	–.018	0.132	–.055		
WS	0.190	0.558	0.144	–.432	0.303	0.509	**0.820**	0.580	0.332	0.485	**0.789**	**0.708**	0.306	–.421	0.281	0.100	
LS	–.243	–.029	–.062	–.256	–.054	–.030	–.052	–.040	–.539	–.263	0.033	0.092	–.122	0.186	–.297	–.047	–.073

architecture is well arranged. This is well exemplified as followed: the longer the leafleted part, the more frequent the leaflets, a thicker petiole and a larger rachis being needed in consequence to support the leaflets. In addition, the derived UPGMA dendrogram has permitted the clustering of cultivars into two main groups supported tree branching made according to fruit characteristics. This is well exemplified in the case of Lemdina ghaïlania, Lemdina gouchatia and Alfa cultivars that are characterized by soft dates, the Tiguidert and Amsakhsi exhibiting a dry date and, the Adaghd, Sekani and Tijeb with a half-soft date. It is worth noting that the similarly called cultivars (i.e.: Ahmar 1 and Ahmar 2) are phenotypically divergent despite their uniformly red colored and soft dates. Similar results were previously obtained when we used plasmid-like DNAs markers (OULD MOHAMED SALEM et al. 2007). Indeed, a high degree of fruit parameter similarity is considered by farmers in the denomination of cultivars. Consequently, taking into account the present data together with those previously reported we suggest that Ahmar is likely a polyclonal variety. Development of more efficient molecular markers such as microsatellites (ZEHDI et al. 2005) would provide a precise genotypic differentiation between the Mauritanian Ahmar ecotypes. Opportunely, despite the recent development of isoenzymes and DNA markers in date-palm (BENDIAB et al. 1998; SEDRA et al. 1998; BEN ABDALLAH et al. 2000; OULD MOHAMED SALEM et al. 2001a, b; SAKKA et al. 2004), the present study proved that morphological markers are very useful in cultivars characterization. Obviously, a precise description of the genetic diversity in Mauritanian date-palms needs a combination of morphological, biochemical and molecular markers. Work is currently in progress to record a large number of markers in order to examine the correlation between these complementary approaches and to record markers of interesting agronomic traits, mainly those related with fruit parameters.

Acknowledgements

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